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2016 Aquatic Ecological Risk Assessment
Tulsequah Chief Mine, Skeena Region

BC Ministry of Environment Contract No.: CS17JHQ0001

April 2017
SLR Project No.: 201.88687.00000

2016 AQUATIC ECOLOGICAL RISK ASSESSMENT
TULSEQUAH CHIEF MINE
SKEENA REGION
Ministry Contract No.: CS17JHQ0001
SLR Project No.: 201.88687.00000

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EXECUTIVE SUMMARY

SLR Consulting (Canada) Ltd. (SLR) was retained by BC MOE to complete water sampling, sediment sampling and a fisheries habitat assessment at the Tulsequah Chief Mine Site in the fall of 2016; and to prepare this aquatic ecological risk assessment (AERA) based on the 2016 results. The purpose of the 2016 AERA was to provide a current state assessment of potential impacts to aquatic receptors within the Tulsequah River, including the mainstem, braided channels and tributaries surrounding the Site.

The main difference in the 2016 sampling program were the areas where samples were collected compared to historical sampling programs. The 2016 program focused on collecting samples from areas exposed to historic mine input sources and/or in areas where aquatic receptors (fish and invertebrates) potentially reside. The 2016 program included an aquatic habitat assessment to identify fish habitat features and fish utilization within these sampling areas. The historical sampling program was designed for environmental monitoring and permitting purposes.

The 2016 AERA study area was divided into four exposure units referred to as “zones”; with each zone having unique mine-related input sources and fish habitat features. A total of 20 surface water, five porewater and six sediment samples were collected within the four zones. Zone 1 was a reference zone while Zones 2 to 4 were impacted by mine-related sources.

The 2016 AERA calculated risk estimates (HQs) for fish, fish eggs, and aquatic invertebrates using maximum concentrations for Contaminants of Potential Concern (COPCs) that were specific to each of the four zones. Three types of media were used to represent exposure sources to the five receptor groups. Surface water concentrations were used for resident and migratory fish, porewater concentrations were used for fish eggs and pelagic invertebrates, and sediment was used for benthic invertebrates. Fish HQ results were further evaluated within the context of what fish species would be present, when they would be present, and their exposure duration within each zone.

HQs were highest in Zone 2. This is likely because multiple undiluted and untreated sources of historic mine waste are discharging into the Tulsequah mainstem and side channels from surface water and groundwater inputs.

Within Zone 2 metal concentrations pose unacceptable risks to fish, fish eggs and pelagic invertebrates. The highest HQ values were cadmium, copper, and zinc HQs for fish, fish eggs and pelagic invertebrates and the aluminum HQ for fish eggs. There also was potential risk identified from aluminum, iron and lead for both fish and pelagic invertebrates, cobalt for pelagic invertebrates, and lead, iron and sulphate for fish eggs. For benthic invertebrates copper was the only elevated HQ identified with potential risk. Based on the SEM/AVS results copper has a high bioavailability to invertebrates within sediments from this zone.

The 2016 habitat assessment identified that it is unlikely that fish and aquatic invertebrates would spend a significant amount of time within Zone 2. This is due to a combination of high turbidity, and low pH input from mine sources documented during the 2016 field program.

HQs were lower in Zone 3 than in Zone 2. HQs were greater in Zone 3 than in Zone 4. Within Zone 3 copper and lead HQs for resident and migratory fish, zinc HQs for resident fish, and the iron HQ for pelagic invertebrates were associated with the highest potential risk. There also

was potential risk identified from cadmium for fish, aluminum for pelagic invertebrates, and aluminum, copper and iron HQs for fish eggs. For benthic invertebrates arsenic was the only elevated HQ identified with potential risk. A moderate level of uncertainty is associated with Zone 3 risk estimates because although maximum concentrations were used it is unclear whether they represent the worst case scenario exposure conditions.

Zone 3 has the potential for the largest number of receptors to be exposed to Tulsequah Chief Mine sources within the study area, although concentrations were not the highest. Elevated HQs identified potential risk for both fish and aquatic invertebrates which were slightly lower than risk levels in Zone 2. The main difference between Zones 2 and 3 are the number of areas with high quality habitat features in Zone 3 compared to Zone 2. As a result both fish and aquatic invertebrates receive constant exposure to mine-related COPCs because they have a high potential to spend a significant amount of time within Zone 3.

Historically samples were not collected within Zone 3 despite containing mine-related sources and high quality fish habitat. Although migratory fish would not spend their entire life cycle within this zone, Zone 3 provides high quality habitat for migratory salmonids. Zone 3 also provides high quality habitat for resident fish such as Trout and Dolly Varden to spawn, rear, and for overwintering juveniles. Exposure would be highest for resident fish such as Stickleback, Sculpin, and sub-adult Dolly Varden. Almost all habitat requirements are met for residents which would allow them to spend all of their life cycle within this Zone, and receive year-round lifelong exposure to mine-related COPCs.

Within Zone 4 all calculated HQs for fish and benthic invertebrates indicated acceptable risk. Porewater was not collected within Zone 4 and therefore HQs weren't calculated for fish eggs and pelagic invertebrates. A high level of exposure is associated with the resident and migratory fish HQs because the amount of time that these fish would spend within this area is substantial.

A moderate level of uncertainty is associated with the 2016 AERA risk estimates because although maximum concentrations were used it is unclear whether they represent the worst case scenario exposure conditions.

Based on the AERA conclusions SLR provides the following recommendations to address site risks and uncertainties, and to provide input into remediation planning:

- Restricting overland flow would reduce exposure and thereby reduce risk to aquatic receptors. Overland discharge of untreated mine source waters from the exfiltration pond and portals into the Tulsequah River are sources of contamination to Tulsequah River and aquatic receptors;

- Full characterization of the spatial extent and contaminant concentrations in all relevant media has not been conducted. Complete follow-up assessment that includes concurrent groundwater, porewater, and surface water sampling in all four zones;

    - Porewater concentrations indicate that groundwater is a source of contamination into the Tulsequah River. Groundwater was not a media evaluated under the current AERA. Trends between groundwater and porewater need to be evaluated to confirm mine sourced COPCs into receiving waters within Zones 2 and 3. An evaluation of groundwater concentrations for current wells surrounding the Non Acid Generating (NAG) and Potentially Acid Generating (PAG) piles relative to porewater would

reduce the uncertainty associated with porewater data relied upon in the assessment;

- Concurrent water sampling should be repeated so that seasonal and temporal variation can be captured under exposure conditions involving both high and low source input;
- Quantify total and speciated chromium to confirm the contribution of chromium VI vs. III to total chromium within all three media; and
- Incorporate all historical information into a follow-up risk assessment.

- Aquatic habitat assessment was limited in 2016 due to the fall/winter season. Complete a follow-up aquatic habitat assessment to confirm:
  - Presence/absence of dominant macrophytes in areas receiving groundwater input and downgradient of NAG/PAG;
  - Presence/absence of resident and migratory fish when the spring (Sockeye, Cutthroat Trout) and fall (Coho, Dolly Varden) migratory fish will be present using capture techniques between Zones 1 to 3; and
  - Changes from the original aquatic habitat assessment.
- Geochemical assessment of NAG and PAG waste rock areas would confirm the acid/metal leaching potential of the piles. Complete a geochemical assessment of future metal availability and loading from source materials into groundwater and surface water; and
- Complete an update of the 2016 AERA to incorporate the above recommendations and once steady-state COPC concentrations have been identified to aid remediation option analysis for reducing the risks to aquatic receptors.

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CONCEPTUAL SITE MODELS (CSM)

CSM 1A: 2016 Tulsequah Impacted Zone 2
CSM 1B: 2016 Tulsequah Impacted Zone 3

CSM 1C: 2016 Tulsequah Impacted Zone 4

APPENDICES

Appendix A BC MOE Correspondence with Chieftain Metals Inc.
Appendix B 2016 ESA Summary and AERA Dataset
Appendix C 2016 Fisheries Habitat Assessment

LIST OF ACRONYMS

µg/L	microgram per litre
µmol/g	micromoles per gram
AERA	Aquatic Ecological Risk Assessment
AET	Apparent Effect Threshold
ARD	Acid Rock Discharge
AVS	Acid Volatile Sulfides
AW	Aquatic Life
AWQG	Approved Water Quality Guidelines
BC	British Columbia
BC MOE	British Columbia Ministry of Environment
BC MOELP	British Columbia Ministry of Environment Land and Parks
CCME	Canadian Council of Ministers of Environment
CEPA	Canadian Environmental Protection Act
CEQG	Canadian Environmental Quality Guidelines
Chieftain	Chieftain Metals Inc
ChV	Chronic Value
COA	Certificate of Analysis
COC	Chain-of-Custody
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
CSR	Contaminated Sites Regulations
DFO	Department of Fisheries and Oceans
DO	Dissolved Oxygen
DQERA	Detailed Quantitative Ecological Risk Assessment
DW	Drinking Water
EC_{20}	Effective Concentration where 20% Effects are Observed
ECCC	Environment and Climate Change Canada
EMA	Environmental Management Act
EPC	Exposure Point Concentrations
ERL	Effects Range Low
ERM	Effects Range Median
ESA	Environmental Site Assessment
FCSAP	Federal Contaminated Sites Action Plan
FIGQG	Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites
HQ	Hazard Quotient
ISQG	Interim Sediment Quality Guideline
IW	Irrigation
km	kilometres
L/s	Litres per second
LC_{20}	Lowest Concentration where 20% effects are observed
LEL	Lowest Effect Level
LMDL	Laboratory Method Detection Limit

LOEC	Lowest Observable Effects Concentration
LW	Livestock
m	metres
masl	Metres Above Sea Level
mbs	Metres Below Surface
mg/kg	milligram per kilogram
MOE	Ministry of Environment
NAG	Non Acid Generating
NOEC	No Observable Effects Concentration
^{o}C	degrees Celsius
PAG	Potentially acid generating
PEC	Probable Effect Concentration
PEL	Probable Effect Level
QA/QC	Quality Assurance and Quality Control
ROC	Receptor of Concern
RPD	Relative Percent Deviation
SARA	Species at Risk Act
SedQC	Sediment Quality Criteria
$SedQC_{SS}$	Sediment Quality Criteria for Sensitive Sites
$SedQC_{TS}$	Sediment Quality Criteria for Typical Sites
SEM	Semi Volatile Metals
SLR	SLR Consulting (Canada) Ltd.
TOC	Total Organic Carbon
TRT	Taku River Tlinglit
TRV	Toxicity Reference Value
USEPA	United States Environmental Protection Agency
WWQG	Working Water Quality Guidelines

1.0 INTRODUCTION

The Tulsequah Chief Mine Site (herein referred to as the "Site") is located in Northwestern BC and is currently in receivership under Chieftain Metals Inc. (Chieftain). British Columbia Ministry of Environment (BC MOE) inspected the Site in fall 2016 and noted major concerns related to the risk of untreated mine water entering the Tulsequah River. On August 24, 2016 MOE identified the following concerns pertaining to the Aquatic Ecological Risk Assessment (2013 AERA) prepared for Chieftain Mines in support of removing the requirement for operation of the interim water treatment plant:

- The conclusion of low to moderate risk hinges on the assumption of low receptor presence in the Tulsequah River mainstem during the period of poorest water quality. Information was not provided as to whether this assumption was field validated;
- The AERA lacked clear information on the methodology used for the selection of sampling sites;
- More rigorous characterization required for adequate site characterization including a larger number of sampling locations; and
- Indicator species chosen for the study are not the species best suited to reflect ecological risk.

SLR Consulting (Canada) Ltd. (SLR) was retained by MOE to complete water sampling, sediment sampling, and fisheries habitat assessment at the Tulsequah Chief mine site in fall 2016; and prepare this aquatic ecological risk assessment (2016 AERA) based on the 2016 results. The purpose of the 2016 AERA was to provide a current state assessment of potential impacts to aquatic receptors within the Tulsequah River, including the mainstem, braided channels and tributaries surrounding the Site. In particular, the 2016 AERA was to address the concerns noted in correspondence dated August 24, 2016 which is presented in Appendix A.

1.1 AERA Objective

The objective of the 2016 AERA report was to evaluate the potential risks to fish (resident, migratory, eggs) and aquatic invertebrates (pelagic and benthic) exposed to acid mine drainage from the Site. The data relied upon in the 2016 AERA is from one season and therefore represents a snapshot of current state conditions at the Site. 2016 sampling locations are presented in Drawing 1. The main premise of the AERA was to specifically address concerns noted in MOE correspondence with the Tulsequah Chief Mine dated August 24, 2016, and presented in Appendix A. The terms of SLR's contract (Schedule A Part 2) also included providing recommendations for follow-up sampling/monitoring if the field work conducted under this contract did not fully capture all relevant risk characterization scenarios.

1.2 Scope of Work

This scope of work associated with the 2016 AERA included:

- The completion of a fish habitat assessment within the Tulsequah River mainstem, side-channels, and tributary side-channels surrounding the Site. This included the identification of fish habitat quality for all fish potentially using these waters. It also included reviewing historical information to identify fish absence/presence and relevant habitat features and utilization for resident and migratory fish;

- A more rigorous characterization within the Tulsequah River mainstem, side-channels, and tributary side-channels (Rogers Creek and Slough). This included the collection of water and sediment samples from areas either receiving historic mine source discharge or where aquatic receptors potentially reside. Identifying and estimating potential risk for aquatic receptors of concern; and
- Providing recommendations to refine aquatic risk characterization.

1.3 AERA Approach

This risk assessment was conducted in general accordance with the ecological risk assessment guidance available from BC MOE, Environment Canada and other regulatory jurisdictions (e.g. USEPA 1998). Primarily, BC Protocol 1 – Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia (Tier 1) (BC MOELP, 1998) and BC Detailed Ecological Risk Assessment Guidance (DQERA) (BC MOE, 2008) documents were used in the risk assessment The regulatory framework followed to complete the AERA is described in Section 2.0.

1.4 Organization of Report

The AERA is organized as follows:

Table 1-1: Report Organization

Report Section	Content
Section 2 – Regulatory Framework	Describes the Federal and provincial acts and regulations that have direct relevance to the AERA.
Section 3 – Problem Formulation	Provides a description of the Site that is the subject of this AERA. Identifies Chemicals of Potential Concern (COPC) at the Site by comparing concentrations to available benchmarks for the protection of environmental health or background conditions. Describes how aquatic ecological receptors of concern (ROCs) typically come into contact with COPCs in environmental media (e.g., sediment, surface water). Identifies the group of ecological receptors that are likely to come in contact with the selected COPCs. Develops a conceptual model for the Site identifying the COPCs - Complete Exposure Pathways - Receptors scenario for which the risks will be quantified. Describes the AERA endpoints.
Section 4 – Exposure Assessment	Identifies the exposure point concentrations (EPC) for the COPCs that are to be evaluated, and estimates the levels of exposure on complete exposure pathways identified in the Problem Formulation
Section 5 – Effects Assessment	Provides and evaluation of relevant toxicity reference values (TRVs) and identifies selected TRVs for ROCs. The selected TRVs are then used to quantify the potential risks that are presented in Section 6.
Section 6 – Risk Characterization	Provides the ecological risk assessment for the COPC - Complete Exposure Pathway - Receptor scenarios identified in the Problem Formulation
Section 7 – Uncertainty Analysis	Discusses the identified sources of uncertainty in the AERA.
Section 8 – Conclusions	Provides the AERA conclusions.
Section 9 –Recommendations	Provides the AERA recommendations.

Table 1-2: Report Organization (continued)

Section 10 – Professional Statement	Identifies authors of the report and provides their contact information.
Section 11 Statement of Limitations	Provides the reliance for the MOE review and limitations for use of the document.
Section 12 – References	Lists all references used in the AERA.

2.0 REGULATORY FRAMEWORK

As of September 2016, Chieftain continued to be in non-compliance with their permitting requirement due to the continual discharge of untreated mine impacted waters into the Tulsequah River. Several provincial and federal regulatory agencies share authority for assessing and managing contaminated sites in BC.

As the mine is located in BC, Canada it is subject to provincial and federal laws with respect to environmental matters and release of toxic substances into the environment. The principal provincial and federal statutes are the *Fisheries Act*, *Environmental Management Act* (EMA) and *Canadian Environmental Protection Act (*CEPA*)* respectively. Water and sediment quality data assessed in the 2016 AERA was screened against provincial and federal criteria as described in Section 3.5. Other Federal acts and regulations that have direct relevance to the AERA include the *Species at Risk Act* (SARA) (ECCC 1994), and *the Migratory Birds Act* (ECCC 2002).

The Tulsequah Chief Mine falls within the provincial regulatory framework established by the EMA and the associated BC *Contaminated Sites Regulation* (CSR). The EMA and CSR have provisions for managing site contamination based on numerical and risk-based standards. The CSR and associated protocols and guidance documents outline the procedures for site assessment, remediation and application for environmental closure for a property.

The following Sections discuss the main regulatory considerations in the context of the AERA.

2.1 BC MOE

The CSR under the EMA is the principal regulatory document defining requirements for contaminated sites management in British Columbia.

The CSR came into effect on April 1, 1997 and has been amended several times, most recently on July 19, 2016. The EMA and CSR have provisions for managing site contamination based on numerical and risk-based standards. The CSR and associated protocols and guidance documents outline the procedures for site assessment, remediation and application for environmental closure for a property. Numerical standards are a key component of the requirements in the CSR, as they define whether or not a site is contaminated. The EMA and CSR also have provisions for risk-based standard approaches to managing site contamination.

2.1.1 Porewater and Surface Water Objectives and Standards

BC Approved and Working Water Quality Guidelines

The BC Approved and Working Water Quality Guidelines [BC AWQG (2017) and BC WWQG (2015), respectively] provide benchmarks for the assessment of water quality. Criteria are safe levels of substances for the protection of a given water use, in this case the protection of freshwater aquatic life. Maximum guideline values are numerical limits based on scientifically defensible toxicological data available for the parameters of interest. Generally they are based on the lowest reliable toxicity data available for sensitive native BC species. These values are then multiplied by a safety factor to derive the specific guideline.

The BC AWQG have been endorsed by the BC MOE for use in BC, whereas the BC WWQG provide references for compounds that have not yet been fully assessed in the context of BC's environmental conditions.

The BC AWQG and BC WWQG for the protection of freshwater aquatic life were applied during COPC screening.

CSR Standards

Numerical standards for water in the CSR are presented in Schedule 6, which references four classes of water use: Aquatic Life (AW), Irrigation (IW), Livestock (LW), and Drinking Water (DW). The AW standards are the most relevant to the Site and were applied in the current AERA.

BC MOE Technical Guidance 15 – *Concentration Limits for the Protection of Aquatic Receiving Environments* (BC MOE 2013a) specifies that CSR standards are not available for groundwater quality assessment for wells located within 10 m of the high water mark of the aquatic receiving environment, which in this case, include the foreshore wells in the Seep Area. The CSR AW standards apply to groundwater at distances greater or equal to 10 m from the high water mark of receiving environment, based on the assumption that groundwater will be diluted at least 10-fold from its initial concentration in the remaining 10 metres before entering the aquatic receiving environment. The BC AWQG and BC WWQG apply to the high water mark of the aquatic receiving environment. 1/10 of the CSR AW freshwater standards were also used for COPC screening purpose in this AERA for COPCs for which no BC AWQG have been developed.

2.1.2 Sediment Standards

CSR Standards

CSR Schedule 9 Generic Numerical Sediment Criteria (SedQC) for aquatic life use are intended to protect sediment-dwelling species from unacceptable effects that may be associated with exposure to contaminated sediments at typical and sensitive sites. Concentration criteria for substances of potential concern are provided for freshwater sediments. The designated use of the aquatic, ecosystem portion of a site is used to classify the site as either typical or sensitive [i.e., for Freshwater, or Marine and Estuarine: Sensitive ($SedQC_{SS}$) and Typical ($SedQC_{TS}$)]. The sensitive $SedQC_{SS}$ were applied to the Site.

2.2 DFO and Environment Canada

The Department of Fisheries and Oceans (DFO) administers the *Fisheries Act*, (DFO 2016) which contains provisions for regulating the release of deleterious substance to waters frequented by fish. DFO's mandate includes both a conservation role (i.e., protection of fish stocks and their habitat), and an allocation and management role for commercial and native food fisheries, and recreational fisheries. DFO is the lead agency responsible for issuance of consumption advisories and closures for recreational fisheries, including advisories or closures related to natural contamination (e.g., paralytic shellfish poisoning outbreaks) and anthropogenic (human-sourced) contamination (e.g., chemical contaminant-related health concerns).

Environment Canada is responsible for oversight/implementation of the CEPA (1999), the *Canadian Environmental Assessment Act* (CEAA 2012), and the SARA, and is the lead federal agency for Canadian Council of Ministers of Environment (CCME). Programs within Environment Canada that are directly relevant to contaminated sites include:

- Federal Contaminated Sites Action Plan (FCSAP)(2012) – overall mandate to reduce the number and environmental impact of contaminated sites in Canada for which federal departments of the Government of Canada have direct responsibility;
- CCME Guideline Development – funding and policy guidance agency for the federal component of CCME; and
- Species at Risk (ECCC 2002) and Migratory Birds Convention (ECCC 1994) Acts – Designation of threatened and endangered species, and protection of migratory birds.

2.3 CCME Guidelines

CEPA originally passed in 1988, was updated in 1999 and provides overall Federal Government legislative authority to manage substances that could cause impairment to the environment. CEPA (1999) defines toxic substances as those substances that enter or may enter the environment at levels or conditions that:

- have or may have a harmful effect on the environment;
- are or could be dangerous to the environment that life depends on; or
- are or could be dangerous to human health or life.

However, CEPA does not specifically regulate concentrations of substances in environmental media. Therefore the CCME was formed as a joint provincial, federal and territorial government environmental committee.

In September 1991, the CCME released the document "Interim Canadian Environmental Quality Criteria for Contaminated Sites" (CCME 1991). Utilizing existing criteria from various areas in Canada, guidelines were established based on land uses. Guidelines were updated for soil in 1997 when the document "Recommended Canadian Soil Quality Guidelines" was issued. Existing and updated soil, sediment and water quality guidelines were published by the CCME in 1999 as "Canadian Environmental Quality Guidelines" (CEQG) and updated in 2007. This document incorporated the 1991 and 1997 guidelines and any updates that have been issued in the interim and is the current federal regulatory guidance for soil, sediment and water quality.

In the absence of BC AWQG or BC WWQG and CSR standards, the CCME guidelines were used as screening benchmarks.

The Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites (FIGQGs) were released by the Federal Contaminated Site Assessment Program (FCSAP) in May 2010 and updated in 2012 to be used until Canadian Environmental Quality Guidelines for groundwater become available (FCSAP, 2012).

3.0 PROBLEM FORMULATION

The purpose of the problem formulation is to identify the COPCs, ROCs, sources of COPCs, and the relevant exposure pathways for the AERA. A summary of these relationships are presented at the end of this section in the form of a Conceptual Site Model (CSM). The CSM explains the applicable exposure pathways between sources of contamination and relevant aquatic receptors that will have risk estimates calculated in the AERA.

3.1 Site Description

3.1.1 Former Mine Site

The former Tulsequah Chief Mine is located at latitude 58°43'N and longitude 133°35'W, on the Tulsequah River in Northwestern BC. The project is located 100 kilometres (km) south of the town of Atlin, BC, (59°35'N, 133°40'W), the nearest Canadian community. Juneau (58°18'N, 134°24'W), the capital of Alaska, is situated 64 km southwest of the Site. The Site is located on the east bank of the Tulsequah River. The Site is accessible by aircraft from Atlin, and by aircraft or water (barge) from Juneau.

The Site is presented in Drawing 1 and pictures of relevant Site features are presented in the 2016 Site Assessment Summary contained in Appendix B. The Site consists of the following relevant mine-related features:

- The Mill portion of the Site houses two uncapped underground portals (5400 and 5200), a non-functioning water treatment plant, an unlined water treatment pond housing a mixture of treated and untreated mine waters, an unlined exfiltration pond receiving discharge from both portals, and mine buildings/structures (Photos B-1 to B-10); and
- The waste-rock portion of the Site is directly south of the Mill; and houses two waste rock piles (Photos B-41 and B-42); currently at grade. The northernmost pile has been identified historically as potentially acid generating (PAG) and the southernmost pile as non-acid generating (NAG). For consistency purposes these will continue to be identified as the PAG and NAG piles.

3.1.2 Aquatic Ecological Setting

The Taku River watershed is located to the south of the town of Atlin and east of the Alaska Panhandle from Skagway all the way south to Juneau, Alaska. The Taku River is fed by a number of rivers and their tributary streams from mountains ranging up to 2500 metres (m) in elevation, and the Taku Glacier, lying mostly in Alaska (Watershed Sentinel 2012). The Tulsequah River is one of the major tributaries draining into the Taku River (Drawing 1), and within the Taku watershed. The River is approximately 20 kilometers (km) in length from the toe of the Tulsequah Glacier to its confluence with the Taku River, 9 km upstream from tidewater.

The Tulsequah River travels within a very broad, flat floodplain. The mainstem gradient is estimated at approximately 1 to 2.5% (Rescan 1997). The Tulsequah River is considered one reach, as no obvious breaks, based on gradient or other important hydraulic/habitat features,

occur. As is typical with rivers in glaciated valleys, the Tulsequah River contains elevated concentrations of suspended sediments and a larger bedload. This abundance of sediment is supplied by the upstream glacier and has allowed the channel to develop the braided morphology with the Tulsequah River (Rescan 1997).

Water input into the Tulsequah River is snow and glacial melt driven. However, on at least one occasion per year the river is subject to extreme flood surges from a glacier impounded lake that drains quickly, and with little warning, beneath the Tulsequah glacier. These events are known as jökulhaups. During a jökulhaup the sudden release of water floods the entire Tulsequah River floodplain. The water levels in the Tulsequah River rise over the period of 24 to 48 hours and then subside to normal summer flow levels. The entire event takes four to seven days. Each year the jökulhaups result in the Tulsequah River forming new channels and abandoning others (Rescan 1997).

3.1.3 Topography

The area of the Site is predominately rugged terrain of the Coast Mountain Range. The Tulsequah River is a braided river with a flood plain width of 500 to 1500 m. The local topographic relief is more than 1500 m with elevations ranging from 50 masl on the river to elevation of 1850 masl at the peak of Mount Eaton (Rescan 1997).

3.1.4 Geology

The surficial geology of the Site is predominantly Pleistocene with recent glacio-fluvial and fluvial process. The river channel stratigraphy is composed mainly of coarse sands and gravels with isolated silt-sand over bank deposits. Soil is poorly developed on alluvial fans. (Rescan 1997)

3.1.5 Hydrogeology

The hydrogeology of the Site from Rescan (1997):

> "*The three general hydrogeologic units which control groundwater flow in the area are: unconsolidated sand and gravel on the valley floors (Unit 1); mixed unconsolidated colluvial and morainal material along the lower slopes (Unit 2); and bedrock (Unit 3).*
>
> *Unit 1 is composed primarily of unconsolidated sand, gravel and cobbles deposited by rivers and glaciers (glacio-fluvial). These materials generally infill the bottom of the valleys which have been deeply incised into the bedrock. Unit 1 deposits are the best aquifers in the region. They typically have a high hydraulic conductivity and are capable of transmitting large quantities of water.*
>
> *Unit 2 is composed of poorly sorted colluvial and glacial material including mud, sand, gravel and boulders. This unit is typically seen blanketing the lower slopes of the valley walls. The colluvial material was put in place by mass wasting or is remnant morainal material deposited by glaciers. This unit will have variable hydraulic conductivity but will be able to transmit water more easily than the underlying bedrock.*
>
> *Unit 3 is generally impermeable and will act as a barrier to the flow of groundwater in the other hydrogeologic units when the units are in contact. Groundwater flow within the bedrock will be limited to structural discontinuities such as fractures or faults. Historically,*

the Tulsequah Chief Mine encountered groundwater inflows related to the intersection of new development and major structural features such as faults. The faults acted as conduits for flow which were likely connected to the surface water table. The water storage capacity of these faults is limited by their vertical extent and a reduction in flow was observed over time as the faults dewatered.

Groundwater recharge will result from rainfall and snowmelt infiltrating into all the units identified above. Groundwater will generally flow down slope toward the valley bottoms. This will create regional flow patterns which are perpendicular to major water courses through Unit 2. Flow within Unit 3 will also be from higher to lower areas but the direction of flow will be partially controlled by the orientation of the structural discontinuities. Where creeks intercept the water table, groundwater will discharge into the creeks. However, in areas where the creeks are perched above the water table the creek water will flow down and recharge the water table. When groundwater gradients are similar to stream gradients, groundwater will flow through the permeable sand and gravel of Unit 1 in the same general direction as the stream flow."

The Tulsequah River valley hydrogeology from Rescan (1997):

"The Tulsequah River valley is filled with thick sequences of unconsolidated glacial outwash deposits. The deposits are likely composed of sand, gravel, cobbles, and boulders which correspond to hydrogeologic Unit 1"…"the potential to transmit groundwater through the valley is estimated by assuming typical hydraulic conductivity values for glacial outwash deposits and determining the depth of the outwash deposits from seismic refraction survey results.

Glacial outwash deposits are typically porous and have high hydraulic conductivity values. Representative hydraulic conductivity values for sedimentary gravel deposits range from 3×10^{-4} to 3×10^{-2} m/s and range from 9×10^{-7} to 5×10^{-4} m/s for medium grained sand deposits (Domenico and Schwartz 1990). A representative hydraulic conductivity value for these deposits would likely be 5×10^{-4} to 8×10^{-5}.

A seismic refraction survey was conducted over the Tulsequah River flood plain adjacent to the mine Site. The results from this survey indicate that the sand and gravel of Unit 1 are extremely thick and that the bedrock walls continue to dip steeply beneath the floodplain gravel likely to form a "U" shaped cross section (Appendix B.2-6). Bedrock depth in the centre of the floodplain could not be determined from the refraction survey due to the excessive depth of the overlying outwash deposits. This result indicates that the depth to bedrock will be greater than 253 m which is the maximum possible detection depth using the refraction configuration under the conditions present in the Tulsequah River deposits. Bedrock depths were approximated from apparent bedrock reflection events in the refraction records. These results indicate that the depth to bedrock is approximately 400 m in the centre of the flood plain in the survey area. The survey also identified possible fine grained deposits in the gravel which could form localized zones of restricted horizontal flow. The restricted flow may produce upward vertical gradients along which groundwater would flow."

3.1.6 Aquatic Resource Uses

The Taku watershed is one of North America's largest, unroaded, unprotected watersheds and probably the continent's richest wildlife habitat (Watershed Sentinel 2012). Many species of migratory Birds, Hawks, Eagles and other birds of prey share the watershed with Black and Grizzly Bears, Moose, Caribou and Mountain Goats. This watershed attracts Wolves, Foxes, Wolverine, Lynx and Cougar to the area (Watershed Sentinel 2012). The Taku River supports abundant runs of all five species of wild Pacific Salmon. Fish species found within the Tulsequah River include: Coho, Pink and Chinook Salmon, Flathead and English Sole, Starry Flounder, Anchovy, Smelts, Sticklebacks, Sculpins, Tomcod, Pacific Dogfish, Striped and Shiner Perch. Additional information regarding what species of fish potentially utilize Tulsequah waters is presented in Appendix C in the 2016 Aquatic Fisheries Habitat Assessment.

The Taku River Tlingit (TRT) people have occupied the watershed for hundreds of years, and the salmon fishery and wildlife are vital to the traditional and subsistence-based lifestyles of these people. The TRT First Nation is located in Atlin, BC which is a small remote community of approximately 400 members. The Tlingit Village, named the Taaltsuxéi by the TRT, is located along the Tulsequah River. The TRT Territory covers over 40,000 square km and includes portions of BC, Yukon, and Alaska. As well, the Taku River also supports a commercial Salmon fishery at its mouth and upstream as far as the Tulsequah River. The Taku River is a transboundary river originating in Northwest BC, flowing 266 km before emptying into the Taku Inlet just south of Juneau, Alaska. The Taku River has a large drainage basin with its headwaters largely inland and consequently experiences less influence from coastal systems than the Tulsequah River. The Taku River flows into Stephens Passage and eventually into the Pacific Ocean. The Taku River is recognized as an International River and is managed accordingly under the International Rivers Improvement Act, International Pacific Salmon Fisheries Commission and International Boundary Treaty Act.

3.2 Source Description

In October and November 2016 SLR completed sampling to identify source inputs and collect samples that were relied upon in the current AERA. This information is presented in Appendix B.

Acid Rock Drainage (ARD) has been leaching from historical sources at the Site into the Tulsequah River since historic mining ceased in 1957 (Core6 *et al*. 2013). During operations in the 1950s there were five portals developed on the slopes rising up from the Tulsequah River to access the 5200, 5400, 5900, 6400, and 6500 portal levels (Rescan, 1997). Existing waste rock currently located at the 5200, 5400 and 5900 is a result of historic mining between 1951 and 1957 and from later underground development to support exploration activities in the 1990's and in 2004.

Under existing conditions, water drains from historical underground workings at the 5200 and 5400 level portals (Photos B-1 to B-6). Portal 5400 is located the furthest from the Mill portion of the Site and at a higher elevation compared to portal 5200. Discharge from the 5200 and 5400 portals are piped by gravity to the exfiltration pond where they converge and drain (overflow and piped) into the Tulsequah River floodplain. As of early January 2012, the 5900 level was redirected to stay underground and discharge via the 5200 level portal. Prior to 2012,

the 5900 level was allowed to discharge to either Camp Creek or Portal Creek. On average, approximately 6.8 L/s drains from the 5200 level portal, approximately 1 L/s drains from the 5400 level portal, and approximately 5 L/s used to drain from the 5900 level portal (Core6 *et al*. 2013).

The existing waste rock currently located at the 5400 and 5200 portal levels is referred to as potentially acid generating (PAG) although the lower portions of these piles are expected to be composed of non-acid generating material (NAG) (Rescan 1997). Waste rock is also contained within two piles located south of the Mill site (Photos B-41, B-42). Both piles are built-up along the banks of the Tulsequah River. The pile closest to the Mill site was historically named the PAG pile and the pile furthest from the Mill site was named the NAG pile.

3.3 Exposure Zones

The Site was divided into four exposure units referred to as “Zones”. The zones were created because each area within a zone has unique mine-related input sources combined with habitat features of differing quality. Also, due to the shifting channels within the Tulsequah River, monitoring locations within a Zone are more applicable for ongoing assessment rather than a point location. Drawing 1 presents an overview of the entire Site and study area along with the four zones, and 2016 sampling locations. Drawings 2 and 3 present zoomed in versions of these zones along with the samples collected within each zone. A description of and the samples collected within each zone is presented below:

- Zone 1 – *Reference Zone* is located immediately North of all mine related sources. A total of four surface water, one porewater and one sediment sample represent the exposure sources within Zone 1. Samples were collected from areas with similar habitat features and substrates that were present in Zones 2 to 4. Concentrations for COPCs within this zone were historically less than those identified by the reference location (W10) used in the 2013 AERA.

- Zone 2 – *Zone of Discharge* is surrounded by the main portion/infrastructure associated with the Site that contains the Mill, water treatment plant, portals, and exfiltration pond. A total of six surface water (plus two duplicates), two porewater (plus one duplicate) and one sediment sample represent the exposure sources within Zone 2. This zone likely represents the worst case exposure scenario because it is immediately adjacent to the Mill and receives input from underground portals (5900, 5400 and 5200), the overflowing unlined exfiltration pond, the unlined water treatment pond, and any leachate potentially generated from exposed waste rock.

- Zone 3 - *Impacted Near Zone* is located approximately 1 km south of the Mill and contains waste rock previously identified as the PAG and NAG waste rock piles. It includes the confluence of Rogers Creek with the Tulsequah River. A total of eight surface water, one porewater, and three sediment samples represent the exposure sources within Zone 3. Rogers Creek was previously identified as containing high quality fish spawning and rearing habitat for both resident and migratory fish.

- Zone 4 – *Impacted Far Zone* is located approximately 2.5 km south of the Mill and is the farthest downstream receiving environment assessed in the 2016 AERA. It includes Rogers Slough which is an estuary fed by the Tulsequah River and is known for high quality fish habitat for both resident and migratory fish. A total of two surface water and one sediment sample represent the exposure sources within Zone 4.

3.4 AERA Dataset

The goal of the 2016 sampling program was to collect samples in areas either receiving historic mine source discharge or where aquatic receptors (fish and invertebrates) potentially reside, and to assess fish habitat quality within Tulsequah River receiving waters surrounding the Site. This is different than the historical sampling program that was designed for environmental monitoring and permitting purposes, and was relied upon in the 2013 AERA (Core6 *et al* 2013). The 2016 AERA study area was divided into four exposure units referred to as "Zones" as described above in Section 3.3. Surface water, porewater and sediment samples were collected within each of the four zones encompassing the Site.

Table 3-1presents a summary of the dataset within each of the four zones. Sample counts are listed and duplicates are identified in brackets. Samples collected within the Tulsequah floodplain mainstem and braided channels were identified as "Tulsequah" and samples collected within tributaries were identified as "tributary".

Table 3-1: 2016 AERA Dataset

Zone	Description	# Surface Water Samples	# Porewater Samples	# Sediment Samples
1	Reference – Tulsequah	3	0	1
1	Reference – tributary	1	1	0
2	Zone of Discharge – source to the Tulsequah *	2 *	0	0
2	Zone of Discharge – source as entering the Tulsequah	1 (1)	0	0
2	Zone of Discharge – diluted and within the Tulsequah	3 (1)	2 (1)	1
3	Impacted Near – Tulsequah	5	0	2
3	Impacted Near – tributary	3	1	1
4	Impacted Far – Tulsequah	1	0	0
4	Impacted Far – tributary	1	0	1

* Indicates that the sample was collected by MOE

3.5 Regulatory and Screening Values

COPC selection is conducted to simplify the risk assessment process by eliminating chemical parameters that are not present in high enough concentrations, or at sufficient frequency or spatial extent, to warrant risk characterization. The numerical standards and criteria that have been applied to the analytical results used in the 2016 AERA are outlined below. These standards/criteria were used to select COPCs requiring further evaluation in the 2016 AERA.

3.5.1 Surface Water

In 2016 two types of surface water samples were collected. Source water samples were collected by BC MOE in September and represent surface water samples undiluted by water from the Tulsequah River mainstem or side channels. Both source samples were collected from the exfiltration pond. An additional 18 surface water samples (plus two duplicates) were

collected by SLR in the October/November 2016 field program. These samples represent surface water just prior to entering the Tulsequah River (16SED-4 plus DUP-1) or diluted by natural surface waters. Surface water analytical results were collected from within the four zones surrounding the Site and were compared to the following guidelines and standards:

- BC AWQG to protect freshwater aquatic life;
- BC WWQG to protect freshwater aquatic life; and
- CSR AW standards to protect freshwater aquatic life (CSR Schedule 6) divided by ten to remove the assumed 10 fold dilution factor (i.e., per Footnote 2 (a) in Schedule 6).

3.5.2 Porewater

Porewater samples (four plus one duplicate) were collected from three of the four zones (Zones 1, 2, and 3) surrounding the Site. Porewater analytical results were compared to the following guidelines:

- BC AWQG to protect freshwater aquatic life;
- BC WWQG to protect freshwater aquatic life; and
- CSR AW standards to protect freshwater aquatic life (CSR Schedule 6) divided by ten to remove the assumed 10 fold dilution factor (i.e., per Footnote 2 (a) in Schedule 6).

Porewater in this report is defined as the interstitial water within the upper 1 meter of sediment (i.e., per the definitions of “porewater” and “ecologically active zone” in BC MOE Technical Guidance 15).

3.5.3 Sediment

Sediment samples (six) were collected within each of the four zones surrounding the Site. Sediment analytical results were compared to the following guidelines and standards:

- BC CSR Schedule 9 Generic Numerical Sediment Criteria for typical and sensitive sediment use ($SedQC_{TS\ and\ SS}$) for the protection of freshwater environments. Sensitive applies to this Site and was used for screening purposes. Both sensitive and typical are presented for context;
- CCME Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL). ISQG was used for screening purposes (CCME 2001). Both ISQG and PEL were presented for context;
- For any COPC identified in surface water or porewater and without a BC CSR or CCME guideline the following resources were used:
    - MacDonald *et al.* (2000) Compendium of Environmental Quality Guidelines Probable Effects Concentration (PEC);
    - USEPA (1999) Apparent Effect Threshold (AET);
    - ON MOE (1993) Lowest Effect Level (LEL) sediment quality guidelines; and
    - Ingersoll *et al.* (2002), Effect Range Low (ERL) and Effect Range Median (ERM) Values.

3.6 COPC Screening

SLR employed a rigorous three step process for COPC selection. The screening process evaluated all chemistry data for substances with CSR standards, as well as for substances that lack standards but were detected with frequency (i.e., in more than one sample), and may be associated with mine-related sources.

3.6.1 COPC Screening Process

All available 2016 surface water, porewater and sediment analytical results considered to be representative of current fall conditions at the Site were used in the COPC screening. Surface water data collected prior to 2016 was available, and in some cases was quite extensive, however, this AERA was completed for the fall 2016 period and is representative of current conditions.

Analytical results relied upon in this risk assessment are compiled in Appendix B. Tables B1 to B10 present the field and laboratory based analytical results for samples collected by SLR. Tables B11 to 15 present the Relative Percent Deviation (RPD) calculations. In addition an ALS laboratory certificate of analysis (COA) contains the results for the two source samples collected by MOE. Duplicate data was presented in addition to the parent sample. When a sampled location had a duplicate sample, the sample with the highest concentration was retained and used.

Summary statistics were not calculated nor used for COPC screening. Maximum COPC concentrations were used to identify COPCs during the three step screening process.

The regulatory and screening values identified in Section 3.5 were used to identify surface water, porewater, and sediment COPCs requiring assessment. The following general criteria were applied in the COPC screening:

- Parameters were retained as preliminary COPCs if the maximum concentration was greater than the available screening guideline/standard; and
- Unregulated parameters that were detected with frequency and considered to be related to the mine-sourced contamination were not retained as COPCs, and will be discussed in the Uncertainty section of the report.

Preliminary COPC screening was the first step of the COPC screening process. Preliminary screening identified COPCs by comparing the maximum COPC concentration to the regulatory and screening values (benchmark). Preliminary screening was specific to each of the three downstream impacted zones. Reference COPC concentrations were not used during the preliminary screening. The highest maximum concentration was selected from both the total and dissolved COPC concentrations. If a COPC exceeded the benchmark then it was retained.

Secondary COPC screening was the second step of the COPC screening process. Secondary screening was completed on any retained preliminary COPC. The maximum concentration within each impacted zone was compared to the same benchmark used during preliminary screening. The highest relevant maximum concentration was identified for either total or dissolved concentrations. The most relevant concentration depended upon what was

recommended by the selected screening value identified in the preliminary screening. A COPC was retained if it exceeded the screening benchmark. If a COPC exceeded the benchmark but not the reference it was not retained. If a COPC exceeded the reference but not the benchmark it was not retained.

Final COPC screening was the third step of the COPC screening process. Analytes identified at the end of the third step were carried forward for assessment in the AERA. A COPC was assessed under the final screening if it was identified as a COPC at the end of the secondary COPC screening. Final screening was specific to each of the three downstream impacted zones (Zones 2 to 4) and excluded the undiluted samples identified as “source”, and sampled by BC MOE in September 2016. A COPC was retained if it exceeded the screening benchmark in at least one of the three zones. If a COPC exceeded the benchmark but not the reference it was not retained. If a COPC exceeded the reference but not the benchmark it was not retained.

Tables 1 to 6 present the COPC screening for surface water, porewater, and sediment respectively. The COPC screening tables include the following information: the number of samples, the maximum concentration of the contaminants, and the screening benchmarks. The rationale for retaining or dismissing substances as preliminary and final COPCs is also presented in these six tables. The dataset relied upon for the 2016 AERA had total chromium concentrations in surface water and porewater samples, not speciated concentrations (chromium VI and chromium III). Therefore it was assumed that the total concentration was better represented by chromium VI+ and not the chromium III, and therefore the chromium VI benchmark was applied. Tables 7 and 8 contain the 2016 results compared to historical concentrations. This data is presented and interpreted in Section 7.0 of the AERA.

3.6.2 Preliminary COPC Screening Results

The results of the preliminary COPC screening identified the following surface water, porewater, and sediment COPCs requiring assessment:

- Surface water (n = 16 + 2 dup + 2 source): pH, aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, and zinc;
- Porewater (n = 3 + 1 dup): pH, aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, sulphate and zinc; and
- Sediment (n = 5): aluminum, arsenic, copper, iron, and zinc.

The benchmark for aluminum, cadmium, and sulphate were based on dissolved concentrations because this is the most relevant concentration according to the recommendations put forward by the BC guideline derivation documents (BC MOE, various years). The benchmark for cadmium, copper, lead, manganese, and zinc were based on total concentrations which are also based on recommendations put forward by the BC guideline derivation documents. Any pH or hardness dependent parameter applied the median reference pH or hardness value to derive the screening benchmark. This is a conservative approach and ensures that the benchmark won’t be underestimated because as pH and hardness increase the benchmark also increases.

3.6.3 Secondary COPC Screening Results

The results of the secondary COPC screening identified the following surface water, porewater, and sediment COPCs requiring assessment within the three impacted zones:

- Surface water:
  - Zone 2 (n = 4 + 2 dups): pH, aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, and zinc;
  - Zone 3 (n = 8): aluminum, arsenic, cadmium, copper, iron, and zinc;
  - Zone 4 (n = 2): aluminum;
- Porewater
  - Zone 2 (n = 2): pH, aluminum, beryllium, cadmium, cobalt, copper, iron, lead, sulphate, and zinc;
  - Zone 3 (n = 1): aluminum, arsenic, and iron;
- Sediment
  - Zone 2 (n = 1): arsenic, copper, and zinc;
  - Zone 3 (n = 3): arsenic, and iron; and
  - Zone 4 (n = 1): arsenic, and iron.

3.6.4 Final COPC Screening Results

The results of the final COPC screening identified the following surface water, porewater and sediment COPCs requiring assessment:

- Surface water: aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead and zinc;
- Porewater: aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, sulphate, and zinc; and
- Sediment: arsenic, copper, iron and zinc.

Due to the volume of water contained within the Tulsequah River receiving environment pH was not retained for assessment. Although source waters prior to entering the Tulsequah River are characterized by very low pH, this pH is almost immediately diluted in surface waters and porewaters and increased to above 6.5. This was confirmed by the pH measured at co-located porewater, surface water and duplicate surface water samples collected at location SW16-5 (7.23), SW16-DUP-1 (4.73) and PW16-3 (3.15)).

A total of nine surface water, ten porewater, and four sediment COPCs were carried forward for assessment in the 2016 AERA.

3.7 ROC Selection

The first step in the selection of ROCs is to identify aquatic ecological receptors that potentially utilize the Site. This information was completed using historical and desktop resources in the 2013 AERA. The 2013 AERA used the ecozone and ecoregion combined with the information presented in the Rescan (1997) baseline environmental assessment report and the Gartner Lee fisheries report (2007) to identify aquatic receptors for the Site. The 2013 AERA presented:

> *"Of the aquatic resources in the Tulsequah River, fish are likely the primary receptors with the highest risk of exposure to mine discharge. Available data on sediment and benthic invertebrates are limited and the hydrologic regime of the Tulsequah River (i.e. seasonal major glacial outbursts) would likely preclude the presence of stable benthic*

invertebrate communities or sediment quality over the years. The focus of the risk assessment on salmonids was due to the known presence of salmonids in the Tulsequah River. Salmonids are also of cultural, economic, recreational and/or ecological importance, and they are understood to be the most sensitive fish receptor." (Core6 2013).

SLR used the ROC information presented in the 2013 AERA combined with the aquatic habitat and ROC assessment from the 2016 field program to identify ROCs for the 2016 AERA. The SLR fisheries biologist completed habitat assessments within each of the four zones to identify fish habitat features and functionality during the 2016 field program. Receptor refinement was then conducted, as it would not be practical or necessary to characterize risks for all of the species belonging to the general receptor groups identified. Risk assessments must limit their focus to a smaller list of specific organisms, known as ROC, that might use a site and come into contact with the COPCs. Therefore, based on the potential ROCs, representative ROCs (e.g. populations, communities) were identified.

3.7.1 Tulsequah Fisheries Historical Summary

The historical information presented within this section was obtained from the 2013 AERA. As a result, focus was placed upon a description of salmonid habitat features.

A comprehensive fish and fish habitat compilation report was developed by Gartner Lee (2007). The report included two detailed maps documenting all known fish species presence and distribution in the Tulsequah watershed. The maps identified the Tulsequah and Taku rivers as supporting up to nine salmonid and several non-salmonid species (e.g., Stickleback and Sculpin) at any one time (Gartner Lee 2007). This included the following species:

- Five Pacific Salmon species (*Oncorhynchus sp.*);
- Dolly Varden (*Salvelinus malma*) (migratory and resident);
- Bull Trout (*Salvelinus confluentus*) (migratory and resident);
- Steelhead/Rainbow (*Oncorhynchus mykiss*);
- Cutthroat Trout (*Oncorhynchus clarki);*
- Arctic Grayling (*Thymallus arcticus*); and
- Round Whitefish (*Prosopium cylindraceum*).

Within the Tulsequah watershed, juvenile Coho Salmon and Dolly Varden were the most common and ubiquitous species captured during previous studies (Gartner Lee 2007).

Fish habitat quality throughout a large portion of the Tulsequah River floodplain is limited by elevated turbidity during most of the open water season, extreme turbidity and low flow during seasonal glacial outburst floods, and the extremely dynamic braided channel morphology. The Tulsequah River is used primarily as a migration corridor, which allows fish access to several minor tributaries. Chum are known to spawn in the lower mainstem and juvenile Coho and Sockeye Salmon and Dolly Varden/Bull Trout have been captured in mainstem habitats upstream and downstream of the Site (Rescan 1997). Previous studies carried out by the TRT First Nation also identified widespread utilization by Dolly Varden and Coho Salmon within the Tulsequah floodplain (Scannell Scientific 2012).

Gartner Lee (2007) identified that much of the Tulsequah mainstem was a migration corridor providing temporary refuge habitat for salmonids and other local fish species. The mainstem didn't provide high value habitat such as rearing or spawning habitat (Gartner Lee 2007).

However, there were seasonally defined, clear water side channels along some sections of the Tulsequah floodplain, mostly located south of the Site on the West side of the river valley. The Gartner Lee (2007) report did not provide an evaluation of habitat quality within side channels located along the eastern portion of the Tulsequah River, adjacent to the Site. Clear water side channels can (but not always) consist of pool, riffle and glide type habitat and provide stable habitat throughout much of the year. These two distinct aquatic environments offer different types and quality of habitat for both resident and migratory fish. Compared with the mainstem, the clear water side channels have the potential to provide exceptional quality fish habitat.

Within the Tulsequah River floodplain, the highest quality salmonid rearing and overwintering habitat is known to occur in clear water side channels along the river margins (both banks) and to a lesser degree in mid-channel areas. Clear water side channels likely originate from a combination of surfacing groundwater and/or small tributaries draining the valley walls (Chieftain 2013). Extensive juvenile salmonid rearing also occurs in accessible wetland areas and in the initial downstream reaches of tributaries of the Tulsequah River (Rescan 1997).

Important overwintering salmonid habitat in the Tulsequah River drainage includes clear water side channels, accessible wetlands and the lower reaches of larger tributaries not subject to freeze-up. These areas are important habitats because they provide consistently warmer water temperatures over the winter, which prevents freezing.

Salmonid spawning habitat quality is species-specific but is generally determined by a suitable combination of substrate, water depth, and velocity. Frequently, preferred spawning areas are observed to coincide with areas of upwelling, which may maintain more consistent water levels and temperatures.

In summary, clear water side channels, accessible wetlands and lower tributary reaches within the Tulsequah watershed are known to support important rearing, overwintering and spawning habitat for salmonid species of economic, cultural and recreational significance. Most clear water side channels occur along the mainstem margins (east and west banks) downstream from and to a lesser degree, upstream from the Site.

3.7.2 Tulsequah Fisheries 2016 Summary

During the 2016 AERA field program SLR assessed habitat quality within the Tulsequah River mainstem, Tulsequah River braided channels, and within tributaries and wetlands along the eastern portion of the Tulsequah River valley. Habitat features and functionality was identified at upstream and downstream locations surrounding the Site within each of the four zones (1 to 4).

In some instances clear water side channel habitat fed by groundwater, and described by Gartner Lee (2007), was present. Habitat quality within areas outside of the Tulsequah River mainstem but within the braided channels varies annually because of jökulhaups. For the 2016 AERA the term “clear water side channels” is defined as watercourses receiving warm groundwater input sources either adjacent to the mainstem and within the Tulsequah braided side-channels or within tributaries draining from the valleys and into the Tulsequah River.

Appendix C presents the results of the 2016 fisheries assessment completed within the four zones surrounding the Site. The purpose of the 2016 fish habitat assessment was to:

- Review available reports prepared by private consultants and government agencies regarding fish and fish habitat existing conditions within the Tulsequah River;
- Conduct a preliminary fish habitat assessment within the Study Area between October 29 and November 2nd concurrent with site assessment activities;
- Correlate habitat information obtained from field investigations with species utilization by resident and migratory fish known to occur within the Tulsequah River; and
- Provide information and recommendations in support of on-going environmental management associated with the project.

A complete list of species with the potential to occur in Tulsequah River was compiled prior to the on-site field investigation. The life-cycle behaviours for these species were reviewed to make appropriate species-habitat connections while documenting existing fish habitat features. Based on a review of life-cycle behaviours, previous reports, and consultation with the TRT First Nation biologist, fish with the potential to occur within the Site have been categorized as migratory and resident species.

Fish typically occur in three different forms; a lake resident form, a migratory form that moves, usually for spawning (between ocean, large rivers and tributaries), and a non-migratory stream-resident form. Multiple forms may be observed within a single river basin and even within a single population.

For the purpose of this report, resident species were classified as non-anadromous species. These fish do not migrate from the ocean to freshwater to feed or spawn. Resident fish may undertake localized movements into smaller tributaries for spawning, feeding, or rearing purposes. Migratory fish are classified as those that undertake migrations to feed in highly productive coastal waters during the summer and/or returning in the fall/spring to their natal streams to spawn or overwinter.

Table C-1 in Appendix C presents habitat preferences and life history strategies for fish species with the potential to occur within Tulsequah waters. Most of these species have been previously identified or captured within the local waters surrounding the Site. The following six resident and eleven migratory fish were identified:

- Resident fish: Three-Spine Stickleback, Coastrange Sculpin, Slimy Sculpin, Lake Chub, Round Whitefish, and Longnose Sucker; and
- Migratory fish: Cutthroat Trout*, Rainbow Trout*, Dolly Varden*, River Lamprey, Pacific Lamprey, Steelhead Trout, Chinook, Chum, Coho, Pink, and Sockeye Salmon.

Fish that are both migratory and resident are identified above using an asterix “*”. A full description of methods and results pertaining to the 2016 fisheries assessment is contained within Appendix C. In particular, Table C-3 provides a description of fish distribution within the four zones, fish habitat features, functionality, and utilization. Table C-4 provides a breakdown of migratory fish life stages and whether these stages overlap with when a fish would reside in Tulsequah waters.

During the October/November sampling period SLR identified the presence of the following fish (visual confirmation): adult salmonids (Zone 1), juvenile salmonids (Zone 4), and Three-Spine Stickleback (Zone 4).

3.7.3 Receptor Description

A ROC is an individual species chosen to serve as a surrogate for other related species. For the 2016 AERA representative ecological receptors were selected according to the following criteria:

- species that are known or likely to be especially sensitive to the COPCs;
- species that are likely to be most exposed to COPCs;
- species that are known to play an integral role in the ecological community structures at the Site;
- species that are susceptible to bioaccumulation of COPCs from a limited number of food items;
- species that are representative of the foraging guild or serve as a food item for higher trophic level species;
- species that are recognized as good indicators or surrogate species (i.e., representative of other similar organisms of a general type and feeding niche);
- sedentary species or species with a small home range; and
- species of aesthetic value or recreational value to the local human population.

3.7.3.1 *Primary Producers – Aquatic Plants, Periphyton, and Phytoplankton*

Primary producers are photosynthetically active organisms that largely consist of macrophytes (aquatic plants), phytoplankton, and periphyton. Aquatic macrophyte is the general term applied to large vascular and non-vascular plants that grow in aquatic systems [including both submergent and emergent plants (e.g. sedges)]. Aquatic macrophytes represent a primary food source for a variety of plant-eating invertebrates. In addition, macrophytes provide habitat for a wide variety of species, including aquatic invertebrates and fish. Phytoplankton are small non-vascular plants that are suspended in the water column, and are comprised of several types of algae. Periphyton are typically larger non-vascular plants that grow on other aquatic plants, or on the bottom surface of the water body often encrusting large cobble and rocks.

During the 2016 field program aquatic macrophyte, and phytoplankton diversity was not quantified in either the Tulsequah River or side channels. Timing of the 2016 field sampling program did not coincide with an ecologically relevant sampling period to assess habitat preferences and identify the presence/absence of macrophytes and phytoplankton. Primary producers as a group are likely present but not abundant adjacent to the main Site and within Zone 2, with higher abundances likely occurring further south in Zones 3 and 4.

Periphyton were sampled by Rescan (1994, 1995) and Gartner Lee (1998, 1999) within Chasm and Shazah Creeks but not within Rogers Creek or the Tulsequah River mainstem. Periphyton phyla varied between the two sites and included: bacillariophyta, chlorophyte, cryptophyta, cyanophyta, and gamophyta. Timing of the 2016 field sampling program did not coincide with an ecologically relevant sampling period to assess habitat preferences and identify the presence/absence of periphyton.

COPC exposure for macrophytes, phytoplankton and periphyton was assumed to be minimal. Primary producers within this biogeoclimatic zone have a yearly seasonal die off which reduces

the amount of exposure time to mine-related COPCs. Because only one main exposure source was identified for primary producers combined with the dilution observed within the waters surrounding the Site this receptor group was not identified as an ROC for the current assessment.

3.7.3.2 *Aquatic Invertebrates*

Aquatic invertebrates play an essential role within aquatic food webs because they consume aquatic plants and provide an important food source for fish and many other aquatic organisms. Declines in the abundance and diversity of aquatic organisms could lead to food web effects that can adversely impact higher trophic level organisms such as fish.

Aquatic invertebrates were sampled by Rescan (1994, 1995) and Gartner Lee (1998, 1999) within Chasm, Rogers, and Shazah Creeks, and within the Tulsequah River mainstem. Invertebrate groups varied between sites and included: nematoda oligochaeta, turbellaria, cladocera, copepoda, ostracoda, arachnida, ephemeroptera, plecoptera, trichoptera, coelenterata, and diptera. Similar to primary producers the timing of the 2016 field program did not coincide with an ecologically relevant sampling period to assess habitat preferences and identify the presence/absence of aquatic invertebrates.

Aquatic invertebrates fall into two main categories: pelagic and benthic. Chironomids are in-faunal benthic invertebrates and Hyalella are epi-faunal aquatic invertebrates confirmed present (Rescan 1994, 1995; Gartner Lee 1998, 1999) in relevant zones within tributaries and the mainstem portion of the Tulsequah River. Pelagic and benthic invertebrates have been retained as ROCs because multiple COPCs were identified in three relevant exposure media with significant and complete exposure pathways. Hyalella species represent the surrogate pelagic invertebrate ROC and Chironomids represent the surrogate benthic invertebrate ROC.

3.7.3.3 *Fish*

Fish occupy a wide range of ecological niches and habitats. Fish represent important components of aquatic food webs by processing energy from aquatic plants (i.e., primary producers), zooplankton and benthic macroinvertebrate species (i.e., primary consumers), and detritivores. Fish also represent important prey species for piscivorous (fish-eating) wildlife, including birds and mammals.

A variety of fish have been confirmed present during previous assessments. Fish were sampled by Rescan (1994, 1995) and Gartner Lee (1998, 1999) within Chasm, Rogers, and Shazah Creeks, and within the Tulsequah River. SLR also confirmed fish habitat for thirteen different fish species, as identified above in Section 3.7.2. Fish species were in either one of two categories: resident or migratory.

Habitat features and functionality required for fish spawning was confirmed to be present within each of the four zones during the 2016 field program. Therefore fish eggs are also a relevant ROC life stage for the current assessment. Table C-4 in Appendix C provides a breakdown of migratory fish life stages and whether these stages overlap with when a fish would reside in Tulsequah waters. Habitat was present to support both spring and fall spawners within each of the four zones.

Fish have been retained as aquatic ROCs because multiple COPCs were identified in three relevant exposure media with significant and complete exposure pathways. Juvenile and adult

fish ROCs were grouped into two categories based on the degree to which they use the Site: residents and migrants. Resident fish have smaller foraging ranges and higher potential exposure compared to migratory fish because they inhabit surrounding watercourses year round. Sculpin was the resident ROC chosen to represent this group. Migratory fish have a lower potential exposure duration compared to residents but their exposure is highly variable. Timing needs to be considered when assessing exposure to mine-sourced COPCs for this group. Salmonids and Steelhead Trout were the migratory ROCs chosen to represent this group.

Salmonids more importantly were retained because of their aesthetic and recreational value to the local resident and First Nations population.

3.8 Exposure Pathway Description

Potential routes of contaminant release or migration from the Site to ROCs include the following:

- Overland surface waters discharging sediment and mine-impacted waters (from portals, waste rock, water treatment plant, and exfiltration pond) into the Tulsequah mainstem, braided channels, and tributaries draining into the Tulsequah River;
- Groundwater containing mine-impacted waters (from infiltration of surface water from portals, waste rock, water treatment plant, and exfiltration pond) and discharging through porewater to surface water into the Tulsequah mainstem, braided channels, and tributaries draining into the Tulsequah River;
- Partitioning between sediment and porewater;
- Partitioning between porewater and surface water, and/or
- Bioaccumulation in the tissues of prey items (movement from sediment, surface water and/or porewater into biota).

Potentially complete and significant exposure pathways between ROCs and COPCs include:

- Direct contact with surface water (eggs, skin, integument or gills);
- Direct contact with porewater (eggs, skin, integument or gills);
- Direct contact with sediment (eggs, skin, integument or gills);
- Ingestion of surface water;
- Ingestion of sediment; and/or
- Ingestion of contaminated prey items.

There were no potentially complete and significant exposure pathways for primary producers. Primary producers were therefore not selected as receptors and were excluded from the current AERA.

Benthic invertebrates had four potentially complete and significant exposure pathways within the four zones at the Site. These exposure pathways included: direct contact with COPCs in sediment, direct contact with porewater, and the ingestion of surface water and sediment. Benthic invertebrates live in continuous contact within the sediment and come into direct contact with porewater. They actively filter and feed upon suspended sediment particles within the water column and at the sediment:water interface. Direct contact with surface water was considered complete but insignificant relative to porewater. The ingestion of prey items was considered complete but insignificant relative to the ingestion of surface water and sediment. Benthic invertebrates were an ROC carried forward for assessment in the AERA. Chironomids were the surrogate ROC identified for this receptor group.

Pelagic invertebrates had four potentially complete and significant exposure pathways within the four zones at the Site. These exposure pathways included: direct contact with COPCs in surface water and porewater, and the ingestion of surface water and sediment. Pelagic invertebrates live within the water column and at the sediment:water interface but not within the sediment (as adults). As a result they come into direct contact with porewater and surface water. They actively filter and feed upon suspended sediment particles within the water column and at the sediment:water interface. Direct contact with sediment was considered complete but insignificant relative to porewater and surface water. The ingestion of prey items was considered complete but insignificant relative to the ingestion of surface water and sediment. Pelagic invertebrates were an ROC carried forward for assessment in the AERA. Hyalella was the surrogate ROC identified for this receptor group.

Fish were assessed under three separate categories: residents, migrants, and eggs. The exposure pathways did not differ between resident and migratory fish but did differ between fish and fish eggs. Juvenile and adult fish had five potentially complete and significant exposure pathways within the four zones at the Site. These exposure pathways included direct contact with COPCs in surface water and sediment, surface water and sediment ingestion, and prey ingestion. Sediment contact and ingestion does vary between fish species. Relative to porewater and sediment, surface water exposure via skin or gills dominates the direct contact pathway for fish. Although fish can accumulate COPCs from the ingestion of various prey items this exposure pathway was outside of the scope of work for the current assessment. Fish were an ROC carried forward for assessment in the AERA. Sculpin was the surrogate ROC identified for residents while trout and salmonids were the surrogate ROC identified for migrants.

Habitat features were present for fish spawning within all four zones. Fish eggs had two potentially complete and significant exposure pathways within the Site: direct contact with porewater and sediment. Fish eggs are laid/fertilized, incubated and hatched either at the sediment:water interface or buried within coarse sediments. Direct contact with surface water was considered complete but insignificant relative to the direct contact pathway for porewater. Fish eggs were ROC carried forward for assessment in the current AERA.

Based on the above considerations, complete and significant exposure pathways with retained COPCs were identified for:

- Benthic invertebrates (Chironomids) exposed to COPCs in surface water, porewater and sediment;
- Pelagic invertebrates (Hyalella) exposed to COPCs in surface water, porewater and sediment;
- Fish (resident and migratory) exposed to COPCs in surface water and sediment; and
- Fish eggs exposed to COPCs in porewater and sediment.

3.9 Fate and Transport

As described in the AERA, the chemicals of potential concern (COPC) identified throughout Site are attributed to historical mining operations. Chemicals identified as ecological COPCs include aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, sulphate, and zinc. COPCs are capable of transforming through physical, chemical and biological processes. Knowledge of the fate and transport mechanisms and transformation processes allows for assessment of the potential form and behaviour of COPCs in each relevant medium.

The fate and transport of metals in environmental media depends on several variables including redox conditions, pH, hardness and the level of organic carbon. These variables influence the oxidation state and the solubility of metals. Metals bind to soil/sediment particles with different affinities depending on the soil/sediment characteristics, and are thus found in different ratios of total versus dissolved metals. Metals are also found in dissolved form or complexed form in water depending on the strength or stability of the metal-ligand binding.

3.10 Site Conceptual Models

Drawings 1A to 1C present the ecological conceptual site models (CSM) that depict: the COPC sources, exposure pathways between environmental media (i.e., surface water, porewater, sediment, and food items) and the ROC groups present within each of the three impacted exposure zones. The main difference between the three CSMs is that the source and the media/transport mechanisms differ between exposure zones. For example the source in Zone 2 is dominated by portal discharge whereas the source in Zone 3 is characterized by portal discharge in combination with input from two physically separate NAG and PAG piles. The routes of intake and ROCs do not vary between exposure zones. Additional site-specific habitat assessment and ROC absence/presence was used to refine the pathways within each exposure zone.

Exposure pathways are defined by the media that COPCs are present in combined with the route of intake. Exposure pathways were considered complete if one or several of the retained COPCs were present in the medium under consideration and if a realistic possibility of exposure to this medium existed (i.e., a route of entry into the organism via ingestion, dermal absorption). Exposure pathways were considered potentially complete but insignificant when the pathway was biologically relevant and exposure sources were insignificant i.e., surface water compared to porewater exposure for benthic invertebrates. A pathway was considered incomplete if it was not biologically relevant i.e., water ingestion for aquatic plants. A pathway was considered non-applicable or irrelevant because to the toxicology (fate and transport) specific to the COPC ie: metals within the current AERA don't biomagnify therefore biomagnification of metals due to the ingestion of fish tissue by other fish was deemed irrelevant.

Complete and significant pathways were shaded green in the CSM drawings and were carried forward for further assessment of risk. Some exposure pathways were considered to be complete, but associated with a low likelihood of exposure, (exposure would be very infrequent, or dose from the exposure would be very low); qualitatively speaking, these pathways would likely pose a low level of risk. These pathways were shaded yellow and considered insignificant and were not carried further in the risk assessment. Incomplete pathways were shaded red and were not considered further in the evaluation of risk.

A summary of the final ROCs retained in the AERA, complete and significant exposure pathways, and retained COPCs are presented below in Table 3-2. Each ROC was assessed in the AERA using COPC concentrations in the most significant exposure media identified in italics below.

Table 3-2: Final Ecological Receptors Retained in the AERA

Receptor Group	Complete and Significant Exposure Pathways	Source Media and COPC
Benthic Invertebrates	Direct contact with sediment and porewater; ingestion of sediment and surface water	*Sediment* - arsenic, copper, iron and zinc.
Pelagic Invertebrates	Direct contact with surface water and porewater; ingestion of sediment and surface water	*Porewater* - aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead and zinc.
Resident Fish	Direct contact with surface water and sediment; ingestion of surface water and sediment	*Surface water* - aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead and zinc.
Migratory Fish	Direct contact with surface water and sediment; ingestion of surface water and sediment	*Surface water* - aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead and zinc.
Fish Eggs	Direct contact with porewater and sediment	*Porewater* - aluminum, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, sulphate, and zinc.

3.11 AERA Assessment and Measurement Endpoints

An assessment endpoint is an “explicit expression of the environmental value that is to be protected, operationally defined by an ecological entity and its attribute” (USEPA 1998). The selection of assessment endpoints is an essential element of the overall risk assessment process because it focuses assessment activities on the key environmental values adversely affected by exposure to environmental contaminants. The three assessment endpoints identified for the 2016 AERA were: maintaining aquatic invertebrate community diversity, maintaining resident fish community diversity, and maintaining migratory fish community diversity.

A measurement endpoint is defined as a “measurable ecological characteristic that is related to the valued characteristic that is selected as the assessment endpoint” and it is a measure of biological effects (e.g., mortality, reproduction, growth; USEPA 1998). Measurement endpoints are frequently numerical based and can be compared to a control and/or reference site. The three measurement endpoints identified for the 2016 AERA were the following risk estimates or HQs:

- Porewater HQs for pelagic invertebrates and sediment HQs for benthic invertebrates;
- Surface water HQs for resident and migratory fish; and
- Porewater HQs for fish eggs.

4.0 EXPOSURE ASSESSMENT

The Exposure Assessment identifies the exposure point concentrations (EPC) for the COPCs that are to be evaluated, and estimates the levels of exposure on complete exposure pathways identified in the Problem Formulation. The COPC screening, which is summarized in Section 3.6, identified COPCs in sediment, porewater, and surface water. The spatial distribution of the COPCs and the potential magnitude of exposure are described in the following sections.

4.1 2016 Exposure Point Concentrations

Maximum surface water, porewater, and sediment concentrations were used as EPCs within each of the four zones. Surface water concentrations for source waters within Zone 2 were not used because these are undiluted and don't represent exposure sources for ROCs within receiving waters. Tables 9 to 12 present the EPCs selected for the five ROC groups.

Benthic and pelagic invertebrate EPCs are presented in Table 9. Benthic EPCs are based on maximum COPC concentrations in sediment and pelagic EPCs are based on maximum COPC concentrations in porewater. Although pelagic invertebrates are exposed to larger volumes of surface water, porewater COPC concentrations were higher and represent the worst case exposure scenario for this ROC. Porewater COPC concentrations were considered the most conservative and therefore pelagic EPCs were based on maximum porewater concentrations

Resident and migratory fish EPCs were the same and were based on maximum COPC concentrations in surface water. These are presented in Tables 10 and 11.

Fish egg EPCs were based on maximum COPC concentrations in porewater and are presented in Table 12.

4.2 Interpretation of Sediment SEM:AVS Ratios and Implications for Sediment COPCs

Measurements of acid volatile sulfide (AVS) and simultaneously extracted metals (SEM) in sediments are used to evaluate the toxicity of metals to aquatic benthic organisms. AVS is volatilized from sediments by the addition of acid and SEM are the metals extracted during the AVS procedure. The AVS/SEM method gives a better indication of sediment toxicity to benthic organisms than measurements of "total" metals by measuring the "bioavailable" fraction of metals present. Toxicity of the sediment is evaluated by calculating the sum of the SEM (µmol/g dry weight) divided by the AVS concentration (in the same units). A SEM:AVS ratio less than or equal to 1 indicates that metals are not bioavailable in sediment, while a ratio of greater than 1 indicates that metals are bioavailable.

Table 4-1 presents the SEM:AVS ratios for the six sediment samples collected during the 2016 field program. Cadmium, copper, lead, nickel, mercury and zinc are SEM/AVS extractable metals and the sum SEM/AVS ratios for the six samples identified ratios exceeding one for five of the six samples. Ratios above one indicate that if SEM/AVS metals are present then they are highly bioavailable.

Table 4-1: SEM:AVS Interpretation

Sample ID and Location	COPCs Exceeding CSR Schedule 9 Sensitive Criteria	SEM:AVS Ratio
SE16-1; Zone 1, main	-	13
SE16-5; Zone 2, main	arsenic, copper, zinc	255
SE16-12; Zone 3, main	Arsenic	25
SE16-14; Zone 3, main	Arsenic	54
SE16-15; Zone 3, tributary	Arsenic	0.55
SE16-17; Zone 4, tributary	Arsenic	75

The SEM:AVS ratios at five of the six sample locations indicated that SEM:AVS extractable metals are highly bioavailable. Arsenic was elevated in four samples with elevated SEM:AVS ratios but arsenic is not an SEM:AVS extractable metal, and therefore high bioavailability cannot be inferred for arsenic using this extraction procedure. The single sediment sample from Zone 2 had elevated copper and zinc concentrations concurrent with the highest SEM:AVS ratio. This means that copper and zinc are highly bioavailable within this sample from Zone 2. It could also be interpreted that the metal source is not likely from natural sources, and from precipitation of metals from the impacted groundwater and overland surface water entering the Tulsequah River.

5.0 EFFECTS ASSESSMENT

Exposure to contaminated surface water, porewater and sediment has the potential to adversely affect aquatic organisms. In order to assess the potential effects and characterize the potential risks to these receptors, toxicological reference values (TRVs) were compiled for each of the final COPCs. A TRV is a receptor-specific concentration of a chemical, above which adverse effects have the potential to occur, and below which there is a low likelihood that adverse effects will occur. The selected TRVs were then used to quantify the potential risks that are presented in Section 6.0.

Literature sources reviewed as part of TRV compilation included:

- Technical supporting documents published by BC MOE as part of the BC AWQG, and WWQG;
- Technical supporting documents published by CCME as part of the Canadian Environmental Quality Guidelines for the protection of aquatic life;
- Technical supporting documents published by the USEPA to support the Ambient Water Quality Guidelines;
- Technical supporting document published by the Ontario Ministry of Energy and Environment as part of the provincial sediment quality standards; and
- Publications of peer reviewed toxicology literature, accessed from Web of Science citation indexing service.

Preference was given to chronic toxicity data for reproduction, growth and survival endpoints, when selecting TRVs. The goal of the AERA was not to protect each individual from a toxic effect, but rather to protect enough individuals so that a viable population and community of organisms can be maintained. This is why EC_{20} values were considered appropriate TRVs where available, which is in keeping with the BC CSR Protocol 1 (BC MOELP 1998) protection goal for aquatic organisms.

The following are additional criteria that SLR applied when identifying potential TRVs:

- Fish TRVs were targeted for resident fish and migratory (anadromous) fish;
- When TRVs were identified for multiple life history stages, the most conservative TRV was selected for the receptor category;
- Only freshwater based studies were considered;
- Studies not providing test duration, exposure concentrations and measured effects were excluded;
- EC/LC_{50} results were used for select chemicals when there was not an abundance of available literature. An EC/LC_{20} TRV was estimated by multiplying the EC/LC_{50} by 0.4;

- Chronic value estimates were used when LOECs were associated with a > 20% effect. The chronic value is calculated by taking the geomean of the NOEC and LOEC;
- Preference was given to studies and associated reference values that used pH and hardness test conditions that were within the range of background (i.e. reference) conditions for the Tulsequah River. The target pH range was 7.44 - 7.91, and the target hardness range was 41.7 - 64.2 mg/L; and
- In those instances where there was insufficient toxicology data for an analyte, SLR resorted to using a regulatory guideline or value suggested by the regulatory agency.

The studies considered and selected TRVs are presented in Tables 13 to 16.

5.1 Aquatic Invertebrate TRVs

TRVs selected for pelagic and benthic invertebrates are presented below in Table 5-1. Pelagic TRVs are based on studies where pelagic invertebrates were exposed to COPCs in porewater or surface water, and benthic TRVs are based on studies where benthic invertebrates were exposed to COPCs in sediments. For additional information pertaining to the chosen TRVs, including general test conditions of the study, or technical guidance documents where the values were obtained, refer to Tables 13 and 14.

Table 5-1: Pelagic and Benthic Invertebrate TRVs

COPCs	TRVs	
	Pelagic (µg/L)	Benthic (mg/kg)
Aluminum	320	NA
Arsenic	520	20
Beryllium	36	NA
Cadmium	1.35	NA
Cobalt	12.5	NA
Copper	5.68	240
Iron	157	32,483
Lead	12.3	NA
Sulphate	855,000	NA
Zinc	47	380

"NA"– Not applicable, as analyte not retained as a final COPC for sediment.

Uncertainties pertaining to the selection for the pelagic and benthic invertebrate TRVs are discussed in Section 8.2.

5.2 Fish TRVs

TRVs selected for resident and migratory fish and fish eggs are presented below in Table 5-2. For additional information pertaining to the chosen TRVs, including general test conditions and test results, refer to Tables 15 and 16.

TRVs for resident and migratory fish, for aluminum, arsenic, beryllium, cobalt, iron and lead are the same due to challenges with finding suitable literature specific to the individual fish categories. Separate resident and migratory TRVs were available for cadmium, copper, and

zinc. Both the cadmium and zinc TRVs were less stringent for migratory fish compared to residents while copper TRVs were more stringent for migratory fish compared to residents. The largest difference in TRVs is for zinc, where the TRV for migratory fish is an order of magnitude larger than the TRV for resident fish.

Fish egg TRVs correspond to the most stringent of resident fish and migratory fish TRVs, with the exception of sulphate. For sulphate an egg/embryo specific TRV was identified because sulphate was only retained as a final COPC in porewater.

Table 5-2: Resident and Migratory Fish and Fish Egg TRVs

COPCs	TRVs (µg/L)		
	Resident	Migratory	Eggs
Aluminum	200	200	200
Arsenic	220	220	220
Beryllium	70.7	70.7	70.7
Cadmium	0.67	1.9	0.67
Cobalt	120	120	120
Copper	2.7	1.9	1.9
Iron	1000	1000	1000
Lead	12	12	12
Sulphate	NA	NA	356,000
Zinc	55	732	55

"NA"– Not applicable, as analyte not retained as a final COPC for surface water.

Uncertainties pertaining to the selection of fish TRVs are discussed in Section 8.2.

6.0 RISK CHARACTERIZATION

Risks to fish and aquatic invertebrates from exposure to COPCs in surface water, porewater, and sediment were quantitatively evaluated by calculating HQs.

6.1 Hazard Quotient Methodology

Risks from each COPC (and media) for which a TRV was identified were characterized through the calculation of HQs. Hazard Quotients were calculated using the following equation:

$$HQ = \frac{EPC}{TRV}$$

Where:

HQ	=	Hazard Quotient
EPC	=	Exposure Point Concentration (µg/L in surface water)
TRV	=	Toxicological Reference Value

When conservative effects-based TRVs are used in risk characterization, as they have been in the current AERA, HQs greater than one indicate the potential for adverse effects to ecological receptors. HQs above one do not indicate that adverse effects are certain as chemical concentrations in media can be considered to be the first line of evidence in risk assessment. Other lines of evidence, such as community structure or toxicity testing, can also be considered in determining site risks to COPCs in media. HQs less than one indicate low to extremely low risk or probability of effects (i.e. negligible risk) (CCME 1997).

6.2 Hazard Quotient Estimates

Maximum COPC concentrations and TRVs were used to calculate risk estimates referred to as HQs. HQs were calculated for pelagic invertebrates, benthic invertebrates, resident fish, migratory fish, and fish eggs. HQ calculations are presented in Tables 9 to 12. HQs below a value of one were simply identified as < 1. HQs calculated from impacted areas were compared to reference HQs. This is because when an HQ exceeds a low level of risk (ie. > 1) it is important to assess the magnitude of that HQ relative to the natural background conditions represented by the reference HQ.

6.2.1 HQ Estimates for Pelagic Invertebrates

HQ estimates for pelagic invertebrates were generated based on COPC concentrations in porewater and are presented below in Table 6-1. Porewater data was available for three of the four zones. No porewater data was available for Zone 4 which is the area furthest from the Mill site.

Table 6-1: Pelagic Invertebrate HQs

Porewater COPCs	Zone 1 (n=1)	Zone 2 (n=2)	Zone 3 (n=1 + 1 dup)
Aluminum	<1	72.5	3.4
Arsenic	<1	<1	<1
Beryllium	<1	<1	<1
Cadmium	<1	170	<1
Cobalt	<1	1.2	<1
Copper	<1	2020	<1
Iron	<1	24.7	10.7
Lead	<1	14	<1
Sulphate	<1	<1	<1
Zinc	<1	1360	<1

Zone 1 – Reference, Zone 2 – Zone of Discharge, Zone 3 – Impacted Near

Pelagic invertebrate HQs were associated with a low level of risk in the reference zone (Zone 1). HQs for Zones 2 and 3 had varying risk levels. Within Zone 2 aluminum, cadmium, cobalt, copper, iron, lead, and zinc HQs exceeded one and were higher than reference HQs. The Zone 2 HQ for cobalt was associated with a HQ close to 1 while HQs for aluminum, iron and lead exceeded one, ranging from 14 to 72.5. Copper and zinc HQs were highest in Zone 2 and exceeded reference HQs by more than three orders of magnitude. Within Zone 3 the HQs aluminum and iron exceeded 1 _(3.4 and 10.7, respectively).

6.2.2 HQ Estimates for Benthic Invertebrates

HQ estimates for benthic invertebrates were generated based on COPC concentrations in sediment and are presented below in Table 6-2.

Table 6-2: Benthic Invertebrate HQs

Sediment COPCs	Zone 1 (n=1)	Zone 2 (n=1)	Zone 3 (n=3)	Zone 4 (n=1)
Arsenic	<1	1	1.5	<1
Copper	<1	1.4	<1	<1
Iron	<1	<1	<1	<1
Zinc	<1	<1	<1	<1

Zone 1 – Reference, Zone 2 – Zone of Discharge, Zone 3 – Impacted Near, Zone 4 – Impacted Far

Benthic invertebrate HQs were associated with a low level of risk in both the reference zone (Zone 1) and Zone 4. Within Zone 2 the copper HQ was above 1 and in Zone 3 the arsenic HQ was above 1.

6.2.3 HQ Estimates for Resident Fish

HQ estimates for resident fish were based on concentrations of COPCs in surface water and are presented below in Table 6-3.

Table 6-3: Resident Fish HQs

COPCs	Zone 1 (n=4)	Zone 2 (n=4 + 2 dups)	Zone 3 (n=8)	Zone 4 (n=2)
Aluminum	11.2	61	8.4	<1
Arsenic	<1	<1	<1	<1
Beryllium	<1	<1	<1	<1
Cadmium	<1	324	3.4	<1
Cobalt	<1	<1	<1	<1
Copper	2.8	3670	38.9	<1
Iron	2.8	42.5	2.3	<1
Lead	<1	13.1	13.3	<1
Zinc	1.8	485	10.2	<1

Zone 1 – Reference, Zone 2 – Zone of Discharge, Zone 3 – Impacted Near, Zone 4 – Impacted Far

Resident fish HQs were associated with a negligible level of risk in Zone 4, while HQs for Zones 1, 2 and 3 had risk levels exceeding 1. Zone 1 (Reference zone) HQs above 1 varied from 1.8 to 11.2). Within Zone 2 aluminum, cadmium, copper, iron, lead, and zinc HQs exceeded one, ranging from 13.1 to 3670, and were higher than reference HQs. Within Zone 3 cadmium, copper, lead, and zinc HQs exceeded one, ranging from 3.4 to 38.9, and were higher than reference HQs. Zone 3 HQs for aluminum and iron exceeded one, ranging from 2.3 to 8.4, and were less than reference HQs in Zone 1.

6.2.4 HQ Estimates for Migratory Fish

HQ estimates for migratory fish were based on concentrations of COPCs in surface water and are presented below in Table 6-4.

Table 6-4: Migratory Fish HQs

COPCs	Zone 1 (n=4)	Zone 2 (n=4 + 2 dups)	Zone 3 (n=8)	Zone 4 (n=2)
Aluminum	11.2	61	8.4	<1
Arsenic	<1	<1	<1	<1
Beryllium	<1	<1	<1	<1
Cadmium	<1	114	1.2	<1
Cobalt	<1	<1	<1	<1
Copper	4.0	5220	55.3	<1
Iron	2.8	42.5	2.3	<1
Lead	<1	13.1	13.3	<1
Zinc	<1	36.5	<1	<1

Zone 1 – Reference, Zone 2 – Zone of Discharge, Zone 3 – Impacted Near, Zone 4 – Impacted Far

Migratory fish HQs were associated with a negligible level of risk in Zone 4. Zone 1 (Reference zone) HQs above 1 varied from 2.8 to 11.2. Within Zone 2 aluminum, cadmium, copper, iron, lead, and zinc HQs exceeded one, ranging from 13.1 to 5220, and were higher than reference HQs. Within Zone 3 cadmium, copper, and lead, HQs exceeded exceed one, ranging from 1.2 to 55.3, and were higher than reference HQs. Zone 3 HQs for aluminum and iron exceeded one, ranging between 2.3 and 8.4, and were less than reference HQs in Zone 1.

6.2.5 HQ Estimates for Fish Eggs

HQ estimates for fish eggs were based on concentrations of COPCs in porewater and are presented below in Table 6-5. Porewater data was available for three of the four zones. No porewater data was available for Zone 4 which is the area furthest from the Mill site.

Table 6-5: Fish Egg HQs

COPCs	Zone 1 (n=1)	Zone 2 (n=2)	Zone 3 (n=1 + 1 dup)
Aluminum	<1	116	5.5
Arsenic	<1	<1	<1
Beryllium	<1	<1	<1
Cadmium	<1	342	<1
Cobalt	<1	<1	<1
Copper	1.2	6050	2.5
Iron	<1	3.9	1.7
Lead	<1	14.3	<1
Sulphate	<1	1.5	<1
Zinc	<1	1160	<1

Zone 1 – Reference, Zone 2 – Zone of Discharge, Zone 3 – Impacted Near

Fish egg HQs were associated with a negligible level of risk in the reference zone with the exception of copper that marginally exceeded 1 (HQ=1.2). HQs for Zones 2 and 3 had varying levels of risk. Within Zone 2 aluminum, cadmium, copper, iron, lead, sulphate, and zinc HQs exceeded one, ranging from 1.5 to 6050, and were higher than reference HQs. Within Zone 3 aluminum, copper, and iron HQs exceeded one, ranging between 1.7 and 5.5, and were higher than reference HQs

6.2.6 HQ Summary Table for all ROC

HQs equal to or below one are associated with a low level of risk for the ROC exposed to the COPC. HQs greater than one and exceeding the reference HQs are associated with potential risk for the ROC. These HQs are presented below for the five ROC groups in Table 6-6.

Table 6-6: Summary of HQs > 1 for AERA ROCs

ROC	COPC WITH HQ > 1 AND > ZONE 1		
	Zone 2	Zone 3	Zone 4
Resident Fish	aluminum, cadmium, copper, iron, lead, zinc	cadmium, copper, lead, zinc	-
Migratory Fish	aluminum, cadmium, copper, iron, lead, zinc	cadmium, copper, lead	-
Fish Eggs	aluminum, cadmium, copper, iron, lead, sulphate, zinc	aluminum, copper, iron	NA
Pelagic Invertebrates	aluminum, cadmium, cobalt, copper, iron, lead, zinc	aluminum, iron	NA
Benthic Invertebrates	copper	arsenic	

6.3 Summary of Hazard Quotients in Impacted Areas Relative to Habitat Quality

The following section contains a summary of habitat features, functionality and fish presence/absence along with HQs within each of the three impacted zones.

6.3.1 Zone 2 - Zone of Discharge

Two types of habitat quality were identified in Zone 2 for resident and migratory fish: mainstem and side-channel. Fish expected to utilize the mainstem are Coho, Sockeye, Chum, Dolly Varden, and Round Whitefish. Within the mainstem habitat functionality for spawning and migration was low due to low gravel compaction and shifting channel boundaries that likely don't offer stable incubation conditions for successful egg incubation. Mainstem areas provided no refuge/rearing or overwintering habitat utilization for migratory fish. Habitat features within side channels were present within Zone 2 but because of the high turbidity and low pH identified in side-channels it is unlikely that any fish would choose to utilize habitat within this zone. It is possible that the high turbidity is not due to Tulsequah Chief Mine sources, although the low pH is associated with Tulsequah Chief Mine sources.

Aluminum, cadmium, copper, iron, lead and zinc HQs for fish, fish eggs and pelagic invertebrates were associated with potential risk with HQs ranging from 3.9 to 6050. The cobalt HQ of 1.2 indicated potential risk for pelagic invertebrates. The sulphate HQ of 1.5 indicated potential risk for fish eggs. The copper HQ of 1.4 indicated potential risk for benthic invertebrates in sediment.

SLR fish biologists identified that although the side channel habitat in Zone 2 appears suitable for spawning, refuge/rearing, and localized movements, resident and migratory fish are not likely to utilize this area for short or long term durations due to elevated concentrations of suspended sediment and source pulses of low pH levels. It is likely that within Zone 2 mainstem habitat is primarily used as a migratory corridor for Sockeye in the spring and Coho and Dolly Varden in the fall.

6.3.2 Zone 3 - Impacted Near

Three types of habitat were identified within Zone 3 for resident and migratory fish: mainstem, side-channel, and tributary. Zone 3 along with Zone 4 provided the highest quality fish habitat. In addition to migratory corridor functions, critical rearing habitat was observed in Zone 3. This habitat appears suitable for Coho, Dolly Varden and Sockeye rearing during the spring, summer and fall. Fall spawners such as Coho, Sockeye and Chum are likely to utilize side channel habitat in Zone 3, which received flow from tributaries and groundwater sources. Suitable habitat for resident species including Stickleback, Sculpin and Dolly Varden was widely distributed throughout Zone 3. These resident species are likely to undertake localized spring movements into tributaries for spawning and rearing functions.

Through direct correspondence with Mark Connor (TRT biologist), parafluvial springs (groundwater discharge to river bottom as clear water springs) are dispersed throughout mainstem habitat in the Tulsequah River and are utilized by Coho for overwintering habitat. The mainstem habitat in Zone 3 is likely to support parafluvial springs, utilized by salmonids from November to late April. SLR biologists confirmed Dolly Varden juveniles overwintering within clearwater side-channels. Substantial clear water side channels are located directly south and east of the NAG area.

Cadmium, copper, and lead HQs for resident and migratory fish and the zinc HQ for resident fish were associated with potential risk with HQs ranging from 1.2 to 55.3. Aluminum, copper, and iron HQs for fish eggs and aluminum and iron HQs for pelagic invertebrates were associated with potential risk with HQs ranging from 1.7 to 5.5 and 3.41 to 10.7, respectively. Aluminum and iron HQs for fish were associated with potential risk (HQs ranging 2.3 to 8.4) but were below HQs calculated in the reference Zone 1. The arsenic HQ of 1.5 indicated potential risk for benthic invertebrates in sediment.

Overall habitat utilization by resident and migratory fish within Zone 3 was high. SLR fish biologists confirmed that the amount of time that resident and migratory fish would spend within Zone 3 is high because there are numerous high quality habitat features within various portions of watercourses surrounding this zone. Within Zone 3 a high level of exposure is associated with the fish HQs because the amount of time that fish would spend within this area is substantial.

6.3.3 Zone 4 - Impacted Far

Two types of habitat were identified within Zone 4 for resident and migratory fish: side-channel and slough. It is likely that side channel habitat can be classified as mainstem depending upon the seasonal flow of water which impacts side channel connectivity with the mainstem. This zone had the most available information regarding fish presence/absence within the Site. Fish expected to utilize the side channels were various species of salmonids. Side channel habitat functionality for refuge/rearing was low because of the limited connectivity to mainstem or tributaries combined with low water levels. Habitat features required for overwintering, spawning or migration were not present within Zone 4 side-channels.

Rogers Slough is the slough located in Zone 4. Habitat functionality for refuge/rearing, overwintering and spawning was identified for both resident and migratory fish within Rogers Slough. Zone 4 along with Zone 3 currently provided the highest quality of habitat, and for Zone 4 the highest quality was largely associated with Rogers Slough. The habitat observed in Zone 4 is suitable to support Coho, Dolly Varden and Cutthroat Trout rearing (Mark Connor, pers. comm.). It is expected that these juvenile fish will occupy Zone 4 in spring, summer and fall. In the fall, Coho have been documented spawning directly downstream of Roger's Slough. With regards to resident fish, SLR confirmed the presence of Stickleback, and documented critical habitat features for sculpin, and yearling and sub-adult Dolly Varden. Zone 4 contained habitat suitable for year round residency of Stickleback.

Within Zone 4 all calculated HQs for fish and benthic invertebrates were associated with a low level of risk. Porewater was not collected within Zone 4 and therefore HQs weren't calculated for fish eggs and pelagic invertebrates.

SLR fish biologists confirmed that the amount of time that resident and migratory fish would spend within Zone 4 is high because there are numerous high quality habitat features within the Slough. Within Zone 4 a high level of exposure is associated with the fish HQs because the amount of time that fish would spend within this area is substantial.

7.0 CONTAMINANT TREND ANALYSIS

The objective of the 2016 AERA was to use current COPC concentrations to assess risk levels for aquatic receptors within the four zones encompassing the Site. It is relevant to identify pertinent trends between historic and current COPC concentrations. A preliminary comparison was completed that presents the maximum surface water concentrations within the 2013 AERA alongside maximum 2016 COPC concentrations for retained surface water COPCs. This information is presented in Tables 7 and 8. Sediment and porewater analytical results and surface water from Zone 3 were not presented in the 2013 AERA and therefore only surface water from Zone 1 (reference; W10), Zone 2 (zone of discharge; W46 or W51), and Zone 4 (impacted far; W32) was compared to the maximum 2016 surface water concentrations.

The following preliminary trends were identified for total metal COPC concentrations:

- Porewater:
    - COPC concentrations decreased with increasing distance from the main mine source (the Mill and portals) with the exception of arsenic;
    - Hardness was highest near the main source inputs in Zone 2;

- Surface Water
  - Within Zone 2 COPC concentrations were 2X to 9X higher for all retained COPCs in 2016 compared to 2013;
  - There is no historical data presented for Zone 3;
  - For the 2016 dataset COPC concentrations in Zone 3 varied for samples within the mainstem (n=5) compared to tributaries (n=3). Aluminum, cobalt, and iron concentrations were higher within the mainstem. Arsenic, cadmium, copper, lead, and zinc concentrations were higher within the tributaries. This is despite similar hardness and pH within both areas;
  - Within Zone 4 COPC concentrations were 2X to 85X lower for all retained COPCs in 2016 compared to 2013;
  - For the 2016 dataset COPC concentrations in Zone 4 varied for samples within the mainstem compared to tributaries. COPC concentrations were either similar to or slightly higher in the tributary sample compared to the mainstem with the exception of arsenic;
  - Hardness was higher in 2016 for all zones compared to 2013 for samples collected within the mainstem. Hardness was highest in Zone 2 and for the most part decreased with increasing distance from Zone 2;
- Sediment
  - Cadmium, copper, lead and zinc concentrations decreased with increasing distance from the main mine source (the Mill and portals);
  - Aluminum and iron concentrations increased with increasing distance from the main mine source; and
  - Arsenic was highest in Zone 3.

The following preliminary trends were identified for dissolved metal COPC concentrations:

- Porewater:
  - COPC concentrations decreased with increasing distance from the main mine source (the Mill and portals) with the exception of arsenic;
  - Hardness was highest near the main source inputs in Zone 2;
- Surface Water
  - Within Zone 2 COPC concentrations were 1.6X to 9.5X higher for all retained COPCs in 2016 compared to 2013;
  - There is no historical data presented for Zone 3;
  - For the 2016 dataset COPC concentrations in Zone 3 varied for samples within the mainstem (n=5) compared to tributaries (n=3). Aluminum, cadmium, copper, and zinc concentrations were higher within the mainstem. Arsenic and iron concentrations were higher within the tributaries. This is despite similar hardness and pH within both areas;
  - Within Zone 4 COPC concentrations were 2X to 85X lower for all retained COPCs in 2016 compared to 2013;
  - For the 2016 dataset COPC concentrations in Zone 4 varied for samples within the mainstem compared to tributaries. COPC concentrations were either similar to or slightly higher in the tributary sample compared to the mainstem with the exception of arsenic and cadmium; and
  - Hardness was higher in 2016 for all zones compared to 2013 for samples collected within the mainstem. Hardness was highest in Zone 2 and for the most part decreased with increasing distance from Zone 2.

Based on this preliminary trend analysis SLR presents the following conclusions:

- COPC concentrations within Zone 2 have increased over time inferring that COPC source input has not reached steady state concentrations. The worst case-scenario may not be captured under the current AERA if source input continues to increase;
- Aluminum, iron, and arsenic concentrations in sediment were highest in Zones 3 and 4;
- The geochemistry within the source and receiving waters (mainstem vs. tributary) is complex as demonstrated by the varying ranges of hardness and pH; and
- There are elevated COPC concentrations within Zone 3 which was not an area sampled prior to 2016.

The above information should be taken under consideration prior to completing future trend analyses within the four zones at the Site.

8.0 UNCERTAINTY ANALYSIS

There are three broad types of uncertainty, which parallel each of the main stages of a risk assessment, and their inherent assumptions. These types of uncertainty are listed and discussed below.

- Exposure assessment uncertainties (including data collection and evaluation uncertainties);
- Effects assessment uncertainties; and
- Risk characterization uncertainties.

The uncertainties associated with the AERA for the Site are discussed in the following sections.

8.1 Exposure Assessment Uncertainties

The exposure assessment described the potential contact between the receptors and the COPC. In doing this, the exposure pathways and extent and magnitude of contact with the COPCs were described for each surrogate ROC. Potential sources of uncertainties in the exposure assessment can include errors in the estimation of the COPC concentrations and data gaps.

The current AERA provides a “snap-shot” of current day source input from the Tulsequah Chief Mine into the Tulsequah River mainstem, side channels and tributaries. As such site characterization within each of the impacted zones is not comprehensive. Seasonal and temporal variation has not been captured within surface water, porewater, and sediment. COPC concentrations within Zone 2 have increased over time which infers that source input has not reached steady state. The worst case-scenario may not be captured under the current AERA if source input continues to increase. In addition based on the data presented within the 2013 AERA there is no historical data for Zone 3. Additional characterization of COPCs within the three impacted zones would reduce the moderate level of uncertainty associated with estimated HQs.

Groundwater was not a media evaluated under the current AERA. The spatial extent of contaminated groundwater has not been determined and therefore, the spatial extent of contaminated porewater has not been determined. Trends between groundwater and porewater need to be evaluated in order to confirm all relevant mine COPC sources into receiving waters within Zones 2 and 3. An evaluation of historical and present day groundwater concentrations

in existing wells (PH-P-07-4, MW11-7, MW11-6, MW11-5, MW11-3) surrounding the NAG and PAG piles relative to porewater would reduce the uncertainty associated with porewater data relied upon in the assessment.

Exposure pathways were present but assumed to be insignificant for primary producers relative to aquatic invertebrates and fish. It was also assumed that primary producers are more abundant in areas less impacted by Tulsequah Chief Mine sources. A habitat assessment to identify the absence/presence of macrophytes, periphyton, and phytoplankton within Tulsequah mainstem compared to side channels and tributaries would need to be completed during an ecologically relevant time period (ie. spring or summer) to reduce the high level of uncertainty currently associated with this assumption.

Exposure for fish is inferred based on the preliminary 2016 habitat assessment completed by a professional biologist. To reduce the moderate level of uncertainty associated with this assumption fish capture methods would need to be employed to confirm the presence/absence of fish within the four zones. In particular confirming use and timing for fish within Zones 2 and 3 is critical since both zones are associated with the highest levels of risk for fish.

8.1.1 Analytical Data

All samples collected by SLR and BC MOE were analyzed by a laboratory accredited by the Canadian Association for Laboratory Accreditation.

SLR implemented a standardized quality assurance and quality control (QA/QC) program that ensures samples are collected according to guidelines established by the BC MOE. Based on the QA/QC results, it is SLR's opinion that the data collected in 2016 can be relied upon. SLR has reviewed the laboratory QA/QC data and verifies that the laboratory internal QA/QC results fall within the lab's own specified acceptance criteria.

Potential data collection/evaluation uncertainties may include:

- Insufficient numbers of samples for proper characterization of contaminants, which may result in either overestimates or underestimates. This was the case for all media in all four zones, in particular for Zone 3;
- Seasonal variation has not been captured and would be required to reduce the uncertainty associated with the data collected and relied upon;
- Based on the trend analysis presented in Tables 7 and 8 it appears that the source input has not reached steady state as COPC concentrations continue to increase over time. This means that worst-case scenario may not be captured within the current AERA and HQs may underestimate the levels of risk identified for ROCs;
- Dissolved metal concentrations were higher than total concentrations for the following samples:
    - SW0 – aluminum, cadmium, copper, zinc;
    - SW2, SW9, SW11, SW13, SW14, SW17 – sodium; and
    - SW4 – thallium.

  No explanation was provided by Maxxam for the randomness associated with inconsistencies between total and dissolved metals. SLR has concluded that these inconsistencies cannot be explained by field error because they were on an analyte basis and not on a sample by sample basis.

8.1.2 COPC Screening

The COPC selection process is designed to be conservative to ensure that no compounds which might adversely affect populations of ecological receptors are inadvertently eliminated during the screening analysis. The screening process minimizes the probability of falsely concluding that there is low potential for risk by using maximum detected concentrations in the screening process and regulatory standards that are protective of environmental health. The COPC screening approach used in this AERA considered guidelines from various sources where BC CSR standards were not available and focused on the lower of available values where more than one screening value was available.

When more than one sample was collected within a zone, the maximum concentration was used in the COPC screening process. Both total and dissolved COPC concentrations were evaluated and the highest between the two was applied in the preliminary screening. During the secondary and final screening the most relevant of total vs. dissolved was used which was identified using recommendations put forward by BC MOE guidance criteria. Any pH or hardness dependent parameter applied either the median reference pH or hardness value to derive the screening benchmark. This is a conservative approach and ensures that the benchmark won't be underestimated because as pH and hardness increase the benchmark also increases.

Based on the above, the screening process is considered to be conservative.

8.2 Effects Assessment Uncertainties

The effects assessment uncertainties associated with HQ risk estimates primarily relate to the methodology by which TRVs are developed. Toxicity information for many chemicals for the selected ecological receptors is often limited. Consequently, there are varying degrees of uncertainty associated with the toxicity values used to determine risk estimates for ecological receptors. These uncertainties may result in overestimates or underestimates of risks. The following measures were taken in order to minimize the uncertainties associated with the effect assessment:

- Toxicity values were obtained from reputable sources, including those recommended by BC MOE, including but not limited to Canadian Environmental Quality Guidelines, BC Approved and Working Water Quality Guidelines, and USEPA Ambient Water Quality Guidelines, Ontario Ministry of Energy and Environment Sediment Guidelines and peer reviewed toxicology studies accessed from the Web of Science citation indexing service; and
- Preference was given to reproductive, growth and survival endpoints, and as detailed in Section 4.0, to species and test conditions that are representative of the Taku watershed.

Key uncertainties associated with selected TRVs are as follows:

- **TRV is a calculated value.** In select instances SLR estimated LC_{20}/EC_{20} concentrations by multiplying LC_{50}/EC_{50} effect concentrations by 0.4, which assumes a linear dose-toxicity relationship. As most dose-response curves are sigmoidal, this method will typically result in a conservative LC_{20}/EC_{20} estimate being generated. This applies to TRVs selected for evaluating fish exposed to aluminum and arsenic in surface water, and fish eggs exposed to porewater;

Chronic value (ChV) estimates, presented in original studies or derived by SLR were also used as TRVs. ChV estimates are calculated by taking the geomean of NOECs and LOEC). Beryllium was the lone analyte where a ChV was identified as a suitable TRV, and was used to evaluate risk to fish and fish eggs exposed to beryllium in surface water and porewater. The LOEC in this study was associated with 45% mortality in test organisms, and as such, it is possible that the TRV may not be overly conservative;

- **Test conditions are not comparable to the Tulsequah River.** The application of laboratory derived effect concentrations for evaluating risks to receptors in natural settings should be viewed critically. In most lab controlled studies, test organisms are contained in a controlled environment and are exposed to a lone chemical or narrow suite of chemicals, whereas organisms in the wild are subject to a broader range of chemicals and stressors. Efforts were made to identify reference values from tests with conditions similar to the Tulsequah River, specifically pH and hardness values that were within the range of background conditions. In some instances TRVs were selected from studies with pH and hardness values outside of the Tulsequah River background range. Hardness and pH are common factors affecting metal toxicity to aquatic organisms. For many chemicals and test organism, susceptibility to chronic toxicity increases with decreasing pH and hardness. As such, TRVs that are associated with studies that maintained pH and hardness at levels below Tulsequah River background may be overly conservative, whereas TRVs from studies that maintained pH and hardness above background may be insufficiently conservative;

- **Test species may not be representative of receptors in the Tulsequah River.** For some analytes the TRV was based on toxicity data specific to animals that are not native to the Tulsequah River. This could result in inaccurate risk estimates. For example, a TRV measuring the effects of beryllium on resident or migratory fish in the Tulsequah was not identified, therefore a value specific to a non-native freshwater Asiatic species (common roach) was used. While TRVs were targeted for both resident and migratory fish (aluminum, arsenic, beryllium, cadmium, cobalt, iron and lead) a TRV specific to one category was used for both resident and migratory categories; and

- **TRV associated with a single life history stage.** Efforts were made to identify TRVs for multiple life histories, and select the most conservative value. For the majority of analytes it was not possible to cross-reference TRVs between life stages due to limited toxicity publications. As such, the chosen TRV may not be protective of other life stages.

  While it is generally assumed that early life history stages are more sensitive to chemical toxicity than later life stages, fish eggs have also been shown to be less sensitive to heavy metals than adults of the same species (Hellawell, 1986). This specifically pertains to the uses of resident and migratory fish TRVs for evaluating risk to fish eggs in porewater, which may also result in overly or less than conservative risk estimates.

8.3 Risk Characterization Uncertainties

Risks were quantitatively evaluated by calculating HQs. Use of a deterministic HQ (point estimate) approach to characterize risks leads to uncertainty as characterization of the risks as a single value does not reflect the various uncertainties in the data, and the exposure and

toxicity assessments, as well as the associated variability in ecological populations. The use of conservative assumptions in this ERA, such as maximum concentrations, will tend to overestimate risks, and the resulting risk estimates are therefore likely overestimating potential risks to ecological receptors.

9.0 SUMMARY AND CONCLUSIONS

This AERA was completed to evaluate whether the contamination associated with the Tulsequah Chief Site potentially poses risk to aquatic ecological receptors residing in the waters surrounding the Site. Potential risks to aquatic receptors were identified in the source zone (Zone 2) and near impacted zone (Zone 3). An aquatic habitat assessment identified that both areas have potential habitat for aquatic receptors, although currently aquatic receptors would not be present in Zone 2 due to high turbidity and low pH.

The approach and assessments of the individual zones is summarized below.

The approach used to assess ecological risks were based on risk assessment procedures commonly used by BC MOE including the Tier 1 (BC MOELP 1998) and DQERA (BC MOE 2008) frameworks. The approach used was as follows:

- COPC were identified for surface water, porewater, and sediments using data collected by MOE and SLR between September and November 2016. Maximum concentrations (both total and dissolved concentrations) were used to identify COPCs within three impacted zones and one reference zone. When a maximum concentration exceeded the provincial and federal criteria and the reference concentration for any of the three zones the COPC was carried forward within the relevant media;

- Aquatic ROCs were identified using the fisheries information presented in the 2013 AERA combined with the habitat assessment completed by SLR during the 2016 field program. A total of five surrogate ROC groups were selected for the 2016 AERA;

- TRVs were selected through consideration of published toxicity literature specific to freshwater fish and aquatic invertebrates. Where available, TRVs for resident fish, migratory fish and fish eggs were selected;

- Risk estimates were generated in the form of HQs for each COPC within each of the three impact zones and reference zone for the five ROC groups:

    - Resident and migratory fish exposure sources were based upon maximum COPC concentrations in surface water;
    - Fish egg exposure sources were based upon maximum COPC concentrations in porewater;
    - Pelagic invertebrates were based upon maximum COPC concentrations in porewater and benthic invertebrates upon maximum COPC concentrations in sediment;

- HQ results were further evaluated within each zone within the context of what species of fish would be present, when they would be present, and their exposure duration; and

- A preliminary COPC trend analysis for both reference and impacted areas presents the maximum COPC concentrations used in both the 2013 and 2016 AERA. This was completed for total and dissolved metals.

The objective of the 2016 AERA report was to evaluate the potential risks to fish (resident, migratory, eggs) and aquatic invertebrates exposed to untreated mine discharge from the Site. This objective was met by calculating risk estimates (HQs) for each ROC by using maximum COPC concentrations specific to the four zones. HQ results were further evaluated within each zone within the context of what species of fish would be present, when they would be present, and their exposure duration.

9.1 Zone 1 – Reference

Elevated concentrations of aluminum, copper, iron and zinc contributed to HQs ranging from 1.8 to 11.2 for resident and migrant fish. Elevated concentrations of copper contributed to an HQ of 1.2 for fish eggs. HQs were all below one for aquatic invertebrates. The reference zone has naturally elevated concentrations of aluminum, copper, iron and zinc that were taken into consideration when calculating risk levels to ROCs. Risks were not identified for fish or fish eggs when the impacted HQ was greater than one but less than the reference HQ.

9.2 Zone 2 - Zone of Discharge

HQs were highest in Zone 2. This is likely because multiple undiluted and untreated sources of historic mine waste water are discharging into the Tulsequah mainstem and side channels from surface water and groundwater inputs.

Metal concentrations pose unacceptable risks to fish, fish eggs and pelagic invertebrates. The highest HQ values were cadmium, copper, and zinc HQs for fish, fish eggs and pelagic invertebrates and the aluminum HQ for fish eggs. There was also potential risk identified from aluminum, iron and lead for both fish and pelagic invertebrates, cobalt for pelagic invertebrates, and lead, iron and sulphate for fish eggs. For benthic invertebrates copper was the only elevated HQ identified with potential risk. Based on the SEM/AVS results copper has a high bioavailability to invertebrates within sediments from this zone.

HQs were based on surface water exposure for resident and migrant fish, porewater exposure for fish eggs and pelagic invertebrates, and sediment exposure for benthic invertebrates. A moderate level of uncertainty is associated with Zone 2 risk estimates because although maximum concentrations were used it is unclear whether they represent the worst case scenario exposure conditions.

It is unlikely that fish and aquatic invertebrates would spend a significant amount of time within this area. This is due to a combination of high turbidity (potentially mine-related but also endemic to this system), and low pH input from mine sources documented during the 2016 field program.

9.3 Zone 3 - Impacted Near

HQs were lower in Zone 3 than in Zone 2, and greater than Zone 4. Copper and lead HQs for resident and migratory fish, zinc HQs for resident fish, and the iron HQ for pelagic invertebrates were associated with the highest potential risk. There also was potential risk identified from cadmium for fish, aluminum for pelagic invertebrates, and aluminum, copper and iron HQs for

fish eggs. For benthic invertebrates arsenic was the only elevated HQ identified with potential risk. A moderate level of uncertainty is associated with Zone 3 risk estimates because although maximum concentrations were used it is unclear whether they represent the worst case scenario exposure conditions.

Zone 3 has the potential for the largest number of receptors to be exposed to Tulsequah mine sources within the study area, although concentrations were not the highest. Elevated HQs identified potential risk for both fish and aquatic invertebrates slightly lower than compared to risk levels in Zone 2. The main difference between Zones 2 and 3 are the number of areas within Zone 3 with high quality habitat features compared to Zone 2. As a result both fish and aquatic invertebrates receive constant exposure to mine-related COPCs because they have a high potential to spend a significant amount of time within this area.

Historically surface water samples were not collected within Zone 3 despite containing mine-related sources and high quality fish habitat. Although migratory fish would not spend their entire life cycle within this zone, Zone 3 provides high quality habitat for migratory salmonids. Zone 3 also provides high quality habitat for resident fish such as Trout and Dolly Varden to spawn, rear, and for overwintering juveniles. Exposure would be highest for resident fish such as Stickleback, Sculpin, and sub-adult Dolly Varden. Almost all habitat requirements are met for residents which would all them to spend all of their life cycle within this Zone, and receive year-round lifelong exposure to mine-related COPCs.

9.4 Zone 4 - Impacted Far

Within Zone 4 all calculated HQs for fish and benthic invertebrates indicated acceptable risk. A moderate level of uncertainty is associated with Zone 4 risk estimates because although maximum concentrations were used it is unclear whether they represent the worst case scenario exposure conditions. Porewater was not collected within Zone 4 and therefore HQs weren't calculated for fish eggs and pelagic invertebrates. A high level of exposure is associated with the resident and migratory fish HQs because the amount of time that these fish would spend within this area is substantial.

10.0 RECOMMENDATIONS

Based on the conclusions presented in Section 9.0 SLR provides the following recommendations to address Site risks and uncertainties, and to provide input into remediation planning:

- Restricting overland flow would reduce exposure and thereby reduce risk to aquatic receptors. Overland discharge of untreated mine source waters from the exfiltration pond and portals into the Tulsequah River are sources of contamination to Tulsequah River and aquatic receptors;

- Full characterization of the spatial extent and contaminant concentrations in all relevant media has not been conducted. Complete follow-up assessment that includes concurrent groundwater, porewater, and surface water sampling in all four zones;

    - Porewater concentrations indicate that groundwater is a source of contamination into the Tulsequah River. Groundwater was not a media evaluated under the current AERA. Trends between groundwater and porewater need to be evaluated to confirm mine sourced COPCs into receiving waters within Zones 2 and 3. An evaluation of groundwater concentrations for current wells surrounding the NAG and PAG piles relative to porewater would reduce the uncertainty associated with porewater data relied upon in the assessment. If additional hydrogeological information is available (pumping tests, slug tests, monitoring data) then this information could be used to assess future input into the Tulsequah River, and direct remedial planning;

    - Concurrent water sampling should be repeated so that seasonal and temporal variation can be captured under exposure conditions involving both high and low source input;

    - Quantify total and speciated chromium to confirm the contribution of chromium VI vs. III to total chromium within all three media;

    - Incorporate all historical information into a follow-up risk assessment;

- Aquatic habitat assessment was limited in 2016 due to the fall/winter season. Complete a follow-up aquatic habitat assessment to confirm:

    - Presence/absence of dominant macrophytes in areas receiving groundwater input and downgradient of NAG/PAG;

    - Presence/absence of resident and migratory fish when the spring (Sockeye, Cutthroat Trout) and fall (Coho, Dolly Varden) migratory fish will be present using capture techniques between Zones 1 to 3;

    - Changes from the original aquatic habitat assessment;

- Geochemical assessment of NAG and PAG waste rock areas would confirm the acid/metal leaching potential of the piles. Complete a geochemical assessment of future metal availability and loading from source materials into groundwater and surface water; and

- Complete an update of the 2016 AERA to incorporate the above recommendations and once steady-state COPC concentrations have been identified to aid remediation option analysis for reducing the risks to aquatic receptors.

11.0 PROFESSIONAL STATEMENT

This report was prepared in accordance with the requirements in the *Environmental Management Act* and the *Contaminated Sites Regulation*. The authors of this report, Mathew Coady, M.E.T., B.I.T., Joline Widmeyer, Ph.D., R.P.Bio. and Cindy Ott, M.Sc., P.Ag., GeoL, P.Chem. have over 40 years of combined experience in the assessment and remediation/risk assessment of similar sites and are familiar with the works carried out within the Site.

In accordance with Section 63 of the Contaminated Sites Regulation, I confirm that I have demonstrable experience in conducting human health and/or ecological risk assessment pertinent to the purposes of the Contaminated Sites Regulation.

I also confirm that:

- The risk assessment performed by me, and reported herein, has been performed to the best of my ability in accordance with ministry approved protocols, guidance, procedures, policies, methods and standards of professional practice, and

- The information used in the performance of the risk assessment and the conclusions of the risk assessment reported herein are true and accurate based on my current knowledge as of the date completed.

Mathew Coady, MSc., B.I.T.		April 2017
Print Name	Signature	Date Completed
Joline Widmeyer, PhD., R.P.Bio.		April 2017
Print Name	Signature	Date Completed
Cindy Ott, M.Sc., P.Ag., GeoL, P.Chem.		April 2017
Print Name	Signature	Date Completed

12.0 STATEMENT OF LIMITATIONS

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

Any conclusions or recommendations made in this report reflect SLR's judgment based on conditions observed at the time of the Site visit on the date(s) set out in this report and on the interpretation of data made in the reports, and on the results of laboratory analyses, which were limited to the quantification in select samples of those substances specifically identified in the report. This report has been prepared for specific application to the Site and it is based, in part upon visual observation of the Site, subsurface investigation at discrete locations and depths, and specific analysis of specific chemical parameters and materials during a specific time interval, all as described in this report. Unless otherwise stated, the findings cannot be extended to future Site conditions, portions of the Site which were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters, materials or analysis which were not addressed. Substances other than those addressed by the investigations described in this report may exist within the Site Area; substances addressed by the investigations may exist in areas of the Site not investigated and concentrations of substances addressed which are different than those reported may exist in areas other than the locations from which samples were taken. SLR expresses no warranty with respect to the accuracy of the laboratory analyses, methodologies used, or presentation of analytical results by the laboratory. Actual concentrations of the substances identified in the samples submitted may vary according to the extraction and testing procedures used.

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

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

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

BC MOE may submit this report to other related British Columbia environmental regulatory authorities or persons for review and comment purposes.

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TABLES

2016 Tulsequah Chief Mine
Aquatic Ecological Risk Assessment
SLR Project No.: 201.88687.00000

Table 1. Preliminary COPC Screening - Total and Dissolved Metals in Surface Water (µg/L)

COPC	Total Metals Impacted (Max conc.)		Dissolved Metals Impacted (Max conc.)		Screening Standard or Guideline			Selected Screening Benchmark	Selected Guideline	Preliminary Surface Water COPC?
	SLR (n = 14 + 2 dups)	BC MOE (n = 2)	SLR (n = 14 + 2 dups)	BC MOE (n = 1)	BCWWQfw	BCWQ AFWg (long-term) *	CSR AWF/10			
pH (range)	**3.3 - 8.06**	3.37	3.3 - 8.06	3.37	ns	>6.5<=9.0	ns	>6.5<=9.0	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Hardness (mg/L) (range)	24 - 237	206-216	**23.3 - 260**	206-216 (Total)	ns	ns	ns	ng	---	No. No benchmark available.
Aluminum	12,200	9,520	**11,600**	**8,900**	ns	**Dissolved Guideline*** '- @ pH ≥ 6.5 = 0.05 mg/L - @ pH < 6.5 = $2.718^{[1.6-3.327(\text{median pH})+0.402(\text{median pH})^2]}$ X 1000 (mg/L to ug/L)	ns	**SLR Data (Dissolved)** @ Min pH (3.3): 6.73 @ Max pH (8.06): 50 ug/L @ Median pH(7.66): 50 ug/L **BC MOE (Dissolved)** @ pH (3.3): 6.73	BCWQ AFWg	**Yes. Max conc. > screening benchmark** @ SLR median pH (7.66) = 50 ug/L
Antimony	**6.33**	2.22	0.64	0.63	9	ns	20	9	BCWWQfw	No. Max conc. < screening benchmark
Arsenic	**151**	46.2	5.59	3.1	ns	5	5	5	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Barium	**88.1**	27.1	78.9	24.8	5000	ns	1000	5000	BCWWQfw	No. Max conc. < screening benchmark
Beryllium	**0.44**	<0.5	0.4	<0.5	0.13	ns	5.3	0.13	BCWWQfw	**Yes. Max conc. > screening benchmark**
Bismuth	**<1**	<0.5	<1	<0.25	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.
Boron	**<50**	<50	<50	<50	ns	1200	5000	1200	BCWQ AFWg	No. Max conc. < screening benchmark
Cadmium	217	201	**205**	185	ns	**Dissolved Guideline*** $e^{[0.736 \times \ln(\text{hardness*}) - 4.943]}$	0.03@H>=30<90 0.05@H>=90<150 0.06@H>=150<210 0.08@H>=210<270	**SLR Data (Dissolved)** @ Min hardness (23.3): 0.07 ug/L @ Max hardness (260): 0.43 ug/L @ Median hardness (56.5): 0.140 ug/L **BC MOE (Dissolved)** @ Min hardness (206): 0.360 ug/L @ Max hardness (216): 0.372 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Calcium	80,600	74,600	**90,500**	71,100	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Chromium (total)	**3.9**	1.4	1.3	1.1	8.9 (3+); 1 (6+)	ns	1	8.9 (Cr^{6+})	BCWWQfw	No. Max conc. < screening benchmark
Cobalt	**9.7**	8.45	9.28	8	ns	4	4	4	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Copper	9,920	**10,300**	9,300	9,540	ns	@ Hardness ≤50 mg/L = ≤2 @ Hardness > 50 mg/L = 0.04 (mean hardness)	2.0@H<50 3.0@H>=50<75 4.0@H>=75<100 5.0@H>=100<125 6.0@H>=125<150 7.0@H>=150<175 8.0@H>=175<200 9.0@H>=200	**SLR Data (Total)** @ Min hardness (24): ≤ 2 ug/L @ Max hardness 237): 9.48 ug/L @ Median hardness (58.4): 2.34 ug/L **BC MOE (Total)** @ Min hardness (206): 0.360 ug/L @ Max hardness (216): 0.372 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Iron	**42,500**	12,300	7,540	7,400	ns	1000 *	ns	1000	BCWQ AFWmg	**Yes. Max conc. > screening benchmark**

Table 1. Preliminary COPC Screening - Total and Dissolved Metals in Surface Water (µg/L)

COPC	Total Metals Impacted (Max conc.)		Dissolved Metals Impacted (Max conc.)		Screening Standard or Guideline			Selected Screening Benchmark	Selected Guideline	Preliminary Surface Water COPC?
	SLR (n = 14 + 2 dups)	BC MOE (n = 2)	SLR (n = 14 + 2 dups)	BC MOE (n = 1)	BCWWQfw	BCWQ AFWg (long-term) *	CSR AWF/10			
Lead	157	**164**	139	156	ns	$3.31 + e^{[1.273 \ln(\text{hardness*}) - 4.704]}$	4@H<50 5@H>=50<100 6@H>=100<200 11@H>=200<300	**SLR Data (Total)** @ Min hardness (24): 3.82 ug/L @ Max hardness 237): 12.8 ug/L @ Median hardness (58.4): 4.92 ug/L **BC MOE (Total)** @ Min hardness (206): 11.3 ug/L @ Max hardness (216): 11.8 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Lithium	**13.3**	---	11.8	---	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Magnesium	**8,710**	7,400	8,380	6,890	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Manganese	**745**	436	690	417	ns	(0.0044 hardness + 0.605) * 1000 (mg/L to ug/L)	ns	**SLR Data (Total)** @ Min hardness (24): 711 ug/L @ Max hardness (237): 1,650 ug/L @ Median hardness (58.4): 862 ug/L **BC MOE (Total)** @ Min hardness (206): 1,511 ug/L @ Max hardness (216): 1,555 ug/L	BCWQ AFWg	No. Max conc. < screening benchmark Note: Hardness for SW16-16, with manganese concentration of 745 ug/L, is 124 mg/L. Corresponding guideline would be 1151 ug/L.
Molybdenum	2.3	0.25	2.5	<0.25	ns	1000	1000	1000	BCWQ AFWg	No. Max conc. < screening benchmark
Nickel	**13.9**	9.5	12.8	8.6	25@H>0<=60 65@H>60<=120 110@H>120<=180 150@H>180	ns	25@H<60 60@H>=60<120 110@H>=120<180 150@H>=180	25@H>0<=60 65@H>60<=120 110@H>120<=180 150@H>180	BCWWQfw	No. Max conc. < screening benchmark
Potassium	**1,330**	900	1,120	840	373000	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Selenium	**0.48**	0.27	0.35	<0.25	ns	2	1	2	BCWQ AFWg	No. Max conc. < screening benchmark
Silver	**0.214**	0.137	0.055	0.101	ns	0.05@H<=100 1.5@H>100	0.05@H<=100 1.5@H>100	0.05@H<=100 1.5@H>100	BCWQ AFWg	No. Max conc. < screening benchmark
Sodium	**4,060**	3,060	4,190	2,870	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Strontium	378	349	**386**	332	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Sulphate	**---**	---	373,000	409,000	ns	128,000@H<=30 218,000@H>30<=75 309,000@H>75<=180 429,000@H>180	100,000	**SLR Data (Dissolved)** @ Min hardness (23.3): 128,000 ug/L @ Max hardness (260): 429,000 ug/L @ Median hardness (56.5): 219,000 ug/L **BC MOE (Dissolved)** @ Min hardness (206): 429,000 ug/L @ Max hardness (216): 429,000 ug/L	BCWQ AFWg	No. Max conc. < screening benchmark
Thallium	**0.533**	0.417	0.279	0.408	0.8	ns	3	0.8	BCWWQfw	No. Max conc. < screening benchmark
Tin	**<5**	<0.5	<5	<0.5	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.

Table 1. Preliminary COPC Screening - Total and Dissolved Metals in Surface Water (µg/L)

COPC	Total Metals Impacted (Max conc.)		Dissolved Metals Impacted (Max conc.)		Screening Standard or Guideline			Selected Screening Benchmark	Selected Guideline	Preliminary Surface Water COPC?
	SLR (n = 14 + 2 dups)	BC MOE (n = 2)	SLR (n = 14 + 2 dups)	BC MOE (n = 1)	BCWWQfw	BCWQ AFWg (long-term) *	CSR AWF/10			
Titanium	**89.6**	<1.5	<5	<1.5	ns	ns	100	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Uranium	6.39	6.77	6.4	6.4	8.5	ns	300	8.5	BCWWQfw	No. Max conc. < screening benchmark
Vanadium	<5	<2.5	<5	<2.5	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.
Zinc	**55,400**	44,100	54,800	41,400	ns	@ Hardness ≤90 mg/L = 7.5 @ hardness > 90 mg/L = 7.5 + 0.75 (hardness* - 90)	7.5@H<90 15@H>=90<100 90@H>=100<200 165@H>=200<300	**SLR Data (Total)** @ Min hardness (24): 7.5 ug/L @ Max hardness 237): 118 ug/L @ Median hardness (58.4): 7.5 ug/L **BC MOE (Total)** @ Min hardness (206): 94.5 ug/L @ Max hardness (216): 102 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Zirconium	**<1**	---	<0.5	---	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.

Notes:
n - sample count
ug/L - micrograms per litre
mg/L - milligrams per litre
"---" - no results for select parameter obtained
ng - no guideline available.
ns - no standard listed
< - less than analytical detection limit
COPC - chemical of potential concern
* BCWQ AFWmg used when no other guideline available
BOLD - Concentration Used for Preliminary Screening
BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)
BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
CSR AWF/10: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life divided by 10.

Table 2. Preliminary COPC Screening - Total and Dissolved Metals in Porewater (µg/L)

COPC	Total Metals Impacted (n = 3 + 1 dup, Max conc.)	Dissolved Metals Impacted (n = 3 + 1 dup, Max conc.)	Screening Standard or Guideline			Selected Screening Benchmark	Selected Guideline	Preliminary Porewater COPC?
			BCWWQfw	BCWQ AFWg (long-term)	CSR AWF/10			
pH (range)	3.15 - 7.87	3.15 - 7.87	ns	>6.5<=9.0	ns	>6.5<=9.0	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Hardness (mg/L) (range)	66.5 - 275	55.8 - 258	ns	ns	ns	ng	---	No. No benchmark available.
Aluminum	23,200	**23,200**	ns	**Dissolved Guideline*** - @ pH ≥ 6.5 = 0.05 mg/L - @ pH < 6.5 = $2.718^{[1.6-3.327(\text{median pH})+0.402(\text{median pH})^2]}$ X 1000 (mg/L to ug/L)	ns	**SLR Data (Dissolved)** @ Min pH (3.15): 7.51 ug/L @ Max pH (7.87): 17.7 ug/L @ Median pH(5.90): 50 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Antimony	**0.52**	<0.5	9	ns	20	9	BCWWQfw	No. Max conc. < screening benchmark
Arsenic	**5.52**	3.52	ns	5	5	5	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Barium	**61.3**	18.3	5000	ns	1000	5000	BCWWQfw	No. Max conc. < screening benchmark
Beryllium	**0.62**	0.6	0.13	ns	5.3	0.13	BCWWQfw	**Yes. Max conc. > screening benchmark**
Bismuth	**<1**	<1	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.
Boron	**<50**	<50	ns	1200	5000	1200	BCWQ AFWg	No. Max conc. < screening benchmark
Cadmium	229	**197**	ns	**Dissolved Guideline*** $e^{[0.736 \times \ln(\text{hardness*}) - 4.943]}$	0.03@H>=30<90 0.05@H>=90<150 0.06@H>=150<210 0.08@H>=210<270	**SLR Data (Dissolved)** @ Min hardness (55.8): 0.13 ug/L @ Max hardness (258): 0.42 ug/L @ Median hardness (153): 0.30 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Calcium	**93,500**	84,200	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Chromium (total)	**7**	5.4	8.9 (5+); 1 (3+)	ns	1	8.9 (Cr^{6+})	CSR AWF/10	No. Max conc. < screening benchmark
Cobalt	**15**	14.2	ns	4	4	4	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Copper	**11,500**	9,820	ns	@ Hardness ≤50 mg/L = ≤2 @ Hardness > 50 mg/L = 0.04 (mean hardness)	2.0@H<50 3.0@H>=50<75 4.0@H>=75<100 5.0@H>=100<125 6.0@H>=125<150 7.0@H>=150<175 8.0@H>=175<200 9.0@H>=200	**SLR Data (Total)** @ Min hardness (66.5): 2.66 ug/L @ Max hardness (275): 11 ug/L @ Median hardness (172): 6.88 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Iron	**3,880**	2,600	ns	ns	ns	1000	BCWQ AFWmg	**Yes. Max conc. > screening benchmark**
Lead	**172**	170	ns	$3.31 + e^{[1.273 \ln(\text{hardness*}) - 4.704]}$	4@H<50 5@H>=50<100 6@H>=100<200 11@H>=200<300	**SLR Data (Total)** @ Min hardness (66.5): 5.20 ug/L @ Max hardness (275): 14.9 ug/L @ Median hardness (172): 9.66 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Lithium	**20.4**	20.2	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Magnesium	**13,400**	12,800	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Manganese	**748**	710	ns	(0.0044 hardness + 0.605) * 1000 (mg/L to ug/L)	ns	**SLR Data (Total)** @ Min hardness (66.5): 898 ug/L @ Max hardness (275): 1815 ug/L @ Median hardness (172): 1362 ug/L	BCWQ AFWg	No. Max conc. < screening benchmark
Molybdenum	**<1**	<1	ns	1000	1000	1000	BCWQ AFWg	No. Max conc. < screening benchmark and all concentrations non-detect

Table 2. Preliminary COPC Screening - Total and Dissolved Metals in Porewater (µg/L)

COPC	Total Metals Impacted (n = 3 + 1 dup, Max conc.)	Dissolved Metals Impacted (n = 3 + 1 dup, Max conc.)	Screening Standard or Guideline			Selected Screening Benchmark	Selected Guideline	Preliminary Porewater COPC?
			BCWWQfw	BCWQ AFWg (long-term)	CSR AWF/10			
Nickel	**25.1**	23.8	25@H>0<=60 65@H>60<=120 110@H>120<=180 150@H>180	ns	25@H<60 60@H>=60<120 110@H>=120<180 150@H>=180	25@H>0<=60 65@H>60<=120 110@H>120<=180 150@H>180	BCWWQfw	No. Max conc. < screening benchmark
Potassium	**1,670**	1,300	373000	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Selenium	0.35	**0.37**	ns	2	1	2	BCWQ AFWmg/g	No. Max conc. < screening benchmark
Silver	**0.188**	0.077	ns	0.05@H<=100 1.5@H>100	0.05@H<=100 1.5@H>100	0.05@H<=100 1.5@H>100	BCWQ AFWg	No. Max conc. < screening benchmark
Sodium	**4,390**	4,170	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Strontium	**443**	346	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Sulphate	---	**542,000**	ns	128,000@H<=30 218,000@H>30<=75 309,000@H>75<=180 429,000@H>180	100,000	**SLR Data (Dissolved)** @ Min hardness (55.8): 218,000 ug/L @ Max hardness (258): 429,000 ug/L @ Median hardness (153): 309,000 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Thallium	**0.313**	0.248	0.8	ns	3	0.8	BCWWQfw	No. Max conc. < screening benchmark
Tin	<5 or < 10	<5	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.
Titanium	**42.4**	<5	ns	ns	100	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Uranium	**7.9**	7.56	8.5	ns	300	8.5	BCWWQfw	No. Max conc. < screening benchmark
Vanadium	**<5**	<5	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.
Zinc	**64,000**	54,400	ns	@ Hardness ≤90 mg/L = 7.5 @ hardness > 90 mg/L = 7.5 + 0.75 (hardness* - 90)	7.5@H<90 15@H>=90<100 90@H>=100<200 165@H>=200<300	**SLR Data (Total)** @ Min hardness (66.5): 7.5ug/L @ Max hardness (275): 146 ug/L @ Median hardness (172): 69 ug/L	BCWQ AFWg	**Yes. Max conc. > screening benchmark**
Zirconium	**<0.5**	<0.5	ns	ns	ns	ng	---	No. No benchmark available. All concentrations non-detect.

Notes:
n - sample count
ug/L - micrograms per litre
mg/L - milligrams per litre
ng - no guideline available.
ns - no standard listed
< - less than analytical detection limit
COPC - chemical of potential concern
* BCWQ AFWmg used when no other guideline available
BOLD - Concentration Used for Preliminary Screening
BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)
CSR AWF/10: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life divided by 10.

Table 3. Preliminary COPC Screening - Total Metals in Sediment (mg/kg)

COPC	Total Metals Impacted (n = 5, Max conc.)	CSR SDfs (sensitive)	CSR SDft (typical)	CCME ISQG FW	CCME PEL FW	Other [a b c d e]	Selected Screening Benchmark	Selected Guideline	Preliminary Sediment COPC?
pH	8.95	ns	ns	ns	ns	ns	ng	---	No. No benchmark available.
Aluminum	17,600	ns	ns	ns	ns	14,000 ERL : 58,000 ERM [d]	14000	---	**Yes. Max conc. > ERL screening benchmark.**
Antimony	7.94	ns	ns	ns	ns	64 [b]	64	---	No. Max conc. < screening benchmark
Arsenic	30.7	11	20	5.9	17	17	11	CSR SDfs	**Yes. Max conc. > screening benchmark.**
Barium	159	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Beryllium	< 0.40	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. All samples non-detect.
Bismuth	0.74	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Cadmium	1.45	2.2	4.2	0.6	3.5	3.5	2.2	CSR SDfs	No. Max conc. < screening benchmark
Calcium	24,000	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Chromium (total)	49	56	110	37.3	90	90	56	CSR SDfs	No. Max conc. < screening benchmark
Cobalt	13.8	ns	ns	ns	ns	50 [c]	50	---	No. Max conc. < screening benchmark
Copper	345	120	240	35.7	197	197	120	CSR SDfs	**Yes. Max conc. > screening benchmark and elevated metal bioavailability.**
Iron	31,000	ns	ns	ns	ns	2% [c]	20,000	---	**Yes. Max conc. > screening benchmark.**
Lead	35.7	57	110	35	91.3	91.3	57	CSR SDfs	No. Max conc. < screening benchmark
Lithium	17.5	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Magnesium	14,300	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Manganese	623	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Mercury	0.097	0.3	0.58	0.17	0.486	0.486	0.3	CSR SDfs	No. Max conc. < screening benchmark
Molybdenum	2.72	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Nickel	33.3	ns	ns	ns	ns	48.6 [a]	48.6	---	No. Max conc. < screening benchmark
Phosphorus	971	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Potassium	1,440	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Selenium	0.97	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Silver	0.278	ns	ns	ns	ns	ns	ns	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Sodium	363	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Strontium	49.1	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Thallium	0.243	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Tin	0.45	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Titanium	1120	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Uranium	2.77	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Vanadium	77.3	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Zinc	282	200	380	123	315	315	200	CSR SDfs	**Yes. Max conc. > screening benchmark.**
Zirconium	1.66	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Sulphide	71	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. To be discussed in the Uncertainty Section.
Acid Volatile Sulphide	2.22	ns	ns	ns	ns	ns	ng	---	No. No benchmark available. An SEM:AVS Ratio > 1 indicates a higher metal bioavailability. This means that the following metals have a high sediment metal bioavailability: Copper, Nickel, and Zinc.
SEM Cadmium (Cd)	0.008	ns	ns	ns	ns	ns	ng	---	
Cd SEM:AVS Ratio	0.081	ns	ns	ns	ns	ns	ng	---	
SEM Copper (Cu)	2.14	ns	ns	ns	ns	ns	ng	---	
Cu SEM:AVS Ratio	21.8	ns	ns	ns	ns	ns	ng	---	
SEM Lead (Pb)	0.073	ns	ns	ns	ns	ns	ng	---	
Pb SEM:AVS Ratio	0.748	ns	ns	ns	ns	ns	ng	---	
SEM Mercury (Hg)	0.0003	ns	ns	ns	ns	ns	ng	---	
Hg SEM:AVS Ratio	0.004	ns	ns	ns	ns	ns	ng	---	
SEM Nickel (Ni)	0.328	ns	ns	ns	ns	ns	ng	---	
Ni SEM:AVS Ratio	3.35	ns	ns	ns	ns	ns	ng	---	
SEM Zinc (Zn)	2.66	ns	ns	ns	ns	ns	ng	---	
Zn SEM:AVS Ratio	27.1	ns	ns	ns	ns	ns	ng	---	

Notes:
mg/kg - milligrams per dry kilogram
ng - no guideline available
ns - no standard listed
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
COPC - chemical of potential concern
[a] - MacDonald et al (2000) Probable Effects Concentration (PEC).
[b] - USEPA (1999) Apparent Effect Threshold (AET)
[c] - ON MOE Lowest Effect Level Sediment Quality Guidelines
[d] - Ingersoll et al. Effect Range Low and Median Values
CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive
CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)

Table 4. Secondary and Final COPC Screening - Total and Dissolved Metals in Surface Water (µg/L)

COPC	Total Metals (Max Conc.)					Dissolved Metals (Max Conc.)					Selected Screening Benchmark	Selected Guideline	Secondary Zone Screening (Relevant for Total vs. Dissolved)			Final Surface Water COPC?
	SLR Reference (n = 4)	BC MOE - Source (n = 2)	ZOD (n = 4 + 2 dups, max and second highest)	Impacted Near (n = 8)	Impacted Far (n = 2)	SLR Reference (n = 4)	BC MOE - Source (n = 2)	ZOD (n = 4 + 2 dups, max and second highest)	Impacted Near (n = 8)	Impacted Far (n = 2)			ZOD	Impacted Near	Impacted Far	
pH (range)	7.44 - 7.91	3.3	3.3 - 7.65	7.6 - 7.86	7.25 - 8.06	7.44 - 7.91	3.37	3.3 - 7.65	7.6 - 7.86	7.25 - 8.06	>6.5<=9.0	BCWQ AFWg	**Yes. Lowest pH below benchmark and is below reference.**	No	No	No, pH is buffered almost instantly once source enters Tulsequah adjacent to the mine site.
Hardness (mg/L) *	41.7 - 64.2	206-216	45.9-237	50.8 - 59.6	24 - 124	33.6 - 61.3	206-216 (Total)	41.1 - 260	46.8 - 62.4	23.3 - 108	ng	---	No	No	No	N/A
Aluminum (dissolved)	20.3 - 2230	9,520	12,200/ 6,710	1,670	51.7	4.9 - 45.7	8,900	11,600/ 2,870	26.6	26.1	6.73 for pH < 6.5 : 0.05 for pH ≥ 6.5 (median background)	BCWQ AFWg	**Yes. Max and second highest above benchmark and reference.**	**Yes. Max exceeds benchmark.**	**Yes. Max exceeds benchmark.**	**Yes - Max. Conc > benchmark in all 3 impacted areas for total and dissolved conc. Also a porewater COPC. Exceeds reference at the source and ZOD.**
Arsenic	0.22 - 1.88	46.2	151/ 23.2	8	2.38	0.17 - 1.6	3.1	3.26/ 0.77	5.59	1.66	5	BCWQ AFWg	**Yes. Max and second highest above benchmark and reference.**	**Yes. Max above benchmark and reference.**	No. Max below benchmark, noted to be above reference.	**Yes - Max. Conc > benchmark at ZOD and near impacted areas for total and dissolved conc. Also a porewater COPC.**
Beryllium	<0.1	<0.5	0.44/ 0.21	<0.1	<0.1	<0.1	<0.5	0.4/ 0.11	<0.1	<0.1	0.13	BCWWQfw	**Yes. Max and second highest above benchmark and background.**	No.	No.	**Yes - Max. Conc > benchmark and reference at ZOD for total conc. Also a porewater COPC.**
Cadmium (dissolved)	<0.01 - 0.054	201	217/ 51	2.25	0.092	<0.01 - 1.01	185	205/ 91.8	0.65	0.034	median background hardness dissolved (56.5) = 0.140;	BCWQ AFWg	**Yes. Max and second highest above benchmark and reference range.**	**Yes. Max above benchmark.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD and near but not far for total and dissolved conc. Also a porewater COPC.**
Cobalt	<0.5 - 1.41	8.45	9.7/ 6.0	1.18	<0.5	<0.5	8	9.28/ 3.76	<0.5	<0.5	4	BCWQ AFWg	**Yes. Max and second highest above benchmark and background.**	No.	No.	**Yes - Max. Conc > benchmark and reference at ZOD for total conc. Also a porewater COPC.**
Copper	4.31 - 7.56	10,300	9,920/ 4,430	105	1.41	<0.2 - 29.5	9,540	9,300/ 3,760	7.52	1.7	median background hardness total (58.4) = 2.34	BCWQ AFWg	**Yes. Max and second highest above benchmark and background.**	**Yes. Max above benchmark and background.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD and near but not far for total conc. Also a porewater COPC.**
Iron	<10 - 2820	12,300	42,500/ 8,060	2,250	872	6.5 - 13.7	7,400	7,540/ 385	<5	373	1000	BCWQ AFWmg*	**Yes. Max and second highest above benchmark and background.**	**Yes. Max above benchmark.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD and impacted near for total conc. Also a porewater COPC.**
Lead	<0.2 - 1.5	164	157/ 68.2	1.59	0.25	<0.2 - 0.3	156	139/ 31.3	<0.2	<0.2	median background hardness total (58.4) = 4.92	BCWQ AFWg	**Yes. Max and second highest above benchmark and reference.**	No. Max below benchmark, noted to be above reference.	No.	**Yes - Max. Conc > benchmark and reference at ZOD but not in two other zones for total and dissolved conc. Also a porewater COPC.**
Zinc	<5 - 98.7	55,400	55,400/ 26,700	562	<5	<5 - 217	41,400	54,800/ 23,700	159	<5	median background hardness total (58.4) = 7.5	BCWQ AFWg	**Yes. Max and second highest above benchmark and reference.**	**Yes. Max above benchmark and reference.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD and near but not far for both total and dissolved conc. Also a porewater COPC**

Notes:
n - sample count
ug/L - micrograms per litre
mg/L - milligrams per litre
ng - no guideline available.
ZOD - zone of discharge
< - less than analytical detection limit
COPC - chemical of potential concern
N/A - not applicable
* - hardness results presented for application of hardness dependent criteria only.
BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)
CSR AWF/10: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life divided by 10.

Table 5. Secondary and Final COPC Screening - Total and Dissolved Metals in Porewater (µg/L)

COPC	Total Metals (Max Conc.)			Dissolved Metals			Selected Screening Benchmark	Selected Guideline	Secondary Zone Screening		Final Porewater COPC?
	Reference (n = 1)	Impacted ZOD (n = 2)	Impacted Near (n = 1 + 1 dup)	Reference (n = 1)	Impacted ZOD (n = 2)	Impacted Near (n = 1 + 1 dup)			ZOD	Impacted Near	
pH (range)	7.91	3.15 - 3.93	7.86 - 7.87	7.91	3.15 - 3.93	7.86 - 7.87	>6.5<=9.0	BCWQ AFWg	**Yes. pH below values benchmark and are below reference.**	No.	
Hardness (mg/L) *	80.5	269 - 275	66.5 - 75.5	75.4	245 - 258	66.5 - 75.5	ng	---	No.	No.	N/A
Aluminum	35.5	23,200	1,090	17.1	23,200	18.6	7.51 for pH < 6.5 : 0.05 for pH ≥ 6.5	BCWQ AFWg	**Yes. Max above benchmark and reference**	**Yes. Max above benchmark and reference.**	**Yes - Max. Conc > benchmark and reference in both impacted areas for total and dissolved conc. Also a surface water COPC.**
Arsenic	1.65	2.72	5.52	1.36	<0.1	3.52	5	BCWQ AFWg	No. Max below benchmark, noted to be above reference.	**Yes. Max above benchmark and reference.**	**Yes - Max. Conc > benchmark at far impacted areas for only total conc. Definitely mine source related. Also a surface water COPC.**
Beryllium	<0.1	0.62	<0.1	<0.1	0.6	<0.1	0.13	BCWWQfw	**Yes. Max above benchmark and reference.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD for total an dissolved conc. Also a surface water COPC.**
Cadmium (dissolved)	0.026	229	0.022	0.042	197	<0.01	median background hardness (153) = 0.30	BCWQ AFWg	**Yes. Max above benchmark and reference.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD for total and dissolved conc. Also a surface water COPC.**
Cobalt	<0.5	15	0.92	<0.5	14.2	<0.5	4	BCWQ AFWg	**Yes. Max above benchmark and reference.**	No. Max below benchmark, noted to be above reference.	**Yes - Max. Conc > benchmark and reference at ZOD for total and dissolved conc. Also a surface water COPC.**
Copper	2.36	11,500	4.75	2.8	9,820	0.29	median background hardness (172) = 6.88	BCWQ AFWg	**Yes. Max above benchmark and reference.**	No. Max below benchmark, noted to be above reference.	**Yes - Max. Conc > benchmark and reference at ZOD for total and dissolved conc. Also a surface water COPC.**
Iron	61	3,880	1680	25.5	2,600	<5	1000	BCWQ AFWmg*	**Yes. Max above benchmark and reference.**	**Yes. Max above benchmark and background.**	**Yes - Max. Conc > benchmark and reference at ZOD and impacted near for total conc. Also a surface water COPC.**
Lead	<0.2	172	0.39	<0.2	170	<0.2	median background hardness (172) = 6.88	BCWQ AFWg	**Yes. Max above benchmark and reference.**	No. Max below benchmark, noted to be above reference.	**Yes - Max. Conc > benchmark and reference at ZOD for total and dissolved conc. Also a surface water COPC.**
Sulphate	-	-	-	9,250	542,000	14,100	median background hardness (153) = 309,000	BCWQ AFWg	**Yes. Max above benchmark and reference.**	No. Max below benchmark, noted to be above reference.	**Yes - Max. Conc > benchmark and reference at ZOD for both total and dissolved conc. Also a surface water COPC.**
Zinc	5.2	64,000	<5	6.9	54,400	7.1	median background hardness (172) = 6.88	BCWQ AFWg	**Yes. Max above benchmark and reference.**	No.	**Yes - Max. Conc > benchmark and reference at ZOD for both total and dissolved conc., and at impacted near for dissolved conc. Also a surface water COPC.**

Notes:
n - sample count
ug/L - micrograms per litre
mg/L - milligrams per litre
ZOD - zone of discharge
ng - no guideline available.
< - less than analytical detection limit
COPC - chemical of potential concern
N/A - not applicable
BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)
CSR AWF/10: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life divided by 10.

Table 6. Secondary and Final COPC Screening - Total Metals in Sediment (mg/kg)

COPC	Reference (n = 1)	Impacted ZOD (n = 1)	Impacted Near (n = 3)	Impacted Far (n = 1)	Selected Screening Benchmark	Selected Guideline	Final Sediment COPC?
Aluminum	7,090	9,090	16,000	17,600	14,000 ERL vs. 58,000 ERM	Ingersoll et al.	No, although > ERL it is < ERM concentration.
Arsenic	4.09	19.6	30.7	15.9	11	CSR SDfs	**Yes, Max conc. > reference and benchmark in all three areas**
Copper	18.9	345	60.8	59	120	CSR SDfs	**Yes, Max conc. > reference and benchmark in one of three areas**
Iron	15,400	18,600	30,700	31,000	20,000	ON MOE	**Yes, Max conc. > reference and benchmark in two of three areas**
Zinc	40.3	282	110	94.5	200	CSR SDfs	**Yes, Max conc. > reference and benchmark in all three areas**

Notes:
n - sample count
ZOD - zone of discharge
m - metres
mg/kg - milligrams per dry kilogram
COPC - chemical of potential concern
ON MOE Lowest Effect Level Sediment Quality Guideline
Ingersoll et al. (1996) Effect Range Low (ERL) and Effect Range Median (ERM) Values
CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

Table 7. Maximum COPC Concentration Trends (Total Metals)

COPC	Porewater ug/L			Surface Water ug/L - Tulsequah Mainstem								Surface Water ug/L - Tributary			Sediment mg/kg			
	Reference (n = 1)	Impacted ZOD (n = 2)	Impacted Near (n = 1 + 1 dup)	SLR Reference (n = 3)	2013 Reference - W10	BC MOE - Source (n = 2)	ZOD (n = 4 + 2 dup)	2013 Source - W46 or W51	Impacted Near (n = 5)	Impacted Far (n = 1)	2013 Impacted Far - W32	SLR Reference (n = 1)	Impacted Near (n = 3)	Impacted Far (n = 1)	Reference (n = 1)	ZOD (n = 1)	Impacted Near (n = 3)	Impacted Far (n = 1)
pH (range)	7.91	3.15 - 3.93	7.86 - 7.87	7.44 - 7.66	7.1-7.8	3.37	3.3 - 7.65	6.67-7.9	7.66 - 7.86	8.06	7.3-8.0	7.91	7.6-7.82	7.25	7.35	5.53	6.28 - 8.95	6.22-6.28
Hardness (mg/L) *	80.5	269 - 275	66.5 - 75.5	41.7 - 62.1	57	206-216	45.9-237	17-158	50.8 - 59.6	124	15-83	64.2	56.4-59.6	24	---	---	---	---
Aluminum	35.5	23,200	1,090	2,230	7,850	9,520	12,200	6,960	1,670	3.9	5,580	20.3	148	51.7	7,190	9,090	16,000	17,600
Arsenic	1.65	2.72	5.52	1.63	3.9	46.2	151	4.29	3.93	2.38	4.8	1.88	8	1.77	4.09	19.6	30.7	15.9
Beryllium	<0.1	0.62	<0.1	<0.1	-	<0.5	0.44	-	<0.1	<0.1	-	<0.1	<0.1	<0.1	< 0.40	< 0.40	< 0.40	< 0.40
Cadmium	0.026	229	0.022	0.045	1.52	201	217	26.1	0.801	0.092	0.91	0.54	2.25	<0.1	0.131	1.45	0.693	0.447
Cobalt	<0.5	15	0.92	1.41	3.9	8.45	9.7	3.83	1.18	<0.5	3.3	<0.5	<0.5	<0.5	5.7	6.93	13.6	13.8
Copper	2.36	11,500	4.75	5.11	17	10,300	9,920	1,700	30.5	0.77	66	7.56	105	1.41	18.9	345	60.8	59
Iron	61	3,880	1,680	2820	9,380	12,300	42,500	8,190	2,250	645	6,740	<10	332	872	15,400	18,600	30,700	31,000
Lead	<0.2	172	0.39	1.5	4.9	164	157	41.9	1.45	<0.2	3.7	<0.2	1.59	0.25	3.31	35.7	14.1	15.6
Zinc	5.2	64,000	<5	10.6	41	55,400	55,400	6,110	199	<5	19.2	98.7	562	<5	40.3	282	110	94.5

Notes:
n - sample count
ug/L - micrograms per litre
mg/L - milligrams per litre
ng - no guideline available.
ZOD - zone of discharge
< - less than analytical detection limit
COPC - chemical of potential concern
ns - no standard listed
N/A - not applicable
2013 Concentrations represent the maximum concentration identified under "not operational" water treatment conditions presented in the 2013 AERA (Core6 2013)

Table 8. Maximum COPC Concentration Trends (Dissolved Metals)

COPC	Porewater ug/L			Surface Water ug/L - Tulsequah Mainstem								Surface Water ug/L - Tributary			Sediment mg/kg			
	Reference (n = 1)	Impacted ZOD (n = 2)	Impacted Near (n = 1 + 1 dup)	SLR Reference (n = 3)	2013 Reference - W10	BC MOE - Source (n = 2)	ZOD (n = 4 + 2 dup)	2013 Source - W46 or W51	Impacted Near (n = 5)	Impacted Far (n = 1)	2013 Impacted Far - W32	SLR Reference (n = 1)	Impacted Near (n = 3)	Impacted Far (n = 1)	Reference (n = 1)	ZOD (n = 1)	Impacted Near (n = 3)	Impacted Far (n = 1)
pH (range)	7.91	3.15 - 3.93	7.86 - 7.87	7.44 - 7.66	7.1-7.8	3.37	3.3 - 7.65	6.67-7.9	7.66 - 7.86	8.06	7.3-8.0	7.91	7.6-7.82	7.25	7.35	5.53	6.28 - 8.95	6.22-6.28
Hardness (mg/L) *	75.4	245 - 258	66.5 - 75.5	33.6 - 54.3	39	206-216 (Total)	41.1 - 260	21-99.5	46.8 - 62.4	108	19-93	61.3	49.6-56.5	24	---	---	---	---
Aluminum	17.1	23,200	18.6	4.9-30.5	379	8,900	11,600	1,550	26.6	3	1,180	45.7	13.5	26.1	7,190	9,090	16,000	17,600
Arsenic	1.36	<0.1	3.52	0.17-0.5	0.81	3.1	3.26	2.04	4.12	1.66	1.9	1.6	5.59	1.09	4.09	19.6	30.7	15.9
Beryllium	<0.1	0.6	<0.1	<0.1	-	<0.5	0.4	-	<0.1	<0.1	-	<0.1	<0.1	<0.1	< 0.40	< 0.40	< 0.40	< 0.40
Cadmium	0.042	197	<0.01	<0.01	0.077	185	205	25.2	0.65	0.034	0.83	1.01	<0.01	0.024	0.131	1.45	0.693	0.447
Cobalt	<0.5	14.2	<0.5	<0.5	0.38	8	9.28	2.43	<0.5	<0.5	1.37	<0.5	<0.5	<0.5	5.7	6.93	13.6	13.8
Copper	2.8	9,820	0.29	<0.2 - 0.29	6	9,540	9,300	1,190	7.52	0.41	37	29.5	0.31	1.7	18.9	345	60.8	59
Iron	25.5	2,600	<5	<5 - 13.1	473	7,400	7,540	1,520	<5	278	1,590	13.7	171	373	15,400	18,600	30,700	31,000
Lead	<0.2	170	<0.2	<0.2	0.54	156	139	16.1	<0.2	<0.2	1.76	0.3	<0.2	<0.2	3.31	35.7	14.1	15.6
Zinc	6.9	54,400	7.1	<5	28.5	41,400	54,800	5,770	159	<5	185	217	<5	<5	40.3	282	110	94.5

Notes:
n - sample count
ug/L - micrograms per litre
mg/L - milligrams per litre
ng - no guideline available.
ZOD - zone of discharge
< - less than analytical detection limit
COPC - chemical of potential concern
ns - no standard listed
N/A - not applicable
2013 Concentrations represent the maximum concentration identified under "not operational" water treatment conditions presented in the 2013 AERA (Core6 2013)

Table 9. 2016 AERA Aquatic Invertebrate EPC, TRV and HQs - Porewater and Sediment

Pelagic Invertebrate - Porewater Analyte	EPC (µg/L)				TRVs	HQ			
	Zone 1	Zone 2	Zone 3	Zone 4		Zone 1	Zone 2	Zone 3	Zone 4
Aluminum	36	23,200	1,090	---	320	0.1	**72.5**	**3.41**	---
Arsenic	1.65	2.72	5.52	---	520	0.003	0.005	0.01	---
Beryllium	<0.1	0.62	<0.1	---	36	nc	0.0172	nc	---
Cadmium	0.026	229	0.022	---	1.35	0.02	**170**	0.02	---
Cobalt	<0.5	15	0.92	---	12.5	nc	1.2	0.07	---
Copper	2.36	11,500	4.75	---	5.68	0.4	**2020**	0.8	---
Iron	61	3,880	1,680	---	157	0.4	**24.7**	**10.7**	---
Lead	<0.2	172	0.39	---	12.3	nc	**14**	0.03	---
Sulphate	9,250	542,000	14,100	---	855,000	0.01	0.6	0.02	---
Zinc	5.2	64,000	<5	---	47	0.1	**1360**	nc	---
Benthic Invertebrate - Sediment Analyte	**EPC (mg/kg)**				**TRVs**	**HQ**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**		**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
Arsenic	4.09	19.6	30.7	15.9	20	0.2	1.0	**1.5**	0.8
Copper	18.9	345	60.8	59	240	0.08	**1.4**	0.3	0.2
Iron	15,400	18,600	30,700	31,000	32,483	nc	0.6	nc	nc
Zinc	40.3	282	110	94.5	380	0.1	0.7	0.3	0.2

Notes:
µg/L - micrograms per lit , mg/kg - milligrams per kilogram
EPC - exposure point concentration, which is the maximum concentration for a respective media and zone
TRV - toxicity reference value
HQ - Hazard quotient, derived by dividing the EPC by the TRV
"---" - no data for given zone
nc - HQ not calculated for EPCs that are below detection limits
Bold - HQ exceeds 1.0

Table 10. 2016 AERA Resident Fish EPCs, TRVs and HQs - Surface Water

Analyte	EPCs (µg/L)				TRVs (µg/L)	HQ			
	Zone 1	Zone 2	Zone 3	Zone 4		Zone 1	Zone 2	Zone 3	Zone 4
Aluminum	2,230	12,200	1,670	51.7	200	**11.2**	**61**	**8.4**	0.3
Arsenic	1.88	151	8	2.38	220	0.009	0.7	0.04	0.01
Beryllium	<0.1	0.44	<0.1	<0.1	70.7	nc	0.006	nc	nc
Cadmium	0.054	217	2.25	0.092	0.67	0.08	**324**	**3.4**	0.1
Cobalt	1.41	9.7	1.18	<0.5	120	0.01	0.08	0.01	nc
Copper	7.56	9,920	105	1.41	2.7	**2.8**	**3670**	**38.9**	0.5
Iron	2,820	42,500	2,250	872	1000	**2.8**	**42.5**	**2.3**	0.9
Lead	1.5	157	159	0.25	12	0.1	**13.1**	**13.3**	0.02
Zinc	98.7	26,700	562	<5	55	**1.8**	**485**	**10.2**	nc

Notes:
µg/L - micrograms per litre
EPC - exposure point concentration, which is the maximum concentration for a respective media and zone
TRV - toxicity reference value
HQ - Hazard quotient, derived by dividing the EPC by the TRV
nc - HQ not calculated for EPCs that are below detection limits
Bold - HQ exceeds 1.0

Table 11. 2016 AERA Migratory Fish EPCs, TRVs and HQs - Surface Water

Analyte	EPC (µg/L)				TRVs (µg/L)	HQ			
	Zone 1	Zone 2	Zone 3	Zone 4		Zone 1	Zone 2	Zone 3	Zone 4
Aluminum	2,230	12,200	1,670	51.7	200	**11.2**	**61**	**8.4**	0.3
Arsenic	1.88	151	8	2.38	220	0.009	0.7	0.04	0.01
Beryllium	<0.1	0.44	<0.1	<0.1	70.7	nc	0.006	nc	nc
Cadmium	0.054	217	2.25	0.092	1.9	0.03	**114**	**1.2**	0.05
Cobalt	1.41	9.7	1.18	<0.5	120	0.01	0.08	0.01	nc
Copper	7.56	9,920	105	1.41	1.9	**4.0**	**5220**	**55.3**	0.7
Iron	2,820	42,500	2,250	872	1000	**2.8**	**42.5**	**2.3**	0.9
Lead	1.5	157	159	0.25	12	0.1	**13.1**	**13.3**	0.02
Zinc	98.7	26,700	562	<5	732	0.1	**36.5**	0.8	nc

Notes:
µg/L - micrograms per litre
EPC - exposure point concentration, which is the maximum concentration for a respective media and zone
TRV - toxicity reference value
HQ - Hazard quotient, derived by dividing the EPC by the TRV
nc - HQ not calculated for EPCs that are below detection limits
Bold - HQ exceeds 1.0

Table 12. 2016 AERA Fish Eggs EPC, TRV and HQs - Porewater

Analyte	EPC (µg/L)			TRVs (µg/L)	HQ		
	Zone 1	Zone 2	Zone 3		Zone 1	Zone 2	Zone 3
Aluminum	36	23,200	1,090	200	0.2	**116**	**5.5**
Arsenic	1.65	2.72	5.52	220	0.008	0.01	0.03
Beryllium	<0.1	0.62	<0.1	70.7	nc	0.009	nc
Cadmium	0.026	229	0.022	0.67	0.04	**342**	0.03
Cobalt	<0.5	15	0.92	120	nc	0.1	0.008
Copper	2.36	11,500	4.75	1.9	**1.2**	**6050**	**2.5**
Iron	61	3,880	1,680	1000	0.06	**3.9**	**1.7**
Lead	<0.2	172	0.39	12	nc	**14.3**	0.03
Sulphate	9,250	542,000	14,100	356,000	0.03	**1.5**	0.04
Zinc	5.2	64,000	<5	55	0.09	**1160**	nc

Notes:
µg/L - micrograms per litre
EPC - exposure point concentration, which is the maximum concentration for a respective media and zone
TRV - toxicity reference value
HQ - Hazard quotient, derived by dividing the EPC by the TRV
nc - HQ not calculated for EPCs that are below detection limits
Bold - HQ exceeds 1.0

Table 13: Summary of Reviewed TRVs for Pelagic Invertebrate Exposure Via Porewater

Chemical	Toxicity	Species	Endpoint, % effect	Hardness / pH	Concentration	Unit	Reference	Main Uncertainties Associated with the TRV
Aluminum	chronic	*Daphnia magna*	16%	pH 7.7	320	ug/L	BC MOE (1988) adopted the CCME maximum guideline for aluminum for the protection of aquatic life but expressed the guideline as dissolved aluminum. The lowest chronic toxicity value reviewed by BC MOE for pH ≥ 6.5 was 320 ug/L for *Daphnia magna.*	Overly conservative compared to the USEPA (1988) chronic criterion developed of 750 ug/L; also lower than either the RAIS LCV for daphnids of 1900 ug/L or the Lowest Test EC20 for daphnids of 540 ug/L.
Arsenic	chronic	*Daphnia magna*	16%	n/a	520	ug/L	In deriving the arsenic guideline for the protection of freshwater aquatic life, CCME reviewed toxicity data for 14 invertebrate species. The lowest CCME (1999a) reported toxicity values for aquatic invertebrates included a 14-d EC20 (growth) of 320 µg/L for the copepod *Cyclops vernalis* and a 21-d EC16 (reproduction) of 520 µg/L for *Daphnia magna* . A 96-h EC50 (immobility) of 850 µg/L for *Bosmina longirostris* , a 7-d LC80 of 960 µg/L for *Gammarus pseudolimnaeus* and a 7-d LOEC (immobilization) of 1000 µg/L for *Ceriodaphnia dubia* were also among the lowest endpoint values reported as part of the toxicity data considered by the CCME (1999b).	Low uncertainty because chronic effects were below the 20% threshold.
Beryllium	chronic	*Daphnia magna*	LOEC	n/a	36	ug/L	Very few studies involving invertebrates and LOECs were available. The study chosen was by Leblanc (1980) and involved a 14-d exposure of beryllium chloride to Daphnia magna. The LOAEL measurement endpoint was reproduction at 36 ug/L, reference # 121018. The lowest LC50 was identified in a study using Hyalella azteca where mortality was observed at 240 ug/L.	Moderate uncertainty because only one study was selected. Study was much lower than any LC50 studies for invertebrates.
Cadmium	chronic	*Daphnia magna*	IC20	varying low to high	1.35	ug/L	Select studies presented in BCMOE (2015) to derive a long-term AWQG based on an IC20 were as follows: *Daphnia pulex* 1.41 ug/L (18-d) and *Daphnia magna* 1.35 ug/L (21-d) (CEC Inc. 2004).	Low uncertainty because chronic effects were for two species under various hardness scenarios.
Cobalt	chronic	*Ceriodaphnia dubia*	LOEC	50 to 200	12.5	ug/L	BC MOE has reviewed the guideline for freshwater aquatic life in 2004 (Nagpal 2004) and noted that based on their literature review, aquatic invertebrates appeared the most sensitive group of organisms to cobalt exposure, followed by fish and plants. NOECs ranged from 10 µg/L to 600 µg/L for invertebrates. This value is based on a LOEC for *Ceriodaphnia dubia* in a 7-day tests listed as part of the key chronic studies from the literature cited by BC MOE (Nagpal 2004).	Low uncertainty because chronic effects were for reproduction and survival under various hardness scenarios.
Copper	chronic	invertebrates - general	LCV	medium to very hard (50 to > 200)	5.68	ug/L	The CCME copper guideline for medium to very hard water is based on the USEPA guideline revision 2007. The USEPA compiled acceptable freshwater chronic toxicity data from early life stage tests, partial life-cycle tests, and full life-cycle tests for 6 invertebrate species. EC20s for invertebrate species ranged from 2.83 (*Daphnia pulex*) to 19.36 µg/L (*Ceriodaphnia dubia)* . The lowest species mean chronic value obtained by the USEPA is 5.68 µg/L for invertebrates.	Low uncertainty as TRV is based on effects associated with a moderate hardness similar to the hardness within the mainstem Tulsequah waters.
Iron	chronic	*Daphnia magna*	LCV	n/a	157	ug/L	This TRV is based on a field study at a site receiving acid mine drainage identified by RAIS (1996a). The LCV for daphnids is a threshold for reproductive effects from a 21 day test of FeCl2 with *Daphnia magna* (Dave 1984).	Moderate uncertainty because guideline was derived using a field based study.
Lead	chronic	invertebrates - general	Mean LCV for daphnids and non-daphnids	n/a	12.3	ug/L	Chronic toxicity data reported in RAIS (1996b) for lead for invertebrates ranged from 12.26 µg/L for daphnids and 25.46 ug/L for non-daphnid invertebrates. *Daphnia magna* were used in 21-day tests to determine lowest chronic toxicity by Chapman et al. (manuscript). Borgmann et al. (1978) provided a chronic value for a life-cycle test on *Lymnaea palastris* , a snail. A mean of the daphnid and non-daphnid LCV was generated and used for the current study.	Moderately conservative compared to the RAIS LCV for daphnids of 12.3 ug/L or the LCV for non-daphnids of 22.3 ug/L.
Sulphate	chronic	*Ceriodaphnia dubia*	E25	n/a	855, 000	ug/L	Elphick *et al.* (2011) exposed a variety of aquatic organisms to sulphate over a range of hardnesses (15 mg/L to 320 mg/L). At a hardness comparable to Tulsequah background conditions (80 mg/L), the study estimated an EC25 of 1,056,000 ug/L for *Hyalelaa azteca* , based on the reproduction endpoint; and 855, 000 ug/L for *Ceriodaphnia dubia,* also based on reproduction endpoint.	Low uncertainty as TRV is based on effects associated with a moderate hardness similar to the hardness within the mainstem Tulsequah waters, and most conservative of applicable EC25 values applied.
Zinc	chronic	invertebrates - general	EC20	n/a	47	ug/L	Soluble species of zinc are readily available for biological reactions and therefore considered most toxic. BCMOE (1991) recommends that dissolved concentrations be used when above the BCMOE guideline. The RAIS (1996c) LCV was 46.73 ug/L for daphnids and >5,243 ug/L for non-daphnids. The difference between both groups was substantial and therefore the daphnid LCV was selected.	Low uncertainty as the RAIS LCV is based on four separate daphnid invertebrate species, and is fully protective of non-daphnid species.

Notes:

EC20 - Effective concentration where 20% effect occurs
IC20 - Inhibitory concentration where 20% effect occurs
LOEC - Lowest observable effects concentration
LCV - Lowest chronic value

Table 14: Summary of Reviewed TRVs for Benthic Invertebrate Exposure Via Sediment

Chemical	Toxicity	Species	Endpoint, % effect	Concentration	Unit	Reference	Main Uncertainties Associated with the TRV
Arsenic	chronic	sensitive benthic invertebrates and life stages	EC20	20	mg/kg	1.2X CCME PEL was applied by MacDonald et al. (2000) to characterize risk to aquatic life for assessing and managing typical contaminated sediments in British Columbia. The sediment quality criteria support the restoration of sediments to a state that will facilitate restoration of productive and diverse benthic macroinvertebrate communities in the longer-term and to minimize the risks to organisms at higher trophic levels in the food web. These sediment quality criteria are defined as the concentrations of COPCs above which there is a moderate probability of observing significant adverse effects in standardized toxicity tests with sensitive benthic species and life stages (i.e., 50% probability of observing an EC20).	Could be overly conservative and not realistic of northern BC organisms present in glacial impacted waters.
Copper				240			
Zinc				380			
Iron	chronic	100 invertebrates	Mean of LEL and SEL	32,483	mg/kg	The Lowest Effect Level (LEL) for iron is calculated as the 5th percentile of the Species Screening Level Concentration (SSLC) by ON MOE (1993). The SSLC is the calculated 90th percentile of the concentration distribution for that species. The SSLC is a plot of the concentration distribution of all the SSLCs for iron, and was calculated using 493 sediment concentrations from 493 locations in and adjacent to the Great Lakes Region, and includes effects from 100 invertebrates. The Severe Effect Level was calculated as the 95th percentile of the SSLC distribution. The concentration chosen was a mean of the combined LEL (21,200 mg/kg) and SEL (43,766 mg/kg) and represents a concentration where effect occur between an EC20 and EC50.	The species sensitivity distribution is not effects based and therefore the mean calculated value likely represents a range of effects between an EC20 and EC50. There is moderate uncertainty associated with this TRV.

Notes:
LEL - Lowest Effect Level
SEL - Severe Effect Level
EC20 - Effects Concentration where 20% Effect Occurs

Table 15: Summary of Reviewed TRVs for Fish Exposure Via Surface Water

Chemical	Toxicity	Species	Migrant / Resident	Endpoint, % effect	Hardness / pH	Concentration	Unit	Reference	Main Uncertainties Associated with the TRV
Aluminum	chronic	rainbow trout (*Oncorhynchus mykiss*) - fingerlings	resident	50%	pH: 6.3-7.3	500 (converted to LC20 OF **200** ug/L)	ug/L	Freeman and Everhart (1971), referenced in the BC Approved Water Quality Guidelines (AWQGs) technical appendix (Butcher, 1988), present an LC50 of 500 mg/L, from a 44-d study with rainbow trout fingerlings, with pH range of 6.3-7.3. An LC20 of 1000 µg/L was reported for brook trout for eyed eggs mortality after 8 days of exposure at pH 6.5 (Butcher, 1988). As stated in the BCWQG for aluminum, sensitivity to aluminum increases with advancing developmental stages, and as such the effect concentration associated with eye-egg study may not protective of more advanced life stages.	High uncertainty, associated with deriving a deriving an LC/EC20 TRV value from an LC50, as it assume a linear dose-toxicity response. Also, the selected study used rainbow trout fingerlings, and may not be protective of adult life stages.
Arsenic	chronic	rainbow trout (*Oncorhynchus mykiss)* - embryo/larvae	resident	50%	Not hardness dependent	550 (converted to LC20 OF **220** ug/L)	ug/L	Birge *et al.* (1979) study referenced in the CCME WQGs for the Protection of Aquatic Life for arsenic present an LC50 of 550 ug/L, from a 28-d study with rainbow trout (CCME, 1999a). LOECs of 500 ug/L is presented from a 7-d study with climbing perch, and 970 ug/L from a 7-day study with catfish (Jana and Sahana 1989).	Moderate to high uncertainty. While LOECs from other studies are either equal to or exceed the LC50 concentration from the Jana and Sahana 1989 study, these studies use fish species not present in the Tulsequah. Conversion of the LC50 from the Birge et al. 1979 study to an LC/EC20, may over or under estimate the actual LC/EC20; as this method assumes a linear exposure concentration-toxicity relationship.
Beryllium	acute	roach (*Rutilus rutilus*) - fry	N/A	ChV (geomean of NOEC and LOEC). LOEC: 45% mortality.	Soft; pH: 5.5	**70.7**	ug/L	Jagoe et al. 1993 study evaluated acute toxicity of beryllium to carp (*Perca fluviatilis*) and roach (*Rutilus rutilus)* in very soft water and low pH (4.5-5.5). The most conservative NOEC and LOECs from the 96 hour study pertained to roach, and were 50 ug/L and 100 ug/L, respectively. The LOEC value is associated with 45% mortality.	Moderate to high uncertainty. Limited freshwater toxicity data available to corroborate results. TRV is a calculated value, from an acute toxicity test using fish not present in the system. pH and hardness levels outside of Tulsequah background range.
Cadmium	chronic	rainbow trout (*Oncorhynchus mykiss)* - swim-up fry	resident	ChV (geomean of NOEC and LOEC). LOEC: 47% mortality.	100	1.9	ug/L	A value of 1.3 ug/L associated with a NOEC from a 98-d study using rainbow trout from BKH (1995) study was used as the TRV in the Core6 AERA. Besser *et al.* (2007) presents a calculated a chronic value (ChV) of 1.9 ug/L for rainbow trout from a 28-d exposure study at a hardness of 100 mg/L based on the percent survival endpoint. The ChV is the geomean of the NOEC value of 1.3 ug/L, and the LOEC value of 2.7 ug/L, associated with 47% mortality. An EC10 of 0.233 ug/L is presented in CCME WQG, that corresponds to 62-d study rainbow trout weight study (CCME, 2014). Life stage and hardness data are not presented.	Low to moderate uncertainty. LOEC from Besser *et al*. (2007) study is associated with 47% mortality, and study used hardness of 100 mg/L which exceeds background range of hardnesses for Tulsequah site. NOEC/LOEC from Besser *et al.* (1997) study are in close proximity to the NOEC presented in BKH (1995) study, but exceed the EC10 for rainbow trout presented in CCME guidelines, so TRV may underestimate toxicity. Also, hardness of test outside of background range.
Cadmium	chronic	bull trout (*Salvelinus confluentus*) - juvenile	resident	10%	50	**0.67**	ug/L	Hansen *et al.* (2002) study presented in CCME WQGs for the Protection of Aquatic Life for cadmium, presents a 55-LOEC for growth and survival in bull trout of 0.787 ug/L at a hardness of 36 mg/L. Mebane *et al.* 2008 presents an EC10 of 0.67 ug/L from a 55-d study measuring survival in juvenile trout, with hardness normalized to 50 mg/L. Other applicable studies for assessing impacts to resident fish include an IC20 of 1.33 ug/L for mountain whitefish (*Prosopium williamsoni*) in a 90-d study (Brinkman & Vieira 2008) and a LOEC (no reported % effect) of 0.764 ug/L from a 21-d study using mottled sculpin (Cottus bairdi) Besser et al. (2007). A 90-d IC10 of 1.25 for mountain whitefish is presented in CCME WQG for cadmium (CCME, 2014), though test conditions, such as life stage and hardness data are unavailable.	Low to moderate uncertainty. LOEC and EC10 values from Hansen *et al.* and Mebane *et al.* studies closely approximate one another. By using the bull trout based TRV, this would capture potential risks to other residential fish, such as whitefish in the system.
Cadmium	chronic	Minnesota mottled sculpin (*Cottus bairdi*) - swim up fry	resident	ChV (geomean of NOEC and LOEC). LOEC: 40% mortality.	100	1.9	ug/L	Besser et al. (2007) presents a calculated a chronic value (ChV) of 1.9 ug/L for Minnesota mottled sculpin from a 28-d exposure study at a hardness of 100 mg/L based on the % survival endpoint. The ChV is the geomean of the NOEC value of 1.4 ug/L, and the LOEC value of 2.6 ug/L, associated with 40% mortality. A ChV of 0.88 ug/L was derived for Missouri mottled sculpin (*Cottus bairi*) calculated using a NOEC of 0.59 ug/l and a LOEC of 1.3 ug/L, that corresponds to a 25% reduction in survival. The ChV from the Minnesota sculpin was selected as the environmental conditions this sub. species is exposed to would more closely resemble those of a sculpin in Northern Canada.	Moderate uncertainty. The ChV value is calculated using a LOEC associated with 40% mortality, and study used hardness of 100 mg/L which exceeds background range of hardnesses for Tulsequah site. In addition, Minnesota sculpin appear to be less sensitive to cadmium than Missouri sculpin.
Cadmium	chronic	chinook salmon (Oncorhynchus tshawytscha)	migratory	10%	50	**1.9**	ug/L	As per BC WQG for Cd (BCMOE, 2014), coho salmon were found to be the least sensitive to cadmium. Eaton *et al.* (1978) identified a LOEC of 3.4 ug/L as part of a 27-d exposure study (hardness of 45 mg/L) and LOECs from longer term studies (47- and 82-d) was reported to be 12.5 ug/L. Mebane *et al.* (2008) presents a summary of EC10s from numerous studies, including a result from Davies *et al.* (1976) that studied early life stage survival in in chinook salmon. The EC10 (normalized to hardness of 50 mg/L) from this 55-d study was 1.9 ug/L.	Low to moderate. While there appears to be a broad range of cadmium sensitivities for Pacific salmon, and coho salmon are the most prominent salmon species in the system, by choosing the chinook EC10 value from Mebane *et al.* (2008), this TRV would provide a conservative estimate of risk to Pacific salmon in the system.
Cobalt	chronic	rainbow trout (*Oncorhynchus mykiss*)	resident	LC20	92-110	120	ug/L	Within BC WQG for cobalt (Nagpal, 2004), Birge *et al.* (1980) presents an LC10 value of 120 ug/L from a 28 day study with rainbow trout, with corresponding hardness of 92-110 mg/L. Less conservative values include an LC20 of 228 ug/L from a 6 day study with rainbow trout (Marr *et al*., 1998). A NOEC from Marr et al. 1998 of 132 ug/L for rainbow trout is also presented in the BC WQG technical appendix. A NOEC of 10,000 ug/L for three-spined stickleback, from a 1939 study is also presented in Nagpal 2004, but few study details are present and the age of the publication and elevated NOEC brings scrutiny to the presented result.	Low to moderate uncertainty. Limited quantity of chronic toxicity data available for cobalt. The selected TRV of 120 ug/L from Birge *et al.* (1980) is below the NOEC of 132 ug/L from Marr *et al.* (1998), which suggests the selected TRV may be conservative.

Table 15: Summary of Reviewed TRVs for Fish Exposure Via Surface Water

Chemical	Toxicity	Species	Migrant / Resident	Endpoint, % effect	Hardness / pH	Concentration	Unit	Reference	Main Uncertainties Associated with the TRV
Copper	chronic	rainbow trout (*Oncorhynchus mykiss*)	resident	EC10	23	**2.7**	ug/L	Marr et al. 1996. Relationship Between Copper Exposure Duration, Tissue Copper Concentration, and Rainbow Trout Growth. Aquatic Toxicology. 36:17-30. Presented in the Core6 AERA. 120-d chronic study. Further supporting this finding is the Besser et al. (2007) study, that presents an effective concentration of 2.7 ug/L that resulted in a 10% reduction in survival to rainbow trout in a 28-d surface water exposure study @ hardness of 100 mg/L.	Low uncertainty. Value corroborated by result from Marr *et al.* study, and result comparable to other EC10 values for salmonids. In addition EC10 considered a conservative TRV.
Copper	chronic	chinook salmon (*Oncorhynchus tshawytscha*) - early life stage	migratory	EC10	24	**1.9**	ug/L	Chapman G.A. (1978). Toxicity of Cadmium, Copper and Zinc to Four Juvenile Stages of Chinook Salmon and Steelhead. Trans Am. Fish Soc. 107: 841-847. Used in the Core6 AERA (2013).	Moderate uncertainty. Could not corroborate study details, as could not locate study. However, value appears to be within range of EC10 values presented for other salmonids.
Copper	chronic	Minnesota molted sculpin (*Cottus bairdi*)	resident	ChV (geomean of NOEC and LOEC). LOEC: 95% mortality.	100	38	ug/L	Besser et al. (2007) presents a calculated a chronic value (ChV) of 38 ug/L for Minnesota mottled sculpin from a 28-d exposure study at a hardness of 100 mg/L based on the % survival endpoint. The ChV is the geomean of the NOEC value of 25 ug/L, and the LOEC value of 57 ug/L, associated with 95% mortality. A ChV of 4.4 ug/L was derived for Missouri mottled sculpin (*Cottus bairi*) calculated using a NOEC of 2.9 ug/l and a LOEC of 5.7 ug/L, that corresponds to a 95% reduction in survival. The ChV from the Minnesota sculpin was selected as the environmental conditions this sub. species is exposed to would more closely resemble those of a sculpin in Northern Canada.	Moderate uncertainty. The ChV value is calculated using a LOEC associated with 95% mortality, and study used hardness of 100 mg/L which exceeds background range of hardnesses for Tulsequah site. In addition, Minnesota sculpin appear to be less sensitive to copper than Missouri sculpin.
Iron	chronic/acute	Multiple spp. - Multiple life histories	N/A	Generic USEPA protective guideline / 96-h LC50	soft	Total: **1000** Dissolved: 640 - converted to LC20 value of 256 ug/L)	ug/L	The USEPA published a chronic ambient water quality criterion for iron in 1976 of 1000 µg/L. The USEPA value has not since been reviewed or updated. The criterion was based on field observations indicating that 1000 µg/L would be adequately protective (USEPA, 1976). For dissolved iron, the BCWQ guidelines contain a 96-hr LC50 result of >640 ug/l for rainbow trout in soft water (Phibben *et al.,* 2008).	High uncertainty. Limited available literature. The total iron TRV is based on a protective guideline put fourth by the US EPA and is based on field observations; and, the dissolved iron TRV comes from an acute toxicity test.
Lead	chronic	rainbow trout (*Oncorhynchus mykiss)*- early life stage (juvenile)	resident	EC10	50	12	ug/L	The Core 6 AERA presents a TRV of 15 ug/L from Mebane *et al.* (2008) that is associated with an EC10 (normalized to hardness of 50 mg/L) from an water exposure study using early life stage rainbow trout, conducted over a duration of 1.6 yrs (570-d), measuring spinal deformities. A more conservative TRV of 12 ug/L is presented in the Mebane *et al*. study, and corresponds to a hardness normalized EC10 (normalized to 50 mg/L) from a 62-d study measuring growth in early life stage rainbow trout.	Low uncertainty. Of the four EC10 (hardness normalized to 50 mg/L) values presented in Mebane *et al.* (2008), from three separate studies, the EC10 derived from the experiment conducted by Mebane *et al.* is the lowest, as such should be suitable for identifying risk to resident fish in the Tulsequah. In addition EC10 considered a conservative TRV.
Zinc	chronic	chinook salmon (*Oncorhynchus tshawytscha*) - early life stage	migratory	chronic	50	**732**	ug/l	Core 6 AERA presents a chronic value of 187 ug/L (@ hardness of 23 mg/L) for chinook salmon, but the study could not be obtained to corroborate details. Mebane *et al.* (2008) study presents an EC10 of 732 ug/L for chinook salmon. The original study was a 28-d exposure study measuring survival in early life stage chinook Chapman (1982). The original EC10 was 407 ug/L, with a corresponding hardness of 25 mg/L.	High uncertainty. TRV for chinook is high compared effect values for other species of fish. Limited available studies available for salmon.
Zinc	chronic	Minnesota mottled sculpin (*Cottus bairdi*)- swim up fry	resident	ChV (geomean of NOEC and LOEC). LOEC: 100% mortality.	100	75	ug/L	Besser *et al.* (2007) presents a calculated a chronic value (ChV) of 75 ug/L for Minnesota mottled sculpin from a 28-d exposure study at a hardness of 100 mg/L based on the % survival endpoint. The ChV is the geomean of the NOEC value of 37 ug/L, and the LOEC value of 150 ug/L, associated with 100% mortality. A ChV was not derived for the 21-d test with Missouri mottled sculpin due to high mortality in the control group, however an LC50/EC50 of 231 ug/kg was estimated, using the median lethal/effective concentration.	Moderate uncertainty. The ChV value is calculated using a LOEC associated with 100% mortality, and study used hardness of 100 mg/L which exceeds background range of hardnesses for Tulsequah site.
Zinc	chronic	rainbow trout (*Oncorhynchus mykiss)*- juvenile	resident	EC10	50	**55**	ug/L	Multiple EC10s (normalized to hardness of 50 mg/L) are presented in Mebane *et al.* (2008) study. EC10s for rainbow trout zinc, ranged from 572 ug/L from a 2 year survival study with early life stage trout, to 55 ug/L from a 30-d study measuring survival an juvenile salmon.	Low uncertainty. Wide range of EC10s presented in Mebane *et al.* (2008) study, by selecting the lowest EC10 associated with the juvenile rainbow trout study, which is the lowest of all zinc EC10s, for all studies and multiple species identified by Mebane *et al*, this value should be protective of mature life stages and other fish species. In addition EC10 considered a conservative TRV.

References
mg/L - milligrams per litre, ug/L - micrograms per litre
ChV - chronic value, geomean of NOEC and LOEC
EC (10-50) - Effective concentration. Number following "EC" refers to proportion of organisms experience effect.
IC(10-50) - Inhibitory concentration. Number following "IC" refers to proportion of organisms experiencing inhibitory effect.
LC(10-50) - Lethal concentration. Number following "LC" refers to the percentage of mortalities.
LOEC - Lowest observable effects concentration
NOEC - No observable effect concentration
WQG - water quality guideline
Values selected as TRVs for resident and migratory fish are **bolded** and underlined.

Table 16: Summary of Reviewed TRVs for Fish Egg Exposure Via Porewater

Chemical	Toxicity	Species	Migrant / Resident	Endpoint, % effect	Hardness / pH	Concentration	Unit	Reference	Main Uncertainties Associated with the TRV
Sulphate	chronic	rainbow trout (*Oncorhynchus mykiss)*- embryo/alevin	resident	EC10	15	**356, 000**	ug/L	Elphick *et al.* (2011) referenced in BC AWQG (Meays and Nordin, 2013) presents an EC10 value of 356, 000 ug/L for rainbow trout, that is based on a 31-d test measuring embryonic development in fertilized eggs. Water hardness in the test was maintained at 15 mg/L.	Low uncertainty. Test conditions carried out in soft water and EC10 considered a conservative TRV.
Sulphate	chronic	coho salmon (*Oncorhynchus kisutch*) - embryo	migratory	EC10	15	941, 000	ug/L	Elphick et al. (2011) presents an EC10 value of 941, 000 ug/L for coho salmon, that is based on a 10-d test measuring embryonic development in fertilized eggs. Water hardness in the test was maintained at 15 mg/L.	Low uncertainty. Test conditions carried out in soft water and EC10 considered a conservative TRV.

Notes:
mg/L - milligrams per litre, ug/L - micrograms per litre
ChV - chronic value, geomean of NOEC and LOEC
EC (10-50) - Effective concentration. Number following "EC" refers to proportion of organisms experience effect.
IC(10-50) - Inhibitory concentration. Number following "IC" refers to proportion of organisms experiencing inhibitory effect.
LC(10-50) - Lethal concentration. Number following "LC" refers to the percentage of mortalities.
LOEC - Lowest observable effects concentration
NOEC - No observable effect concentration
AWQG - approved water quality guideline
WWQG - working water quality guideline
Values selected as TRVs for resident and migratory fish are **bolded** and underlined.

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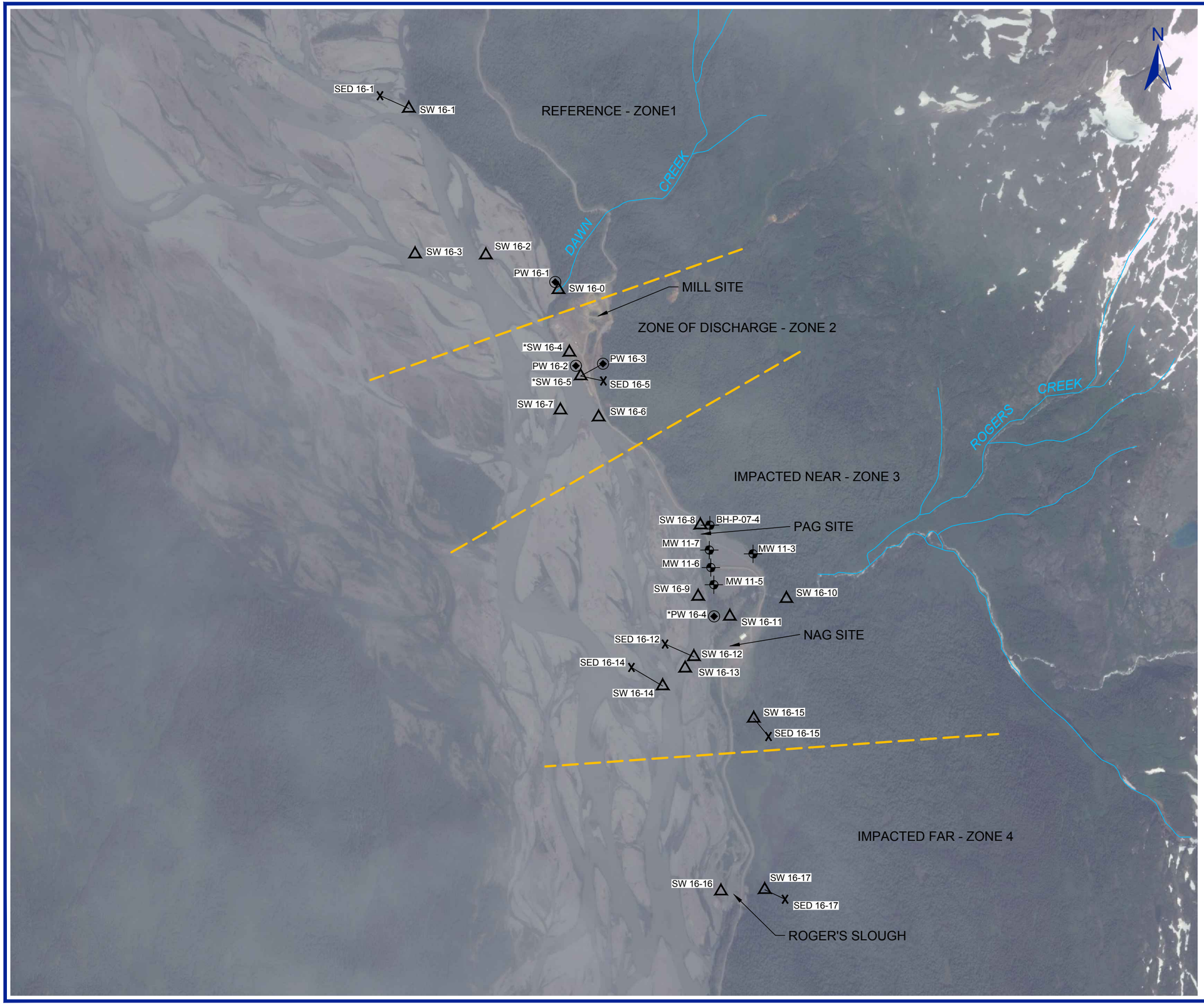
TRV Selection Criteria (not order of priority)

1. Primary Fish focus (small range): sculpin, stickelback, dolly varden/bull trout
2. Secondary Fish focus: salmonids, steelhead/rainbow trout, cutthroat trout
3. Endpoints involving: growth, reproduction, survival unless fish eggs - then more flexible
4. Only freshwater based chronic studies were considered - nothing acute. Preference to non-diet uptake ie: water exposure source.
5. Studies not providing test duration, endpoint or exposure concentrations were eliminated
6. Chronic EC20 concentrations preferred. If not reported other endpoints considered and adjusted to an estimated EC20 value. Alternatively a LOAEL was used so long as the effect was identified.
7. A geomean of the NOAEL and LOAEL was calculated when the LOAEL was associated with an effect > 20%
8. For adjustment from chronic LC50 to chronic EC20 a factor was used based on an asusmed linear chronic dose-response with zero response at EC0 and 50% response at the EC50 concentration

For fish - try and find a TRV for smaller year round fish, a second for juvenile salmonids, a third for adult salmonids, and a fourth for fish eggs.
COPCs will be those identified after the refined screening but I think we have 7 for sure and 3 maybe:
SW/PW COPCs to find TRVs: Al, As, Cd, Cu, Fe, Pb, Zn.
Unsure about: Be, Cr, Co

DRAWINGS

2016 Tulsequah Chief Mine
Aquatic Ecological Risk Assessment
SLR Project No.: 201.88687.00000



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SW 16-16 RELOCATED TO CURRENT LOCATION

LEGEND:

- ZONE BOUNDARY
- X SURFACE WATER SAMPLE
- GROUNDWATER SAMPLE
- POREWATER SAMPLE
- SEDIMENT SAMPLE
- * DUP
- NAG NON-ACID GENERATING WASTE ROCK
- PAG POTENTIALLY ACID GENERATING WASTE ROCK

0 0.25 0.5 1.0 km

SCALE 1:15,000
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 9 U

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

MINISTRY OF ENVIRONMENT
TULSEQUAH CHIEF MINE SITE
ATLIN, BC

2016 TULSEQUAH CHIEF MINE SITE AERA

2016 TULSEQUAH CHIEF AERA SAMPLE LOCATIONS - OVERVIEW

Date: December 22, 2016	Drawing No. 1
Project No. 201.88687.00000	

SLR global environmental solutions

Cadfile name: S_201-88687-00000-A1.dwg

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SW 16-16 RELOCATED TO CURRENT LOCATION

LEGEND:

- ZONE BOUNDARY
- X SURFACE WATER SAMPLE
- GROUNDWATER SAMPLE
- POREWATER SAMPLE
- SEDIMENT SAMPLE
- * DUP
- NAG NON-ACID GENERATING WASTE ROCK
- PAG POTENTIALLY ACID GENERATING WASTE ROCK

0 50 100 200 300 400 m

SCALE 1:7,500
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 9 U

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

MINISTRY OF ENVIRONMENT
TULSEQUAH CHIEF MINE SITE
ATLIN, BC

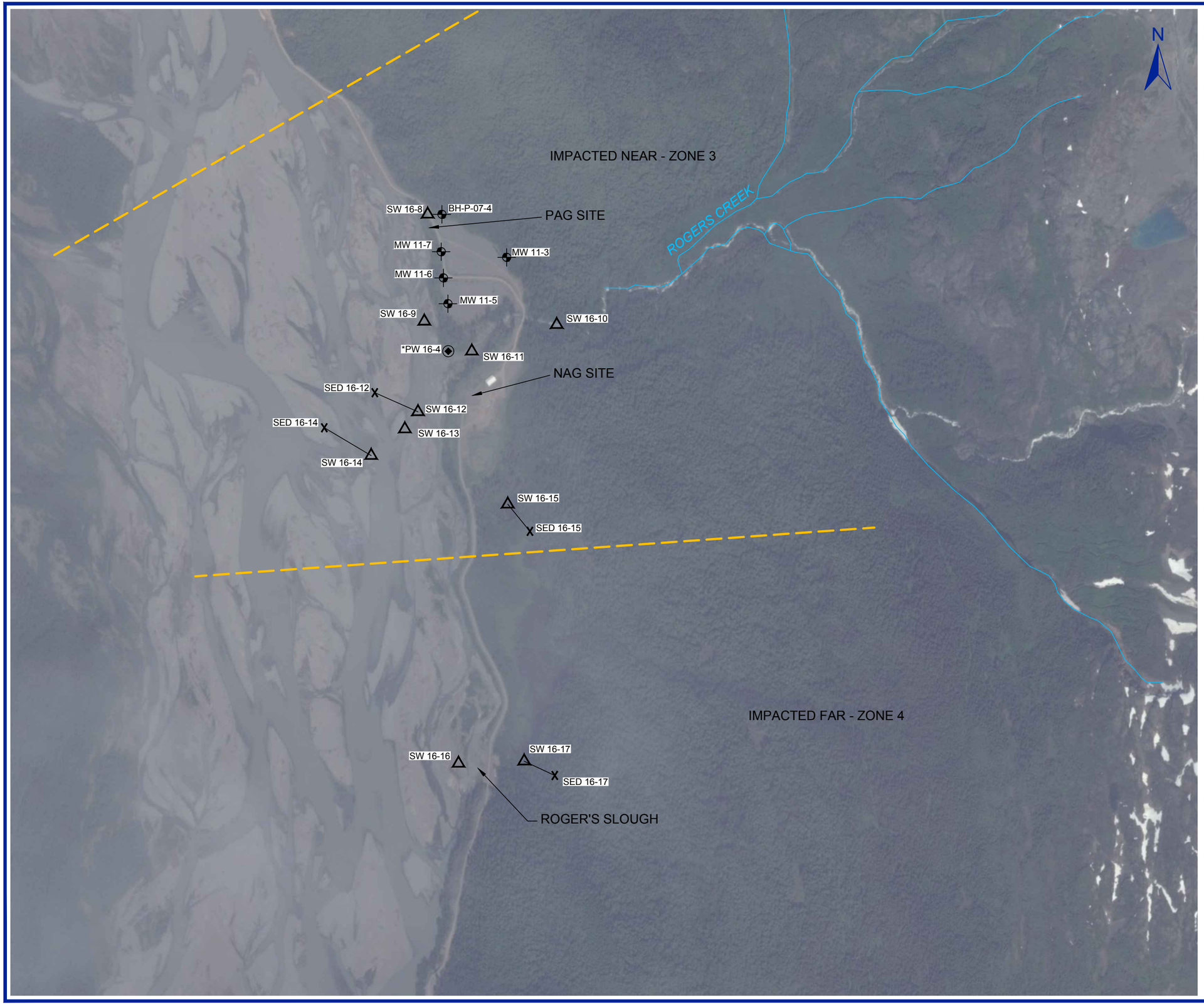
2016 TULSEQUAH CHIEF MINE SITE AERA

2016 TULSEQUAH CUIEF AERA SAMPLE LOCATIONS - ZONES 1 AND 2

Date: December 22, 2016	Drawing No. 2
Project No. 201.88687.00000	

SLR global environmental solutions

Cadfile name: S_201-88687-00000-A1.dwg



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SW 16-16 RELOCATED TO CURRENT LOCATION

LEGEND:

- ZONE BOUNDARY
- SURFACE WATER SAMPLE
- GROUNDWATER SAMPLE
- POREWATER SAMPLE
- SEDIMENT SAMPLE
- * DUP
- NAG — NON-ACID GENERATING WASTE ROCK
- PAG — POTENTIALLY ACID GENERATING WASTE ROCK

0 100 200 400 600 m

SCALE 1:10,000
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 9 U

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

MINISTRY OF ENVIRONMENT
TULSEQUAH CHIEF MINE SITE
ATLIN, BC

2016 TULSEQUAH CHIEF MINE SITE AERA

2016 TULSEQUAH CUIEF AERA SAMPLE LOCATIONS - ZONES 3 AND 4

Date: December 22, 2016	Drawing No. 3
Project No. 201.88687.00000	

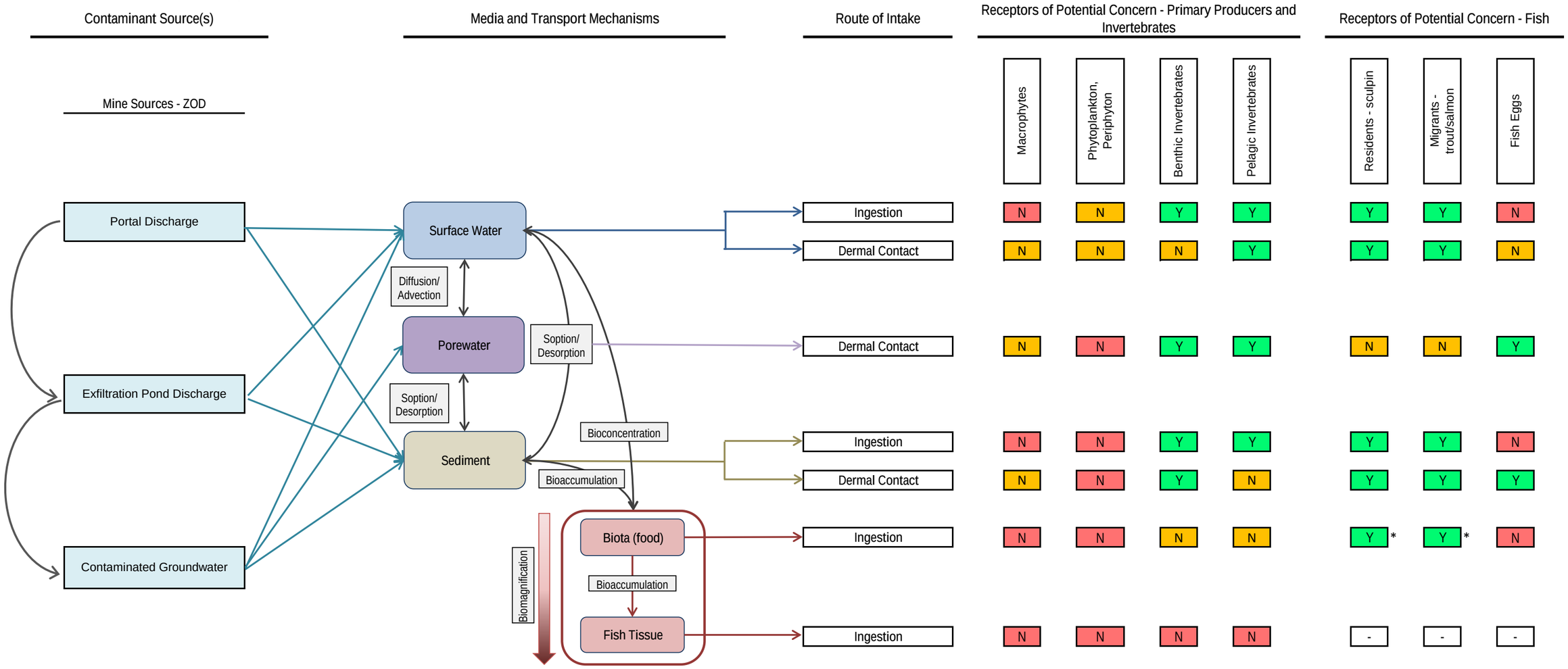
SLR global environmental solutions

Cadfile name: S_201-88687-00000-A1.dwg

CONCEPTUAL SITE MODELS (CSM)

2016 Tulsequah Chief Mine
Aquatic Ecological Risk Assessment
SLR Project No.: 201.88687.00000

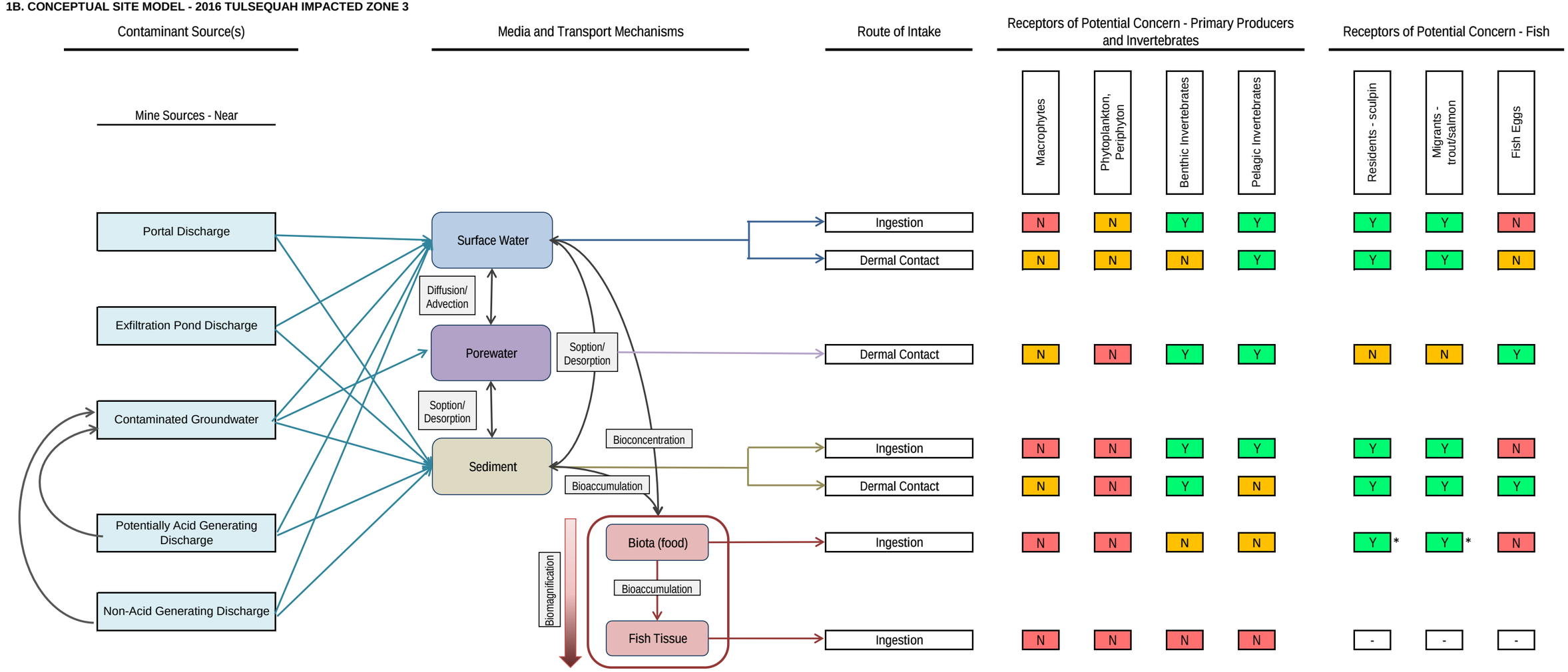
1A. CONCEPTUAL SITE MODEL - 2016 TULSEQUAH IMPACTED ZONE 2



Notes:

Y	Pathway is complete
N	Pathway is potentially complete, but insignificant
N	Pathway is incomplete
-	Pathway is non-applicable or irrelevant
———	Complete connection and potentially significant
*	Pathway is complete but outside of the scope of work for the current AERA

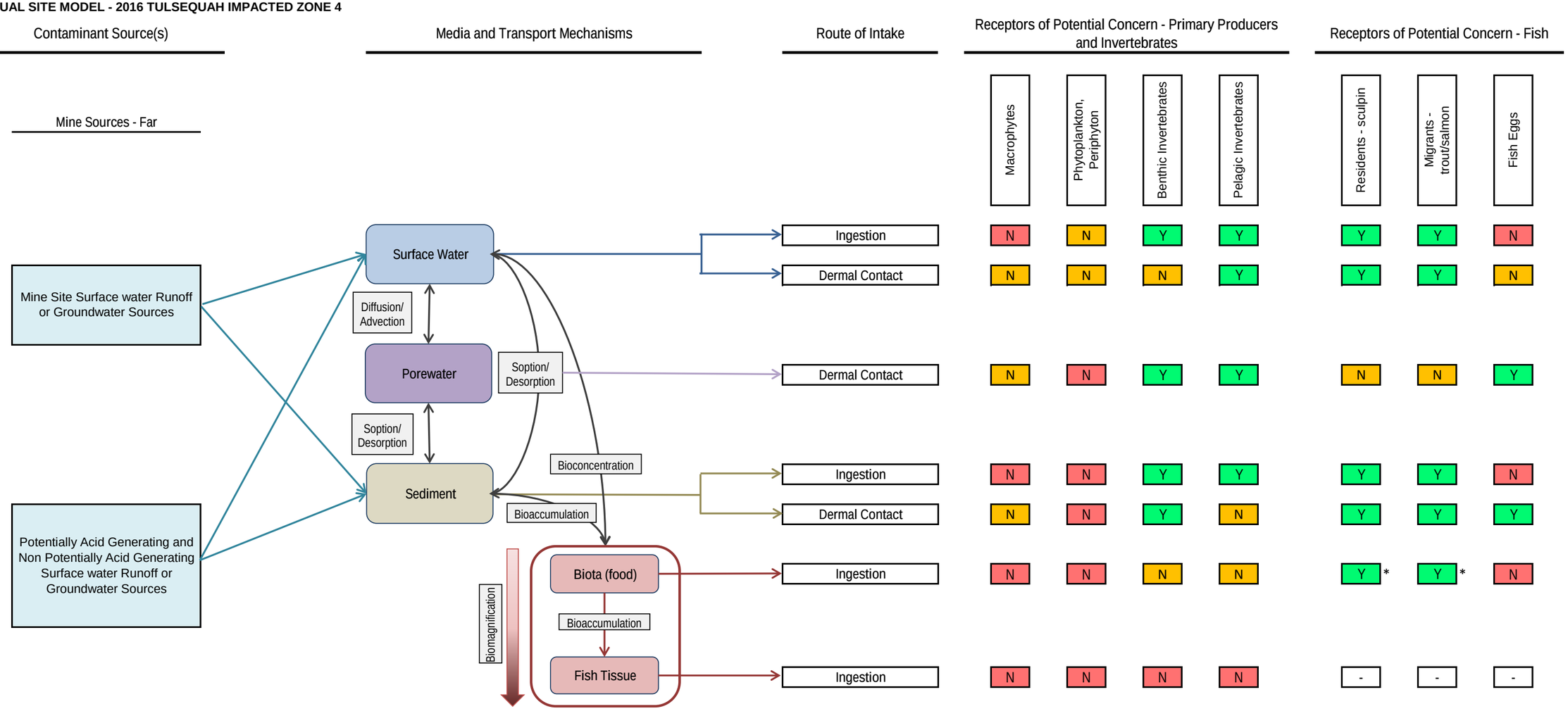
1B. CONCEPTUAL SITE MODEL - 2016 TULSEQUAH IMPACTED ZONE 3



Notes:

Y	Pathway is complete
N	Pathway is potentially complete, but insignificant
N	Pathway is incomplete
-	Pathway is non-applicable or irrelevant
———	Complete connection and potentially significant
*	Pathway is complete but outside of the scope of work for the current AERA

1C. CONCEPTUAL SITE MODEL - 2016 TULSEQUAH IMPACTED ZONE 4



Notes:

Y	Pathway is complete
N	Pathway is potentially complete, but insignificant
N	Pathway is incomplete
-	Pathway is non-applicable or irrelevant
———	Complete connection and potentially significant
*	Pathway is complete but outside of the scope of work for the current AERA

APPENDIX A
BC MOE Correspondence with Chieftain Metals Inc.

2016 Tulsequah Chief Mine
Aquatic Ecological Risk Assessment
SLR Project No.: 201.88687.00000

August 24, 2016 File: 10046-60/105719

Mr. Keith Boyle
Chief Operating Officer
Chieftain Metals Corp.
2 Bloor Street West
Toronto, ON M4W 3E2

Dear Mr. Boyle,

The Ministry of Environment (MOE) has reviewed the application submitted by Chieftain Metals Inc. (CMI) in pursuit of an amendment to permit #105719, issued under the *Environmental Management Act*. The permit was issued in April of 2012 and regulates the discharge of mine effluent. The proposed amendment requests a reduction in the frequency of monitoring and sampling at the site, and the removal of the condition requiring the operation of the water treatment plant (WTP) during the extended care and maintenance period. The MOE has engaged the Taku River Tlingit First Nation (TRT) in relation to the proposed reduction in monitoring frequency and a decision in this regard is pending. Regarding the removal of the requirement to operate the WTP, the MOE finds that the application contains insufficient information to support a decision on the proposal. At this time, I'm recommending that a decision be made regarding only the reduction in monitoring frequency. Should CMI choose to pursue the amendment relating to the operation of the WTP, a new application would be required. The Terms of Reference for that application would be developed through the ministry's pre-application process and an Information Requirements Table. The following are some of the deficiencies noted in your application in regards to removal of the interim WTP permit condition.

An aquatic ecological risk assessment (AERA) was conducted in the Tulsequah River in support of removing the requirement for operation of the interim water treatment plant. The AERA evaluated the potential risks to aquatic resources as a result of untreated mine discharge from the historic Tulsequah Chief Mine. A letter from the MOE acknowledging receipt and review of the AERA, dated June 12, 2014, identified several areas that required further clarification. CMI's response dated December 22, 2014 addresses the MOE's concerns with one apparent exception. The MOE identifies that the main-stem of the Tulsequah River likely functions primarily as a migration corridor, but that it's unclear if there is any information regarding how that corridor is utilized and during what periods of the year. CMI's response letter (December 22, 2014) recognizes that the conclusion of low to moderate risk from the AERA does, in part hinge on the assumption of low receptor presence in the Tulsequah River main-stem during the period of poorest water quality. Information was not provided as to whether this assumption was field validated.

…. 2

In addition, upon further review, it was noted that the AERA lacked clear information on the methodology used for the selection of sampling sites. Gravel-bed river floodplains located in mountainous terrain represent diverse and complex environments (Hauer et al., 2016). As such more rigorous characterization (i.e. a larger number of sampling locations) is required for adequate site characterization. The AERA bases its conclusion of low to moderate risk on water quality samples from four sites – three in near proximity to the AMD discharge location, and one site 2.7 km downstream of the discharge site. Additional resolution in site characterization is required to better represent the complexity of the site, including the hydrology and hydrogeology contributing to contaminant distribution in the affected area.

In addition, the indicator species chosen for the study are not the species best suited to reflect ecological risk. Where the constituents in the mine effluent represent a source of biological stress in the Tulsequah River, ideal bioindicator species should: exhibit measureable and persistent sensitivity to the stressor, wide ranging distribution in the study area, high abundance and low mobility among, other factors (Yang, Chen, Li, Zheng, & Liu, 2010; Burger & Gochfeld, 2001). The bioindicator organisms used in the study were Salmon and Dolly Varden. These species fail to meet two critical criteria for suitable bioindicators due to their lower abundances than organisms at lower-trophic levels and their high mobility (Bramblett et. al. 2002).

Specific details regarding the information requirements for an updated amendment application for the removal of water treatment would be determined at the time of re-application. CMI may wish to re-apply for this amendment. Please refer to MOE's newly published pre-application information notice which outlines the procedure mining applicants must follow in order to develop information requirements for EMA permit applications. The information notice can be found here: http://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/guidance-documents/ug_pre-app.pdf.

I will be formalizing my recommendations on your application to the Director by August 31, 2016. Please respond during this period with any concerns you have about the approach discussed herein. If you have any questions regarding the requested information, please contact Arash Janfada at 604-582-5365 or Arash.Janfada@gov.bc.ca or Mark Love at 250-847-7416 or Mark.Love@gov.bc.ca.

Sincerely,

Arash Janfada, M.Sc., P. Eng.
Environmental Protection Officer

REFERENCES:

Bramblett, R. G., M. D. Bryant, B. E. Wright, and R. G. White. 2002. Seasonal use of small tributary and main-stem habitats by juvenile steelhead, coho salmon, and Dolly Varden in a southeastern Alaska drainage basin. Transactions of the American Fisheries Society 131:498-506.

Burger, J., & Gochfeld, M. (2001). On Developing Bioindicators for Human and Ecological Health. *Environmental Monitoring & Assessment*, *66*(1), 23–46.

Hauer, F. R., Locke, H., Dreitz, V. J., Hebblewhite, M., Lowe, W. H., Muhlfeld, C. C., … Rood, S. B. (2016). Gravel-bed river floodplains are the ecological nexus of glaciated mountain landscapes. *Science Advances*, *2*(6).

Yang, Z., Chen, B., Li, L., Zheng, B., & Liu, L. (2010). International Conference on Ecological Informatics and Ecosystem Conservation (ISEIS 2010) Biomonitoring and Bioindicators Used for River Ecosystems: Definitions, Approaches and Trends. *Procedia Environmental Sciences*, *2*, 1510–1524.

CC:

Eric Telford (via email)	Lands Engagement Coordinator, Taku River Tlingit First Nation	lands.engagement@gov.trtfn.com
Kyle Moselle (via email)	Large Mine Project Manager Alaska Dept. of Natural Resources	Kyle.moselle@alaska.gov

September 12, 2016

Tracking Number: 350102
Authorization Number: 105719

REGISTERED MAIL

Chieftain Metals Inc.
c/o Lawdell Corporate Services Limited
1600 - 925 West Georgia Street
Vancouver BC V6C 3L2

Dear Permittee:

Enclosed are amendments to Section 4 -Monitoring Requirements of Permit 105719 issued under the provisions of the Environmental Management Act. Your attention is respectfully directed to the amended monitoring requirements outlined in the attachments to this letter. The amended Section 4 replaces previous monitoring requirements. All other terms and conditions of Permit 105719 remain in force and effect.

Failure to comply with the requirements set out in your Permit, including the attached monitoring requirements, is an offence under the *Environmental Management Act*.

It is also the responsibility of the permittee to ensure that all activities conducted under this authorization are carried out with regard to the rights of third parties, and comply with other applicable legislation that may be in force.

This decision may be appealed to the Environmental Appeal Board in accordance with Part 8 of the Environmental Management Act. An appeal must be delivered within 30 days from the date that notice of this decision is given. For further information, please contact the Environmental Appeal Board at (250) 387-3464.

Administration of this permit will be carried out by staff from the Environmental Protection Division's Regional Operations Branch. Plans, data and reports pertinent to the permit are to be submitted by email or electronic transfer to the Director, designated Officer, or as further instructed.

Yours truly,

Environmental Protection Division
Ministry of Environment
Bag 5000
Smithers, BC V0J 2N0
Authorizations - North Region
Telephone: (250) 847-7260
Facsimile: (250) 847-7591

Douglas J. Hill, P.Eng.
for Director, *Environmental Management Act*
Mining Operations

Enclosure

cc: Environment Canada

4. MONITORING REQUIREMENTS

4.1. Discharge and Receiving Environment Water Monitoring Program

The Permittee must undertake the following meteorological, hydrometric and water quality measurements, samples and analyses:

Sampling Location	Location Description/Rationale	Frequency of Field Parameters* and Lab Analysis
Shazah Camp	Climate Data – HOBO weather station and glycol precipitation gauge	April, August and October - download dataloggers; replenish glycol
Chasm Creek and Shazah Creek	Hydrometric stations	April or May, August and October – download dataloggers (including barologger), record staff gauge reading; take manual flow measurements
NMW Discharge **E277509**	Neutral pH Mine Water Discharge from 5400 adit to Portal Creek	April/May/August/October: Field parameters, flow, general chemistry, total and dissolved metals
SE-2	Exfiltration pond spillway	April/May/August/October: total and dissolved metals, general chemistry
P-07-03, MW11-3 and MW11-5 to MW11-7	Near proposed PAG Facility	Download datalogger and record water levels at least once per year
MW11-9 to -10	Near proposed NAG Dump	Record water levels at least once per year
SP11-01 to -03 **E287309** **E287310** **E287311**	Near Lime Sludge Pit at airstrip	April/May/August/October - water levels; April and October: groundwater field parameters, dissolved metals, general chemistry
W10 **E272544**	Tulsequah River mainstem upstream of Project	April/May/August/October: field parameters , total and dissolved metals, general chemistry
W32 **E272546**	Tulsequah River mainstem downstream of Mine Site	April/May/August/October (in duplicate): field parameters, total and dissolved metals, general chemistry

Date issued: April 3, 2012
Date amended: September 12, 2016
(most recent)

Douglas J. Hill, P.Eng.
for Director, *Environmental Management Act*
Authorizations - North Region

Sampling Location	Location Description/Rationale	Frequency of Field Parameters* and Lab Analysis
W51 **E272547**	Downstream of SE-2/NMW discharge	April/May/August/October: field parameters, total and dissolved metals,
Borrow Pit	Near culvert	April, measure Dissolved Oxygen if ice cover present
Taku River downstream of the Tulsequah River confluence	Near WSC gauge Station 08BB005) located downstream of the Tulsequah River confluence near the Canada US Border	Once per year in October: field parameters, total and dissolved metals, general chemistry

Date issued: April 3, 2012
Date amended: September 12, 2016
(most recent)

Douglas J. Hill, P.Eng.
for Director, *Environmental Management Act*
Authorizations - North Region

Analysis of water samples for field parameters, general chemistry and total and dissolved metals must be as follows:

Analysis Group	Parameter List
Field Parameters	pH
	Temperature (°C)
	Conductivity (µS/cm)
General Chemistry	Alkalinity, Total as $CaCO_3$
	Acidity as $CaCO_3$
	Hardness as $CaCO_3$
	Total Suspended Solids
	Sulphate (SO_4)

Analysis Group	Parameter List
Total & Dissolved Metals	Aluminum
	Antimony
	Arsenic
	Barium
	Cadmium
	Calcium
	Chromium
	Cobalt
	Copper
	Iron
	Lead
	Lithium
	Magnesium
	Manganese
	Molybdenum
	Nickel
	Potassium
	Selenium
	Silver
	Sodium
	Thallium
	Tin
	Titanium
	Uranium
	Vanadium
	Zinc

Table Notes:

1. Each heading represents a list of parameters that can be analyzed using a single bottle with appropriate preservative and/or sample preparation.
2. Detection Limits to meet the requirement of BC Aquatic Life Guidelines

Date issued: April 3, 2012
Date amended: September 12, 2016
(most recent)

Douglas J. Hill, P.Eng.
for Director, *Environmental Management Act*
Authorizations - North Region

When the treatment plant is operating the discharge and initial dilution zone must be sampled as follows:

Location	*Site I.D.*	*Parameter*	*Frequency*
Water Treatment Plant Discharge	**E272507**	**Field: pH, Conductivity, Turbidity, Temperature,**	**Daily**
		Lab: Total and Dissolved Metals (ICP/ICPMS) including Mercury*	**Weekly for first 5 weeks, then monthly**
		Lab: pH, Conductivity, Turbidity, Total Suspended Solids, Hardness, Alkalinity	**Monthly**
		Flow	**Continuous Data-logger (hourly sampling interval)[1]**
		Toxicity:	
		Rainbow Trout 96 hr LC 50	**Monthly for three months (first sample within 24 hours of commencement of discharge), then quarterly.**
		***Ceriodaphnia dubia* reproduction and survival test** (Reference Method EPS 1/RM/21)	**Annually**
		Rainbow Trout (Oncorhynchus mykiss) Embryo development Test (Reference Method EPS 1/RM/28)	**Annually**
		Algal growth inhibition test using Pseudokirchneriella subcapitata (Reference Method EPS 1/RM/25)	**Annually**
		Macrophyte growth inhibition test using Lemna minor (Reference Method EPS 1/RM/37)	**Annually**
Tulsequah River IDZ (W46)	**E272548**	**Total and Dissolved Metals (ICP/ICPMS) including Mercury*; pH, Conductivity, Turbidity, Total Suspended Solids, Hardness, Alkalinity**	**Monthly[2]**

*Mercury sampling will be monthly for 12 months. The need for continued monitoring will be evaluated based on sample results.
[1]Hourly data must be retained on site, only daily volumes will be reported.
[2] Weather and freezing conditions may prevent the collection of a monthly sample. The Permittee must

Date issued: April 3, 2012
Date amended: September 12, 2016
(most recent)

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for Director, *Environmental Management Act*
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notify the Regional Manager in the event that samples cannot be collected.

4.2. Monitoring Procedures

4.2.1 Sampling Procedures

Sampling is to be carried out in accordance with the procedures described in the most recent edition of the "British Columbia Field Sampling Manual for Continuous Monitoring Plus the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples", or by suitable alternative procedures as authorized by the Director.

A copy of the above manual may be purchased from the Queen's Printer Publications Centre, P. O. Box 9452, Stn. Prov. Gov't. Victoria, British Columbia, V8W 9V7 (1-800-663-6105 or 250-387-6409). A copy of the manual is also available for inspection at all Environmental Protection offices.

4.2.2 Analyses

Water analyses and toxicity testing procedures are to be carried out in accordance with procedures described in the most recent edition of the "British Columbia Laboratory Methods Manual for the Analysis of Water, Wastewater, Sediment, Biological Materials and Discrete Ambient Air", or by suitable alternative procedures as authorized by the Director.

A copy of the above manual may be purchased from the Queen's Printer Publications Centre.

4.2.3 Quality Assurance

Analyses of samples for parameters designated under the Environmental Data Quality Assurance Regulation must be at a laboratory registered for the designated parameter. At the request of the Director, the Permittee must provide the laboratory quality assurance data, associated field blanks and duplicate analysis results along with the submission of data required under Section 4.1 of the permit. In addition, the Permittee must participate in quality assurance audits as required under the Environmental Data Quality Assurance Regulation.

Date issued: April 3, 2012
Date amended: September 12, 2016
(most recent)

Douglas J. Hill, P.Eng.
for Director, *Environmental Management Act*
Authorizations - North Region

APPENDIX B
2016 ESA Summary and AERA Dataset

2016 Tulsequah Chief Mine
Aquatic Ecological Risk Assessment
SLR Project No.: 201.88687.00000

APPENDIX B:
2016 TULSEQUAH CHIEF MINE SITE
ENVIRONMENTAL SITE ASSESSMENT SUMMARY

1.0 INTRODUCTION

SLR Consulting (Canada) Ltd. was retained by the British Columbia Ministry of the Environment (BC MOE) to complete a 2016 Aquatic Ecological Risk Assessment (AERA) for the Tulsequah Chieftain Mine Site (hereafter referred to as the "Site"). The purpose of the 2016 AERA was to provide a current state assessment of potential impacts to aquatic receptors within the Tulsequah mainstem and tributary side-channels surrounding the Site.

SLR field staff was accompanied by a wildlife monitor on site at the Tulsequah Chieftain Mine Site between October 29, 2016 and November 2, 2016. On November 1st and 2nd a Taku River Tlingit (TRT) First Nations representative joined to help conduct the field program. SLR field personnel, the wildlife monitor, and the TRT representative were flown to and from site daily by Discovery Helicopter operating out of Atlin, BC.

Weather conditions were optimal during the course of the program, temperatures ranged from 2-7 ˚C, with no precipitation while on site. The helicopter pilot, who was very familiar with the area, noted that she had not seen the water level as low as it was during the field program in the eight years she has been flying in the area.

In order to assess potential risks to aquatic receptors within the Tulsequah system, an environmental site assessment (ESA) was undertaken to quantify the current conditions on site and assess the impact to the Tulsequah River system. The ESA included site recognisance to understand the site characteristics, porewater sampling to assess the potential impact of subsurface water flow, surface water sampling to assess the impact to potential aquatic receptors, and sediment sampling to assess the impacts to the lower trophic aquatic receptors. A summary of the ESA field program and observations is included in the following sections.

2.0 STUDY LOCATION

The Tulsequah River is located in northwestern British Columbia and is within the Taku River watershed. The Tulsequah River confluences with the Taku River approximately 5 kilometres upstream of the Canada-United States border. From the toe of the Tulsequah Glacier to the confluence with the Taku River, the river is approximately 20 km in length and drops approximately 110 m in elevation over this distance. The Tulsequah River drains an area of 737 km^2, approximately 35% of which is glaciated. Tulsequah Lake and Lake No Lake are dammed by the Tulsequah glacier and only once or twice a year the glacial dams fail and flood the Tulsequah River (jökulhlaups) (AERA, 2013).

The Tulsequah Chief Mine is located on the east bank of the Tulsequah River, approximately 100 km south of the town of Atlin, BC.

For the purpose of the AERA investigation, the Study Area was divided into four exposure zones; one reference and three impacted zones. Zone 1 - Reference, is located directly upstream of the Site, and Zone 2 - Zone of Discharge, is located adjacent to the Site. Zone 3 - Impacted Near, is located approximately 1 km downstream of the Site. Zone 4- Impacted Far, is located approximately 2.5 km downstream of the Site. Drawings 1, 2 and 3 of the AERA show the sampling zones in the Tulsequah River.

3.0 SITE RECONNAISSANCE

On October 29, 2016 and November 2, 2016, SLR field staff conducted site reconnaissance at the Mine Site and the surrounding areas, the non-acid generating (NAG) storage site, and the potential acid generating (PAG) storage site (PAG). SLR did not test the ARD potential within existing upland waste rock at the Site and therefore cannot confirm whether the PAG and NAG piles differ in their Acid Rock Drainage (ARD) potential. During the events surface water monitoring was conducted to better understand the source contaminated materials and the extent of observational impacts on, adjacent, and downstream of the mine site. The volume of impacted water reaching the Tulsequah River system was estimated and previously unknown groundwater monitoring wells were discovered. A summary of the site reconnaissance is provided in the following sections.

3.1 Surface Water Monitoring

On October 29, 2016 SLR executed a site reconnaissance to familiarize with the mine site location and the immediate surrounding area. The objectives were to understand and locate the sources of the contaminant, trace the overland passage, and identify potential seepage/drainage points leading to the Tulsequah River, side channels, or its tributaries. To identify the contaminants path, field readings were recorded using a YSI Pro DSS with the capability of recording pH, temperature, conductivity, dissolved oxygen (DO), oxidation reduction potential (ORP), and turbidity. GPS coordinates and elevations were recorded from a handheld Delorme InReach device at each observation location for future reference.

Table 3-A provides a summary of the monitored locations including a Location ID, Location Description, and Photo ID. Photos are provided following the text.

Table 3-A: Surface Water Monitoring – Location Descriptions

Location ID	Location Description	Photo ID
1	Piped water originating from inside Portal 5400 discharging into diversion channel running south of the main site.	B-1
2	Surface flow of water originating from mouth of Portal 5400	B-2
3	Stained ditch on north side of access road to Portal 5400	B-3
4	Surface flow in ditch originating from Portal 5400	B-4
5	Surface flow of water originating from mouth of Portal 5200	B-5
6	Exfiltration Pond	B-6
7	WTP Pond at surface (0.15 mbs)	B-7
8	WTP Pond at 0.6 mbs	B-7
9	Riverside North of Water Treatment Plant Sludge Pit	B-8
10	10 m west of Confluence of Dawn Creek and side tributary of Tulsequah	B-9
11	At groundwater entrance into side channel upstream of WTP	B-10
12	At confluence of groundwater and side channel west of WTP	B-10
13	Confluence of Exfiltration pond overflow and side channel	B-11
14	On shoreline, prior to surface runoff from Exfiltration Pond reaching Tulsequah side channel	B-12
15	Pooled water in the non-acid generating site excavation	B-13

Table 3-B displays the surface water monitoring observations, the location ID's, GPS co-ordinates, elevation relative to sea level, parameters recorded by the YSI, and the presence or absence of staining. The surface water monitoring locations are illustrated on Drawing B-1 following the text. Additionally, photos of the surface water monitoring locations are provided following the text.

Table 3-B: Surface water Monitoring – Spatial and Parameter Observations

Location ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Date	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	2-Nov-16
Northing	581049	581052	580997	580959	580966	580919	nm	nm	580792	580840	580776	580805	580923	nm	581581
Easting	6511525	6511537	6511542	6511383	6511328	6511357	nm	nm	6511546	6511654	6511440	6511424	6511305	nm	6510139
Elevation (m)	105	104	85	50	64	40	nm	nm	27	45	41	43	43	nm	61
Temp (˚C)	8.1	5.5	4.8	5.3	6	5.1	4.4	4.3	3.6	4	1.9	3.2	3.1	5.7	4
pH	8.58	3.61	3.54	3.48	3.44	3.44	5.65	6.22	6.86	7.37	8.12	7.71	7.69	3.56	8.13
DO (mg/L)	11.2	12	8.68	12.32	11.9	12.24	12.69	12.89	11.14	12.68	10.94	11.74	11.37	12.2	10.94
Turbidity (NTU)	0.5	29.3	3.5	13.2	20-35	16.3	0.9	2.7	1.3	0.6	nm	1.3	2.5	13.5	2.1
SPC (µS)	368.9	864	728	830	961	963	472.5	466	146.5	136.9	114.9	131.7	157.5	919	201.5
Cond (µS)	249.6	542	447.8	518	614	598	286.4	281.7	86.6	81.7	64.1	77	91.7	581	201.5
ORP	96.5	512.8	442.3	518.7	499.6	511.2	437.1	405.5	337	356.9	nm	349	208.7	507.5	120.8
Staining present	N	Y	Y	Y	Y	Y	Y*	Y*	N	N	N**	N	Y	Y	N

Notes:

N- no staining observed

Y - staining observed

* - Algal growth on floor and sides of pond.

** - some other staining or algal growth present yellow, not orange

nm - not measured

3.2 Exfiltration Pond Flow Rate

On October 29, 2016 SLR executed several tests to determine the flow rate of two surficial run-off inputs entering the exfiltration pond. The two inputs were traced from portal 5400 and portal 5200.

3.2.1 Flow Rate Methodology

An uninterrupted section of the run-off ditch in close proximity upstream of the exfiltration pond was selected for ease of access, uniformity, requisite length, and absence of debris. The length of transect measured was 7 meters and 10 meters for Portal 5400 and Portal 5200 respectively. The length of time for a flow-measuring ball to reach the end of the transect was recorded. Three replicate tests were completed at each location and the fastest of the three times was used to determine the estimated velocity. Width and depth of the channel at specified intervals was recorded and an average of the channel cross section was used to determine the estimated cross section.

3.2.2 Exfiltration Pond Input Flow Rate Results

Stream velocity at Portal 5400 was measured at 0.30 m/s (7m/23s) and at Portal 5200, stream velocity was measured at 0.59 m/s (10m/17sec).

At the time of the work program, with little to no precipitation in the previous 24 hours, the combined estimated surficial flow reaching the Exfiltration Pond was 0.036 m^3/s. Table 3-C presents the calculation for the Exfiltration Pond input flow rate.

Table 3-C: Exfiltration Pond input Flow Rate Calculation

Input Origin	Interval (m)	Stream Width (m)	Stream Depth (m)	Cross Sectional Area (m^2)	Average Cross Section (m^2)	Velocity (m/s)	Flow Rate (m^3/s)
Portal 5400	0	1.00	0.04	0.035	0.0400	0.3000	0.012
	3	0.80	0.05	0.036			
	6	0.95	0.06	0.057			
	7	0.80	0.04	0.032			
Portal 5200	2	0.84	0.04	0.0336	0.03984	0.59	0.024
	4	0.84	0.07	0.0588			
	6	0.50	0.06	0.03			
	8	0.60	0.07	0.039			
	10	0.54	0.07	0.0378			

At present, there is no treatment of the Exfiltration Pond water. The water breaches the berm and spills over to the Tulsequah River bed or passes through the membrane lining of the pond into the soils beneath. Table 3-D shows the estimated calculation of Exfiltration Pond Input over a minute, an hour, a day, and a month.

Table 3-D: Estimated Surface Flow Input to Exfiltration Pond

Unit	Cubic Metes	Litres
Per Second	0.036	35.6
Per Minute	2.137	2136.6
Per Hour	128.193	128193.1
Per Day	3076.635	3076635.5
Per Month	92299.065	92299065.0

3.3 Monitoring Well Survey

On November 2, 2016 SLR executed a second reconnaissance to familiarize with the southern portion of the Site including the PAG and NAG sites. Surrounding the PAG site cells, five previously unknown groundwater monitoring wells were located. All wells were 1" diameter installations and at location BH-P-07-4, a data logger was located within the monitoring well monument. All locations were identified with GPS locations and elevations using a Delorme InReach device for potential future sampling events. Depth to water, depth to end of hole, and field parameters could not be retrieved as field equipment designated for 1" diameter wells was not available.

Table 3-E provides a summary of the discovered monitoring well location ID's and relative spatial data, and Photo ID. Photos are provided following the text and Drawing B-2 summarizes well locations.

Table 3-E: Discovered Monitoring Well Locations

Location ID	MW 11-3	MW 11-5	MW 11-6	MW 11-7	BH-P-07-4
Northing	581617	581460	581448	581442	581444
Easting	6510594	6510470	6510539	6510609	6510709
Elevation (m)	43	43	45	49	35
Accuracy (+/-)	11	4	4	6	4
Photo ID	14	15	16	17	18

4.0 POREWATER SAMPLING

The 2016 field program included installation of four drive point piezometers for assessment of porewater quality adjacent to the Tulsequah mine Site. Three zones of the Tulsequah western shoreline were investigated during the field program. The porewater IDs, shoreline station description, rationale for the installations, and corresponding photo ID are provided in Table 4-A. Photos are provided following the text and porewater sampling locations are shown in Drawing 3 of the AERA report

Table 4-A: Porewater Station Description

Zone	Porewater ID	Shoreline Station Description	Station Reasoning	Photo ID
Zone 1	PW16-1	30 m north of the confluence of Dawn Creek and a Tulsequah side channel	Assess background conditions upstream of the site	D-19
Zone 2	PW16-2	East of exfiltration pond	Assess subsurface seepage through exfiltration pond seal	D-20
	PW16-3	East of Portal 5200	Assess subsurface groundwater flow of discharged water from Portal 5200	D-21
Zone 3	PW16-4	North shoreline at the mouth of Rogers Creek	Assess potential impacts of the PAG site	D-22

Drive point installation locations were chosen with consideration of the annual flooding event known as the jökulhlaups. The event causes significant flooding and alteration of river bed materials. Prior to selecting the locations for drive point stations a visual inspection for indications of seepage (i.e. stressed vegetation or flow paths) was conducted on the west side of the Tulsequah River. Obvious signs of impact were visible including overland flow and staining present in Zone 2. No staining observations were noted at PW16-1 or PW16-4 install stations. The drive point installation and porewater sampling methodology are provided in the following sections.

4.1 Drive Point Installation

The drive points consisted of a six inch Solinst stainless steel (no barb) drive point piezometer with multiple three foot stainless steel extensions (one inch diameter). The drive points were installed using a Solinst drive head assembly and a slide hammer was employed to drive the point into the shoreline. Coarse ground conditions in Zone 2 adjacent to the Site proved difficult to penetrate the sub-surface. The steep embankment and large boulder/rip rap material used to protect the roadway resulted in refusal of installation at several locations and the destruction of one drive point and extension.

Drive point depths were determined by adequate recharge of the sampling apparatus and recorded in the event one or more of the points were destroyed during the jökulhlaups. Upon completion of the installation and sampling events an NPT threaded cap was installed on the drive points and the stations were flagged with flagging tape for easy re-location. Location PW16-4 was removed from its station due to the higher likelihood of impact during the spring flood. The location was flagged on the shoreline for future events.

4.2 Porewater Sampling Methodology

Once below the water table (typically at a depth of approx. 0.75 m), dedicated high density polyethylene tubing was inserted into the drive point. Drive point stations were purged and sampled in accordance with Contaminated Sites Regulations (CSR) Protocol No.7 using a peristaltic pump and following the low flow method described in Section 4.5. The temperature difference between surface water (<1°C), and porewater (3°C to 4°C warmer than surface water) was used to confirm that representative porewater samples were being collected.

4.3 Porewater Field Observations

At each station, prior to sample retrieval, physical parameters (pH, temperature, conductivity, DO, ORP, and turbidity) were measured and recorded using a YSI Pro DSS. A sample was collected upon parameter stabilization. GPS coordinates and elevations were recorded from a handheld Delorme InrReach device at each station for future reference.

Table 4-B provides a summary of the Sample ID, Duplicate ID, Sample Date, GPS Spatial Data, and the physical parameters observed.

Table 4-B: Porewater Sampling – Field Observations

Sample ID	PW16-1	PW16-2	PW16-3	PW16-4
Duplicate ID	---	---	---	PW DUP 1
Sample Date	31-Oct-16	31-Oct-16	31-Oct-16	1-Nov-16
Northing	580824	580907	580930	581461
Easting	6511684	6511348	6511317	6510343
Elevation (m)	nm	39	37	36
Acc. (+/-)	nm	2	3	4
Temperature (˚C)	nm	5.4	6	3.2
pH	7.51	4.01	3.2	8.21
DO (mg/L)	10.52	11.52	12.04	123.62
Turbidity (NTU)	nm	nm	nm	nm
SPC (µS)	164.1	842	1245	133.1
Cond (µS)	115.6	528	796	77.8
ORP	164.1	385.9	541.3	238.2

Notes
nm - not monitored

Five porewater samples including one blind field duplicate (BFD) were placed in laboratory-prepared glass or plastic bottles, provided by Maxxam Analytics, and stored in a cooler with ice. Labelled samples and completed Chain-of-Custody forms were subsequently transported to the Maxxam Whitehorse Depot within laboratory required holding time for analysis. A copy of the laboratory Certificates of Analysis are also provided in Appendix B.

5.0 SURFACE WATER SAMPLING

From October 20, 2016 through November 2, 2016 SLR executed a surface water sampling program in Zone 1, Zone 2, Zone 3, and Zone 4 to assess the impact of the mine Site on the Tulsequah River ecosystem.

Table 5-A provides a summary of the Station ID, a description of the station location, and corresponding Photo ID. Photos are provided following the text and station locations are shown in Drawing 3 of the AERA report.

Table 5-A: Surface Water Sampling – Station Description

Station ID	Station Description	Photo ID
SW 16-0	30 m upstream of confluence of Dawn Creek in Tulsequah side channel	D-23
SW 16-1	Tulsequah River, upsteam of Dawn Creek side channel	D-24
SW 16-2	Main stem of the Tulsequah River, adjacent to Dawn Creek	D-25
SW 16-3	Upstream of Dawn Creek - Riffle area	D-26
SW 16-4	Where the overland flow from the pond crests the bank leading to the side channel	D-27
SW 16-5	Confluence of Exfiltrant overflow with Tulsequah side channel - mixing zone	D-28
SW 16-6	Confluence of side channel and main reach of Tulsequah River	D-29
SW 16-7	Split of mainstem and side channel, confluence with Exfiltration Pond	D-30
SW 16-8	Trauna Creek at NW corner of PAG - collects all sw flow off of mountain to east	D-31
SW 16-9	PAG discharge in side channel	D-32
SW 16-10	At pool below falls on Roger Creek - 80m from bridge	D-33
SW 16-11	100m E of Rogers Creek confluence, in creek	D-34
SW 16-12	At confluence of side channel from Main Site and mainstem	D-35
SW 16-13	Below confluence of Rogers Creek, in main stem, downstream of PAG site	D-36
SW 16-14	Downstream of PAG site	D-37
SW 16-15	In pond south of NAG site	D-38
SW 16-16	South of Rogers Slough, where drainage from slough ran to ground	D-39
SW 16-17	South end of slouth on eastern bank	D-40

A total of 20 surface water samples (including 2 BFD's) were collected by SLR field staff using a pole sampler or hand grab at each location. Surface water sampling locations were determined by confluences of side channels with the main stem, splits in the main stem or side channels, proximity to the Site, potentially impacted tributaries to the Tulsequah River, or by evidence of staining on the shoreline.

5.1 Surface Water Sampling Methodology

Collection of the sample was attained from the centre of the watercourse at approximately 20 cm below the surface in a well-mixed area. All samples were obtained upstream of any debris, log jams, or other water quality influencers. Water was then transferred to laboratory-supplied bottles for chemistry analysis. Samples were then labelled, placed in coolers and stored at appropriate temperature until shipment to Maxxam Analytics, Whitehorse along with completed chain of custody forms and within the acceptable sample holding times.

5.2 Surface Water Field Observations

At each station, prior to sample retrieval, depth of water was determined and physical parameters (pH, temperature, conductivity, DO, ORP, and turbidity) were measured and recorded using a YSI Pro DSS. A sample was collected at an upstream location. GPS coordinates and elevations were recorded from a handheld Delorme InReach device at each station location for future reference.

Table 5-B following the text provides a summary of the station and surface water sample ID, sediment sample ID, sample date, GPS spatial data, depth of water, and the physical parameters observed.

Table 5-B: Surface Water and Sediment Sampling – Field Observations

Station ID	SW 16-0	SW 16-1	SW 16-2	SW 16-3	SW 16-4	SW 16-5	SW 16-6	SW 16-7	SW 16-8	SW 16-9	SW 16-10	SW 16-11	SW 16-12	SW 16-13	SW 16-14	SW 16-15	SW 16-16	SW 16-17
Sediment Sample ID	---	SE 16-1	---	---	---	SE 16-5	---	---	---	---	---	---	SE 16-12	---	SE 16-14	SE 16-15	---	SE 16-17
Sample Date	2-Nov-16	30-Oct-16	30-Oct-16	2-Nov-16	1-Nov-16	30-Oct-16	30-Oct-16	30-Oct-16	1-Nov-16	1-Nov-16	2-Nov-16	1-Nov-16	1-Nov-16	1-Nov-16	1-Nov-16	2-Nov-16	1-Nov-16	1-Nov-16
Northing	580837	580237	580546	580262	580881	580926	580998	580845	581406	581397	581751	581524	581380	581345	581255	581620	581498	581664
Easting	6511653	6512380	6511792	6511796	6511402	6511307	6511142	6511170	6510709	6510423	6510414	6510343	6510181	6510135	6510064	6509934	6519109	6509247
Elevation (m)	41	nm	nm	42	46	nm	33	nm	46	44	47	51	37	nm	36	43	37	40
Acc. (+/-)	3	nm	nm	2	2	3	3	nm	8	1	27	8	2	nm	4	15	4	5
Depth of water (m)	0.4	0.7	0.35	0.35	0.15	0.55	0.65	0.45	0.2	0.5	0.5	0.2	0.6	0.3	0.4	0.3	0.3	0.3
Temperature (˚C)	3.9	1.8	1.7	3.2	3.3	4.5	2.3	1.8	3.2	3.7	1.8	1.4	1.6	3.1	1.5	3.9	6.2	3.8
pH	8.17	7.76	7.71	8.1	3.29	4.64	6.45	6.9	8.13	7.99	8.06	6.65	7.65	8.19	7.81	7.72	7.57	7.81
pH (mV)	-80.5	-58.2	-55.5	-76.8	6.65	110	12	-14.1	nm	-71	-74	nm	nm	-81.4	-60.8	-55.8	-48.5	-60.3
DO (mg/L)	12.91	13.06	13.13	12.97	13.25	11.61	12.7	12.9	12.91	11.36	13.6	13.25	13.32	11.33	13.13	8.32	5.05	10.36
Turbidity (NTU)	nm	100-140	40-60	1.3	40-50	40-50	75	58	1.8	3	1.2	0.9	1.2	16.1	40-60	3	4.2	5.4
SPC (µS)	140.3	82.4	101	143.2	561	506	109.7	103.8	111.5	153.7	128.4	128.4	128.6	130.8	111.3	119	247.1	53.9
Cond (µS)	83.8	46.5	56.1	83.5	9.7	307.5	62.2	57.8	65	91.1	71.4	76	71.2	76.1	61.4	71.1	158.2	32.1
ORP	139.5	293	211.6	190.8	509.5	383	386.8	359.2	214.8	264.8	184.5	342.8	321.2	253.3	225.4	210.1	39.6	235.9

Notes:
nm - not monitored

6.0 SEDIMENT SAMPLING

From October 30, 2016 through November 2, 2016 SLR executed a sediment sampling program in Zone 1, Zone 2, Zone 3, and Zone 4 corresponding to the surface water sampling stations to assess the impact of the mine Site on the lower trophic aquatic receptors in the Tulsequah River.

Table 6-A provides a summary of the Station ID in relation to the surface water station, station description, sediment sample ID, and corresponding photo ID. Photos are provided following the text and station locations are shown in Drawing 3 of the AERA report.

Table 6-A: Sediment Sampling – Station Description

Station ID	Station Description	Sediment Sample ID	Photo ID
SW 16-1	Tulsequah River, upstream of Dawn Creek side channel	SE 16-1	D-24
SW 16-5	Confluence of Exfiltrant overflow with Tulsequah side channel - mixing zone	SE 16-5	D-28
SW 16-12	At Confluence of side channel from Main Site and mainstem	SE 16-12	D-35
SW 16-14	Downstream of PAG site	SE 16-14	D-37
SW 16-15	In pond south of NAG site	SE 16-15	D-38
SW 16-17	South end of slouth on Eastern bank	SE 16-17	D-40

A total of 7 sediment samples were collected by SLR field staff using a pole sampler or hand grab at each location. Sediment sampling locations were located in conjunction with surface water samples determined by confluences of side channels with the main stem, splits in the main stem or side channels, proximity to the Site, potentially impacted tributaries to the Tulsequah River, or by evidence of staining on the shoreline.

6.1 Sediment Sampling Methodology

Sediment samples were obtained by removing the top 0.01-0.02m of debris to expose the underlying materials. Using a trowel or nitrile covered hand; the sample was retrieved from a depth of 0-0.15m below grade on the immediate shoreline of the waterbody or watercourse. GPS co-ordinates were obtained using a Delorme InReach device, the lithography was logged, and general site characteristics were noted.

6.2 Sediment Field Observations

At each station, the lithography was logged and general site characteristics were noted. GPS co-ordinates were taken in conjunction with surface water samples. In general at stations SW16-1, SW16-5, SW16-12, and SW16-14 the lithography was consistent across the sampling program. Alluvial deposits at water level in the Tulsequah River bed were consistently loose fine – medium grain sands. Sediment samples gathered from Station SW16-15 and SW16-17, located within Rogers Slough was dense, brown, moist, organic silt. Visual signs of yellow-orange staining were observed where sample SE16-5 was retrieved.

Table 6-A in the previous section provides a summary of the sediment sample ID, sample date, GPS spatial data, and the physical parameters observed during the corresponding surface water sampling.

7.0 LABORATORY ANALYSIS

On November 3, 2016, porewater, surface water and sediment samples were submitted to the Maxxam depot in Whitehorse, YT for analyses. Table 7-A presents a summary of the analytical parameters analysed for the two medias submitted. The analytical schedule followed previous monitoring programs as specified under the BC MOE water discharge permit.

Table 7-A: Summary of Analytical parameters

Media	Parameters
Pore Water and Surface Water	alkalinity, acidity, hardness, Total Suspended Solids (TSS), sulphate, total metals, and dissolved metals
Sediment	particle size, total organic carbon (TOC), total metals, and simultaneous extracted metals and acid volatile sulfide (SEM:AVS)

8.0 QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

SLR implemented a standardized corporate QA/QC program which outlines procedures for samples collected during the environmental investigation. Field and Lab QA/QC sheets were completed for all laboratory certificates of analysis received by SLR and are also presented with the respective laboratory reports in Appendix B.

8.1 Field Program QA/QC

Standard field QA/QC procedures were followed during the execution of the surface water monitoring program; porewater sampling program; surface water sampling program; and, sediment sampling program to prevent sample contamination. The field QA/QC procedure included:

- Cleaning sampling and monitoring equipment with Alconox and rinsing with distilled water prior to departing for the field;
- Using disposable powderless gloves during handling of all bottles and equipment;
- Using new gloves at each sampling site;
- Avoid touching the inner portion of the sample bottles and caps;
- Sampling in an order from sites of lowest suspected contamination to highest suspected contamination;
- Collecting water samples upstream of stream discharge measurements;
- Working from a downstream to an upstream direction when taking multiple samples from the same watercourse;
- Collecting samples below the surface to avoid any surface film;
- Avoiding disturbance to the bottom sediment of the watercourse;
- Rinsing the collection jars three times before decanting the sample;
- Field filtering the dissolved metal samples using a dedicated disposable syringe;
- Sealing together the water quality samples in a Ziploc bag to prevent any possible cross-contamination to other samples while in transportation;
- Storing all samples with ice packs in a cooler until receipt at the laboratory;
- Ensure that water quality samples remain upright and secured in the cooler, and the cooler sealed with tap prior to shipping;

- Complete the chain-of-custody (COC) form with the water quality samples to the analytical laboratory for analysis; and
- Shipping the samples to the laboratory as quickly as possible to ensure hold times are met and to prevent deterioration of the water quality samples.

8.1.1 Duplicate Sampling

Blind field duplicate samples were collected and submitted for laboratory analysis during the monitoring program. The relative percent difference (RPD – the absolute difference between the two values, divided by the mean) of duplicate analyses is used to evaluate the sample result variability. Where the concentration of a parameter is less than five times the laboratory method detection limit (LMDL), the results are less quantifiable and the RPD is not reliable.

The calculated RPD values were compared to QA/QC program guidelines to evaluate the sample result variability. The guidelines for the following parameters: general chemistry and inorganics, salinity, other parameters, total metals, and dissolved metals have been recommended by the BC Environmental Laboratory Quality Assurance Advisory Committee to the BC MOE.

Two duplicate surface water samples and one duplicate porewater samples were collected by SLR and submitted for analysis during the environmental monitoring program. RPD calculations for the parameters analysed during this event are presented in Tables B-11 through B-15.

8.1.2 Duplicate Sample QA/QC

RPD values calculated pH. hardness, conductivity, alkalinity, total suspended solids, aluminum, antimony, arsenic, barium, calcium, cadmium, cobalt, copper, iron, lead, magnesium, manganese, nickel, silver, strontium, sulphur, sulphate, thallium, titanium, uranium, and zinc outside of the SLR QA/QC program guidelines. SLR inquired with Maxxam as to reasons why these RPD values were so high. Maxxam responded that these differences were likely attributed to sample matrix heterogeneity. Hold times and arrival temperatures were within guidelines. SLR's review of sample integrity indicates the data were reproducible and representative of field conditions. Overall data quality for water samples was deemed acceptable.

Sampling at stations SW16-4 and SW16-5 was conducted in Zone 2 where groundwater, over flow surface water from the Exfiltration Pond, and Tulsequah River side channel surface water was mixing. The frigid water conditions and number of samples bottles retrieved may have contributed to the RPD discrepancy.

SLR's review of sample integrity indicates the data were reproducible and representative of field conditions. Overall data quality for water samples was deemed acceptable.

8.2 Laboratory QA/QC

Samples were analyzed by Maxxam, a BC MOE laboratory accredited by the Canadian Association for Laboratory Accreditation that uses BC recognized methods to conduct laboratory analyses. As conveyed by the laboratories, method blanks, control standards samples, certified reference material standards, method spikes, replicates, duplicates and instrument blanks are routinely analyzed as part of their QA/QC programs. Copies of laboratory certificates of analysis are also presented in Appendix B.

SLR reviewed the laboratory QA/QC data for the submissions. Laboratory QA/QC results indicated that the data fell within the acceptable ranges for method blanks, certified reference materials, method spikes, duplicates, surrogates and laboratory control samples. For CSR Total Metals in Water - the LMDL was raised due to sample matrix interference for two samples (PW16-2 and SW16-4). All results were qualified by Maxxam indicating that the data were reproducible and representative of field conditions.

TABLE B1. SEDIMENT ANALYTICAL RESULTS - SALINITY AND INORGANIC (NON-METAL) PARAMETERS (mg/kg)

Sample ID	Location	Date	pH	Calcium	Magnesium	Potassium	Sodium	Phosphorus	Sodium	Sulphide
SE16-1	reference - main	31-Oct-2016	7.35	4010	5260	1410	< 100	580	< 100	3.14
SE16-5	impacted - ZOD	31-Oct-2016	5.53	3550	6450	1040	< 100	489	< 100	0.63
SE16-12	impacted - near	01-Nov-2016	8.95	24000	14300	685	155	888	155	2.25
SE16-14	impacted - near	01-Nov-2016	8.80	9050	6400	1120	171	543	171	1.27
SE16-15	impacted - near, tributary	02-Nov-2016	6.28	8260	10900	1440	347	971	347	71.0
SE16-17	impacted - far, tributary	01-Nov-2016	6.22	6470	11100	1010	363	726	363	0.92

Notes:
mg/kg - milligrams per kilogram
< - less than analytical detection limit indicated
"---" - sample not analyzed for parameter indicated

TABLE B2. SEDIMENT ANALYTICAL RESULTS - GRAINSIZE PARAMETERS

Sample ID	ID	Date	Moisture (%)	Sand (%)	Silt (%)	Clay (%)	Gravel (%)
SE16-1	reference - main	31-Oct-2016	15	98	< 2.0	< 2.0	---
SE16-5	impacted - ZOD	31-Oct-2016	16	95	4.0	< 2.0	---
SE16-12	impacted - near	01-Nov-2016	12	96	3.7	< 2.0	---
SE16-14	impacted - near	01-Nov-2016	17	82	16	2.1	---
SE16-15	impacted - near, tributary	02-Nov-2016	77	13	78	8.3	---
SE16-17	impacted - far, tributary	01-Nov-2016	48	20	68	12	---

Notes:
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated

TABLE B3. SEDIMENT ANALYTICAL RESULTS - METALS PARAMETERS (mg/kg)

Sample ID	ID	Date	Depth (m)	pH	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cadmium	Calcium	Chromium (total)	Cobalt
SE16-1	reference - main	31-Oct-2016	surficial	7.35	7190	0.20	4.09	62.1	< 0.40	< 0.10	0.131	4010	15.5	5.70
SE16-5	impacted - ZOD	31-Oct-2016	surficial	5.53	9090	1.70	19.6	95.5	< 0.40	0.74	1.45	3550	26.0	6.93
SE16-12	impacted - near	01-Nov-2016	surficial	8.95	16000	1.01	12.4	48.3	< 0.40	< 0.10	0.214	24000	43.6	13.6
SE16-14	impacted - near	01-Nov-2016	surficial	8.80	7440	7.94	17.0	97.6	< 0.40	0.11	0.557	9050	22.0	7.18
SE16-15	impacted - near, tributary	02-Nov-2016	surficial	6.28	15600	2.14	30.7	115	< 0.40	0.27	0.692	8260	41.9	13.4
SE16-17	impacted - far, tributary	01-Nov-2016	surficial	6.22	17600	0.95	15.9	159	< 0.40	0.31	0.447	6470	49.0	13.8
CSR SDft			ns	ns	ns	ns	20	ns	ns	ns	4.2	ns	110	ns
CSR SDfs			ns	ns	ns	ns	11	ns	ns	ns	2.2	ns	56	ns

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE B3. SEDIMENT ANALYTICAL RESULTS - METALS PARAMETERS (mg/kg)

Sample ID	ID	Date	Depth (m)	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Potassium
SE16-1	reference - main	31-Oct-2016	surficial	18.9	15400	3.31	8.9	5260	273	< 0.050	0.89	10.8	580	1410
SE16-5	impacted - ZOD	31-Oct-2016	surficial	345	18600	35.7	10.7	6450	279	0.067	2.72	23.3	489	1040
SE16-12	impacted - near	01-Nov-2016	surficial	31.7	30700	2.81	17.5	14300	623	< 0.050	0.42	33.3	888	685
SE16-14	impacted - near	01-Nov-2016	surficial	45.8	17800	6.81	10.9	6400	327	0.097	2.23	26.5	543	1120
SE16-15	impacted - near, tributary	02-Nov-2016	surficial	60.8	23000	14.1	14.1	10900	366	< 0.050	2.47	33.1	971	1440
SE16-17	impacted - far, tributary	01-Nov-2016	surficial	59.0	31000	15.6	14.6	11100	599	< 0.050	1.78	31.7	726	1010
CSR SDft			ns	240	ns	110	ns	ns	ns	0.58	ns	ns	ns	ns
CSR SDfs			ns	120	ns	57	ns	ns	ns	0.3	ns	ns	ns	ns

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE B3. SEDIMENT ANALYTICAL RESULTS - METALS PARAMETERS (mg/kg)

Sample ID	ID	Date	Depth (m)	Selenium	Silver	Sodium	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Zirconium
SE16-1	reference - main	31-Oct-2016	surficial	< 0.50	0.073	< 100	19.8	0.088	0.15	422	0.613	38.0	40.3	< 0.50
SE16-5	impacted - ZOD	31-Oct-2016	surficial	< 0.50	0.159	< 100	22.2	0.243	0.21	410	1.57	35.8	282	0.55
SE16-12	impacted - near	01-Nov-2016	surficial	< 0.50	0.067	155	49.1	< 0.050	0.22	898	0.306	56.2	70.0	1.13
SE16-14	impacted - near	01-Nov-2016	surficial	< 0.50	0.094	171	37.7	0.165	0.20	383	0.777	38.3	92.7	0.50
SE16-15	impacted - near, tributary	02-Nov-2016	surficial	0.97	0.278	347	39.6	0.132	0.41	1110	2.77	65.5	110	1.66
SE16-17	impacted - far, tributary	01-Nov-2016	surficial	< 0.50	0.162	363	33.2	0.134	0.45	1120	1.92	77.3	94.5	1.65
CSR SDft			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	380	ns
CSR SDfs			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	200	ns

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE B4. SEDIMENT ANALYTICAL RESULTS - AVS/SEM PARAMETERS (umole/g)

Sample ID	ID	Date	SEM:AVS Ratio	Acid Volatile Sulphide	SEM Cadmium (Cd)	SEM Copper (Cu)	SEM Lead (Pb)	SEM Mercury (Hg)	SEM Nickel (Ni)	SEM Zinc (Zn)
SE16-1	reference - main	31-Oct-2016	13	0.098	0.00172	0.262	0.0161	< 0.00030	0.204	0.823
SE16-5	impacted - ZOD	31-Oct-2016	255	0.02	0.00794	2.14	0.0733	0.00039	0.209	2.66
SE16-12	impacted - near	01-Nov-2016	25	0.07	0.00205	0.362	0.0129	< 0.00030	0.326	1.08
SE16-14	impacted - near	01-Nov-2016	54	0.039	0.00354	0.374	0.0192	< 0.00030	0.272	1.44
SE16-15	impacted - near, tributary	02-Nov-2016	0.55	2.22	0.00151	0.245	0.0201	< 0.00030	0.148	0.806
SE16-17	impacted - far, tributary	01-Nov-2016	75	0.029	0.00279	0.63	0.0514	< 0.00030	0.328	1.17
CSR SDft				ns	ns	ns	ns	ns	ns	ns
CSR SDfs				ns	ns	ns	ns	ns	ns	ns

Notes:
umole/g - micrograms per mole
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
SEM:AVS ratio is calculated as the sum of SEM for an analyte divided by the AVS concentration - all units umole/g dry weight
SEM:AVS ratio > 1

TABLE B5. WATER ANALYTICAL RESULTS - GENERAL CHEMISTRY AND INORGANICS (mg/L)

Sample ID	Location	Date	pH	Hardness	Conductivity	Alkalinity (total as CACO23)	Total Suspended Solids (TSS)	Dissolved Sulphur	Dissolved Sulphate
Porewater									
PW16-1	reference, tributary	31-Oct-2016	7.91	80.5	155	74.4	367	< 3.0	9.25
PW16-2	impacted - ZOD	31-Oct-2016	**3.93**	275	835	< 0.50	247	131	394
PW16-3	impacted - ZOD	31-Oct-2016	**3.15**	269	1180	< 0.50	102	162	**542**
PW16-4	impacted - near, tributary	01-Nov-2016	7.87	75.5	131	54.4	124	3.7	14.2
PW DUP1	impacted - near	01-Nov-2016	7.86	66.5	131	51.9	78.8	4.3	14.1
Surface Water									
SW16-0	reference - tributary	02-Nov-2016	7.91	64.2	135	61.8	< 1.0	< 3.0	7.54
SW16-1	reference - main	31-Oct-2016	7.60	41.7	85.8	32.2	31.4	3.6	12.3
SW16-2	reference - main	31-Oct-2016	7.44	50.9	97.0	35.2	36.8	4.6	15.1
SW16-3	reference - main	02-Nov-2016	7.66	62.1	141	43.1	< 1.0	6.3	23.6
SW16-4	impacted - ZOD	01-Nov-2016	**3.30**	228	905	< 0.50	23.6	120	373
SW16-DUP2	impacted - ZOD	01-Nov-2016	**3.31**	237	901	< 0.50	90.0	139	368
SW16-5	impacted - ZOD	31-Oct-2016	7.23	107	196	30.2	35.5	33.2	64.2
SW16-DUP1	impacted - ZOD	31-Oct-2016	**4.73**	157	449	< 0.50	39.0	61.3	194
SW16-6	impacted - ZOD	31-Oct-2016	7.65	51.3	105	35.6	36.5	5.0	16.9
SW16-7	impacted - ZOD	31-Oct-2016	7.65	45.9	102	36.9	38.4	4.6	15.5
SW16-8	impacted - near	02-Nov-2016	7.79	51.5	111	47.3	< 1.0	< 3.0	9.80
SW16-9	impacted - near	01-Nov-2016	7.86	71.1	150	55.3	< 1.0	5.3	18.5
SW16-10	impacted - near, tributary	02-Nov-2016	7.82	59.6	124	51.2	< 1.0	3.8	14.2
SW16-11	impacted - near, tributary	01-Nov-2016	7.70	58.4	123	48.4	< 1.0	4.2	13.2
SW16-12	impacted - near	01-Nov-2016	7.69	58.1	126	49.0	2.6	4.1	14.1
SW16-13	impacted - near	01-Nov-2016	7.70	50.8	119	41.3	10.1	5.6	18.2
SW16-14	impacted - near	01-Nov-2016	7.66	56.3	108	37.6	35.9	5.5	16.3
SW16-15	impacted - near, tributary	02-Nov-2016	7.60	56.4	116	56.8	1.0	< 3.0	7.00
SW16-16	impacted - far	01-Nov-2016	8.06	124	244	126	6.7	< 3.0	3.02
SW16-17	impacted - far, tributary	01-Nov-2016	7.25	24.0	54.0	24.8	4.0	< 3.0	2.67
CSR AWF			ns	ns	ns	ns	ns	ns	1000
BCWWQfw			ns	ns	ns	**Check Note**	ns	ns	ns
BCWQ AFWmg			>6.5<=9.0	ns	ns	ns	ns	ns	ns
BCWQ AFWg			>6.5<=9.0	ns	ns	ns	ns	ns	128@H<=30 218@H>30<=75 309@H>75<=180 429@H>180

Notes:
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life
Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B6. WATER ANALYTICAL RESULTS - SALINITY PARAMETERS (mg/L)

Sample ID	Location	Date	pH	Calcium	Dissolved Calcium	Magnesium	Dissolved Magnesium	Potassium	Dissolved Potassium	Sodium	Dissolved Sodium
Porewater											
PW16-1	reference, tributary	31-Oct-2016	7.91	29.9	28.2	1.41	1.22	0.720	0.637	0.944	0.821
PW16-2	impacted - ZOD	31-Oct-2016	**3.93**	93.5	84.2	10.2	8.47	1.67	1.30	4.27	3.36
PW16-3	impacted - ZOD	31-Oct-2016	**3.15**	85.5	82.1	13.4	12.8	1.18	1.07	4.39	4.17
PW16-4	impacted - near, tributary	01-Nov-2016	7.87	26.4	20.3	2.33	1.23	0.534	0.313	0.959	0.732
PW DUP1	impacted - near	01-Nov-2016	7.86	23.2	22.1	2.08	1.39	0.498	0.361	0.840	0.832
Surface Water											
SW16-0	reference - tributary	02-Nov-2016	7.91	24.5	23.4	0.744	0.685	0.411	0.367	0.755	0.723
SW16-1	reference - main	31-Oct-2016	7.60	12.9	11.3	2.33	1.28	1.41	0.968	0.922	0.733
SW16-2	reference - main	31-Oct-2016	7.44	15.6	15.0	2.90	1.57	1.23	0.789	0.874	1.15
SW16-3	reference - main	02-Nov-2016	7.66	19.9	17.2	3.05	2.72	1.56	1.30	1.27	1.15
SW16-4	impacted - ZOD	01-Nov-2016	**3.30**	77.2	67.6	8.54	7.59	1.01	0.864	4.06	3.34
SW16-DUP2	impacted - ZOD	01-Nov-2016	**3.31**	80.6	90.5	8.71	8.38	1.06	1.03	3.69	4.19
SW16-5	impacted - ZOD	31-Oct-2016	7.23	37.1	34.4	3.52	3.40	1.09	1.12	2.07	2.21
SW16-DUP1	impacted - ZOD	31-Oct-2016	**4.73**	52.9	47.3	6.08	4.54	1.29	0.921	2.55	2.16
SW16-6	impacted - ZOD	31-Oct-2016	7.65	16.3	14.7	2.57	1.55	1.20	0.788	0.923	0.731
SW16-7	impacted - ZOD	31-Oct-2016	7.65	14.3	14.0	2.46	1.51	1.11	0.769	0.827	0.689
SW16-8	impacted - near	02-Nov-2016	7.79	19.5	18.9	0.656	0.611	0.331	0.297	0.732	0.668
SW16-9	impacted - near	01-Nov-2016	7.86	25.5	22.3	1.81	1.65	0.988	0.849	0.803	1.11
SW16-10	impacted - near, tributary	02-Nov-2016	7.82	21.5	19.0	1.41	1.17	0.332	0.277	0.820	0.714
SW16-11	impacted - near, tributary	01-Nov-2016	7.70	21.1	20.4	1.36	1.34	0.315	0.335	0.804	1.28
SW16-12	impacted - near	01-Nov-2016	7.69	21.2	20.7	1.28	1.34	0.320	0.332	0.754	0.858
SW16-13	impacted - near	01-Nov-2016	7.70	17.2	18.2	1.89	1.73	0.910	0.911	0.736	1.19
SW16-14	impacted - near	01-Nov-2016	7.66	17.9	15.7	2.83	1.82	1.33	0.925	1.05	1.29
SW16-15	impacted - near, tributary	02-Nov-2016	7.60	21.1	18.6	0.882	0.767	0.552	0.483	1.23	1.12
SW16-16	impacted - far	01-Nov-2016	8.06	45.4	39.6	2.52	2.23	1.23	1.04	1.25	1.15
SW16-17	impacted - far, tributary	01-Nov-2016	7.25	8.63	8.34	0.598	0.599	0.587	0.634	0.737	1.36
CSR AWF			ns	ns	ns	ns	ns	ns	ns	ns	ns
BCWWQfw			ns	ns	ns	ns	ns	373	ns	ns	ns
BCWQ AFWmg			>6.5<=9.0	ns	ns	ns	ns	ns	ns	ns	ns
BCWQ AFWg			>6.5<=9.0	ns	ns	ns	ns	ns	ns	ns	ns

Notes:
mg/L - milligrams per litre
< - less than analytical detection limit indicated
"---" - sample not analyzed for parameter indicated
ns - no standard listed
CSR AWF/10: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life
BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B7. WATER ANALYTICAL RESULTS - OTHER PARAMETERS (mg/L)

Sample ID	Location	Date	pH	Hardness	Conductivity	Alkalinity	Suspended Solids (	Dissolved Calcium	Dissolved Iron	Dissolved Magnesium	Dissolved Manganese	Dissolved Potassium	Dissolved Sodium
PW16-1	reference, tributary	31-Oct-2016	7.91	80.5	155	74.4	367	28.2	0.0255	1.22	<0.001	0.637	0.821
PW16-2	impacted - ZOD	31-Oct-2016	**3.93**	275	835	< 0.50	247	84.2	0.143	8.47	0.522	1.30	3.36
PW16-3	impacted - ZOD	31-Oct-2016	**3.15**	269	1180	< 0.50	102	82.1	2.6	12.8	0.71	1.07	4.17
PW16-4	impacted - near, tributary	01-Nov-2016	7.87	75.5	131	54.4	124	20.3	<0.005	1.23	0.0012	0.313	0.732
PW DUP1	impacted - near	01-Nov-2016	7.86	66.5	131	51.9	78.8	22.1	<0.005	1.39	0.0012	0.361	0.832
SW16-0	reference - tributary	02-Nov-2016	7.91	64.2	135	61.8	< 1.0	23.4	0.0137	0.685	0.0017	0.367	0.723
SW16-1	reference - main	31-Oct-2016	7.60	41.7	85.8	32.2	31.4	11.3	0.0131	1.28	0.0037	0.968	0.733
SW16-2	reference - main	31-Oct-2016	7.44	50.9	97.0	35.2	36.8	15.0	0.0065	1.57	0.0125	0.789	1.15
SW16-3	reference - main	02-Nov-2016	7.66	62.1	141	43.1	< 1.0	17.2	<0.005	2.72	<0.001	1.30	1.15
SW16-4	impacted - ZOD	01-Nov-2016	**3.30**	228	905	< 0.50	23.6	67.6	6.3	7.59	0.429	0.864	3.34
SW16-DUP2	impacted - ZOD	01-Nov-2016	**3.31**	237	901	< 0.50	90.0	90.5	7.54	8.38	0.478	1.03	4.19
SW16-5	impacted - ZOD	31-Oct-2016	7.23	107	196	30.2	35.5	34.4	0.385	3.40	0.107	1.12	2.21
SW16-DUP1	impacted - ZOD	31-Oct-2016	**4.73**	157	449	< 0.50	39.0	47.3	0.319	4.54	0.21	0.921	2.16
SW16-6	impacted - ZOD	31-Oct-2016	7.65	51.3	105	35.6	36.5	14.7	0.0347	1.55	0.0124	0.788	0.731
SW16-7	impacted - ZOD	31-Oct-2016	7.65	45.9	102	36.9	38.4	14.0	0.0095	1.51	0.0107	0.769	0.689
SW16-8	impacted - near	02-Nov-2016	7.79	51.5	111	47.3	< 1.0	18.9	<0.005	0.611	<0.001	0.297	0.668
SW16-9	impacted - near	01-Nov-2016	7.86	71.1	150	55.3	< 1.0	22.3	<0.005	1.65	0.0052	0.849	1.11
SW16-10	impacted - near, tributary	02-Nov-2016	7.82	59.6	124	51.2	< 1.0	19.0	<0.005	1.17	<0.001	0.277	0.714
SW16-11	impacted - near, tributary	01-Nov-2016	7.70	58.4	123	48.4	< 1.0	20.4	<0.005	1.34	<0.001	0.335	1.28
SW16-12	impacted - near	01-Nov-2016	7.69	58.1	126	49.0	2.6	20.7	<0.005	1.34	<0.001	0.332	0.858
SW16-13	impacted - near	01-Nov-2016	7.70	50.8	119	41.3	10.1	18.2	<0.005	1.73	0.0048	0.911	1.19
SW16-14	impacted - near	01-Nov-2016	7.66	56.3	108	37.6	35.9	15.7	<0.005	1.82	0.0129	0.925	1.29
SW16-15	impacted - near, tributary	02-Nov-2016	7.60	56.4	116	56.8	1.0	18.6	0.171	0.767	0.022	0.483	1.12
SW16-16	impacted - far	01-Nov-2016	8.06	124	244	126	6.7	39.6	0.278	2.23	0.69	1.04	1.15
SW16-17	impacted - far, tributary	01-Nov-2016	7.25	24.0	54.0	24.8	4.0	8.34	0.373	0.599	0.0254	0.634	1.36
CSR AWF			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BCWWQfw			ns	ns	ns	**Check Note**	ns	**Check Note**	ns	ns	ns	ns	ns
BCWQ AFWmg			>6.5<=9.0	ns	ns	ns	ns	ns	0.35	ns	**Check Note**	ns	ns
BCWQ AFWg			>6.5<=9.0	ns	ns	ns	ns	ns	ns	ns	**Check Note**	ns	ns

Notes:
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life
Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aqu
Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)
Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B8. WATER ANALYTICAL RESULTS - TOTAL METALS (ug/L)

Sample ID	Location	Date	pH	Hardness (mg/L)	Aluminum	Antimony	Arsenic	Barium	Bismuth	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt
PW16-1	reference, tributary	31-Oct-2016	7.91	80.5	35.5	0.99	1.65	26.2	<1	<0.1	<50	0.026	29900	<1	<0.5
PW16-2	impacted - ZOD	31-Oct-2016	**3.93**	275	**14100**	<1	2.04	17	<2	0.45	<100	**229**	93500	<2	**11.7**
PW16-3	impacted - ZOD	31-Oct-2016	**3.15**	269	**23200**	0.52	2.72	61.3	<1	0.62	<50	**195**	85500	7	**15**
PW16-4	impacted - near, tributary	01-Nov-2016	7.87	75.5	**1090**	<0.5	**5.52**	30.8	<1	<0.1	<50	0.022	26400	2.6	0.92
PW DUP1	impacted - near	01-Nov-2016	7.86	66.5	**1020**	<0.5	4.96	26.7	<1	<0.1	<50	0.016	23200	2.4	0.79
SW16-0	reference - tributary	02-Nov-2016	7.91	64.2	20.3	1.05	1.88	15.5	<1	<0.1	<50	**0.54**	24500	<1	<0.5
SW16-1	reference - main	31-Oct-2016	7.6	41.7	**2230**	<0.5	1.35	48.9	<1	<0.1	<50	0.033	12900	3.7	1.17
SW16-2	reference - main	31-Oct-2016	7.44	50.9	**1980**	<0.5	1.63	50.4	<1	<0.1	<50	0.045	15600	3.7	1.41
SW16-3	reference - main	02-Nov-2016	7.66	62.1	30.6	<0.5	0.22	42.5	<1	<0.1	<50	<0.01	19900	<1	<0.5
SW16-4	impacted - ZOD	01-Nov-2016	**3.3**	228	**11500**	3	**80.6**	26.9	<2	0.37	<100	**211**	77200	<2	**9.4**
SW16-DUP2	impacted - ZOD	01-Nov-2016	**3.31**	237	**12200**	6.33	**151**	35.5	<1	0.44	<50	**217**	80600	2.3	**9.7**
SW16-5	impacted - ZOD	31-Oct-2016	7.23	107	**2530**	0.66	**7.78**	27.1	<1	<0.1	<50	**51**	37100	<1	2.19
SW16-DUP1	impacted - ZOD	31-Oct-2016	**4.73**	157	**6710**	1.46	**23.2**	56.2	<1	0.21	<50	**96.4**	52900	3.9	**6**
SW16-6	impacted - ZOD	31-Oct-2016	7.65	51.3	**1650**	<0.5	1.46	46.5	<1	<0.1	<50	**0.562**	16300	3.2	1.14
SW16-7	impacted - ZOD	31-Oct-2016	7.65	45.9	**2160**	<0.5	1.46	53.9	<1	<0.1	<50	**0.361**	14300	3.5	1.15
SW16-8	impacted - near	02-Nov-2016	7.79	51.5	16.5	0.5	1.9	13.7	<1	<0.1	<50	<0.01	19500	<1	<0.5
SW16-9	impacted - near	01-Nov-2016	7.86	71.1	45	0.55	0.85	36	<1	<0.1	<50	0.106	25500	<1	<0.5
SW16-10	impacted - near, tributary	02-Nov-2016	7.82	59.6	**148**	<0.5	4.92	17.5	<1	<0.1	<50	**2.25**	21500	<1	<0.5
SW16-11	impacted - near, tributary	01-Nov-2016	7.7	58.4	27.5	<0.5	4.19	17.3	<1	<0.1	<50	<0.01	21100	<1	<0.5
SW16-12	impacted - near	01-Nov-2016	7.69	58.1	28.7	<0.5	3.93	16.4	<1	<0.1	<50	<0.01	21200	<1	<0.5
SW16-13	impacted - near	01-Nov-2016	7.7	50.8	**719**	<0.5	0.96	35.5	<1	<0.1	<50	**0.325**	17200	1.3	<0.5
SW16-14	impacted - near	01-Nov-2016	7.66	56.3	**1670**	<0.5	1.51	48.7	<1	<0.1	<50	**0.801**	17900	2.9	1.18
SW16-15	impacted - near, tributary	02-Nov-2016	7.6	56.4	25.4	<0.5	**8**	11.8	<1	<0.1	<50	<0.01	21100	<1	<0.5
SW16-16	impacted - far	01-Nov-2016	8.06	124	3.9	<0.5	2.38	88.1	<1	<0.1	<50	0.092	45400	<1	<0.5
SW16-17	impacted - far, tributary	01-Nov-2016	7.25	24	51.7	<0.5	1.77	26.8	<1	<0.1	<50	<0.01	8630	<1	<0.5
CSR AWF		ns	ns	ns	200	50	10000	ns	53	50000	0.1@H<30 0.3@H>=30<90 0.5@H>=90<150 0.6@H>=150<210 0.8@H>=210<270 0.9@H>=270<330 1.1@H>=330<390 1.2@H>=390<450 1.3@H>=450<500	ns	10	40
BCWWQfw		ns	ns	ns	9	ns	5000	ns	0.13	ns	ns	Refer to Footnotes Tab	8.9 (5); 1 (3)	ns
BCWQ AFWg		>6.5<=9.0	ns	Refer to Footnotes Tab	ns	5	ns	ns	ns	1200	Refer to Guideline Calculations Tab	ns	ns	4

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
H - Hardness (as CaCO3)
CL - chloride
WAD - weak acid dissociable
< - less than analytical detection limit
'---' - sample not analyzed for parameter indicated
ns - no standard listed

Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life

Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life

Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)

Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B8. WATER ANALYTICAL RESULTS - TOTAL METALS (ug/L)

Sample ID	Location	Date	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Mn guideline	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium
PW16-1	reference, tributary	31-Oct-2016	2.36	61	<0.2	<5	1410	2.3	959	<1	<1	720	0.13	<0.02	944
PW16-2	impacted - ZOD	31-Oct-2016	**11500**	252	**172**	15	10200	617	1815	<2	18.5	1670	<0.2	<0.04	4270
PW16-3	impacted - ZOD	31-Oct-2016	**8730**	3880	**116**	20.4	13400	748	1789	<1	25.1	1180	0.3	0.188	4390
PW16-4	impacted - near, tributary	01-Nov-2016	**4.75**	1680	0.39	<5	2330	65.2	937	<1	2.3	534	0.34	<0.02	959
PW DUP1	impacted - near	01-Nov-2016	**2.95**	1540	0.28	<5	2080	47.6	898	<1	2.1	498	0.35	<0.02	840
SW16-0	reference - tributary	02-Nov-2016	**7.56**	<10	<0.2	<5	744	<1	887	<1	<1	411	0.1	<0.02	755
SW16-1	reference - main	31-Oct-2016	**4.31**	2450	1.24	<5	2330	53.9	788	2.3	4.5	1410	0.2	<0.02	922
SW16-2	reference - main	31-Oct-2016	**5.11**	2820	1.5	<5	2900	71.5	829	1.9	5.5	1230	0.19	<0.02	874
SW16-3	reference - main	02-Nov-2016	<0.5	25	<0.2	<5	3050	1.1	878	2.5	<1	1560	0.49	<0.02	1270
SW16-4	impacted - ZOD	01-Nov-2016	**9710**	18300	**142**	<10	8540	474	1608	<2	13	1010	0.22	<0.04	4060
SW16-DUP2	impacted - ZOD	01-Nov-2016	**9920**	42500	**157**	13.3	8710	488	1648	<1	13.9	1060	0.36	0.214	3690
SW16-5	impacted - ZOD	31-Oct-2016	2240	2360	**30.6**	5.1	3520	121	1076	2.1	3.4	1090	0.29	<0.02	2070
SW16-DUP1	impacted - ZOD	31-Oct-2016	**4430**	8060	**68.2**	6.9	6080	303	1296	1.9	12.8	1290	0.48	0.087	2550
SW16-6	impacted - ZOD	31-Oct-2016	**22.4**	2310	1.33	<5	2570	56.6	831	2	4.4	1200	0.24	<0.02	923
SW16-7	impacted - ZOD	31-Oct-2016	**17.7**	2470	1.48	<5	2460	59.4	807	2.1	4.6	1110	0.22	<0.02	827
SW16-8	impacted - near	02-Nov-2016	<0.5	<10	<0.2	<5	656	<1	832	<1	<1	331	0.21	<0.02	732
SW16-9	impacted - near	01-Nov-2016	1.07	61	<0.2	<5	1810	6.9	918	1.8	<1	988	0.23	<0.02	803
SW16-10	impacted - near, tributary	02-Nov-2016	**105**	218	1.59	<5	1410	6.1	867	<1	<1	332	0.36	<0.02	820
SW16-11	impacted - near, tributary	01-Nov-2016	<0.5	12	<0.2	<5	1360	<1	862	<1	<1	315	0.36	<0.02	804
SW16-12	impacted - near	01-Nov-2016	<0.5	19	<0.2	<5	1280	1.2	861	<1	<1	320	0.37	<0.02	754
SW16-13	impacted - near	01-Nov-2016	**11.6**	815	0.51	<5	1890	20.8	829	2	1.7	910	0.26	<0.02	736
SW16-14	impacted - near	01-Nov-2016	**30.5**	2250	1.45	<5	2830	58.6	853	2.3	4.4	1330	0.24	<0.02	1050
SW16-15	impacted - near, tributary	02-Nov-2016	<0.5	332	<0.2	<5	882	26	853	<1	<1	552	<0.1	<0.02	1230
SW16-16	impacted - far	01-Nov-2016	0.77	654	<0.2	<5	2520	745	1151	1.3	1.2	1230	<0.1	<0.02	1250
SW16-17	impacted - far, tributary	01-Nov-2016	1.41	872	0.25	<5	598	26.1	711	<1	<1	587	<0.1	<0.02	737
CSR AWF			20@H<50 30@H>=50<75 40@H>=75<100 50@H>=100<125 60@H>=125<150 70@H>=150<175 80@H>=175<200 90@H>=200	ns	40@H<50 50@H>=50<100 60@H>=100<200 110@H>=200<300 160@H>=300	ns	ns	ns		10000	250@H<60 650@H>=60<120 1100@H>=120<180 1500@H>=180	ns	10	0.5@H<=100 15@H>100	ns
BCWWQfw			ns	ns	ns	ns	ns	ns		ns	25@H>0<=60 65@H>60<=120 110@H>120<=180 150@H>180	373000	ns	ns	ns
BCWQ AFWg			Refer to Guideline Calculations Tab	ns	Refer to Guideline Calculations Tab	ns	ns	Refer to Footnotes Tab		1000	ns	ns	2	0.05@H<=100 1.5@H>100	ns

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
H - Hardness (as CaCO3)
CL - chloride
WAD - weak acid dissociable
< - less than analytical detection limit
'---' - sample not analyzed for parameter indicated
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Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life

Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life

Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)

Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B8. WATER ANALYTICAL RESULTS - TOTAL METALS (ug/L)

Sample ID	Location	Date	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Zirconium
PW16-1	reference, tributary	31-Oct-2016	79	<0.05	<5	<5	0.18	<5	5.2	<0.5
PW16-2	impacted - ZOD	31-Oct-2016	443	<0.1	<10	<10	7.9	<10	**64000**	<1
PW16-3	impacted - ZOD	31-Oct-2016	342	0.313	<5	16.5	6.22	<5	**54400**	<0.5
PW16-4	impacted - near, tributary	01-Nov-2016	82.8	<0.05	<5	37.1	0.46	<5	<5	<0.5
PW DUP1	impacted - near	01-Nov-2016	76.3	<0.05	<5	42.4	0.43	<5	<5	<0.5
SW16-0	reference - tributary	02-Nov-2016	60	<0.05	<5	<5	0.11	<5	**98.7**	<0.5
SW16-1	reference - main	31-Oct-2016	62.7	<0.05	<5	96.3	0.47	5.4	**9.2**	<0.5
SW16-2	reference - main	31-Oct-2016	82.4	<0.05	<5	96.6	0.54	5.6	**10.6**	<0.5
SW16-3	reference - main	02-Nov-2016	78.8	<0.05	<5	<5	0.41	<5	<5	<0.5
SW16-4	impacted - ZOD	01-Nov-2016	378	0.11	<10	<10	6.32	<10	**54700**	<1
SW16-DUP2	impacted - ZOD	01-Nov-2016	369	0.533	<5	7.8	6.39	<5	**55400**	<0.5
SW16-5	impacted - ZOD	31-Oct-2016	161	<0.05	<5	<5	1.93	<5	**13700**	<0.5
SW16-DUP1	impacted - ZOD	31-Oct-2016	234	0.282	<5	40.5	3.52	<5	**26700**	<0.5
SW16-6	impacted - ZOD	31-Oct-2016	78.6	<0.05	<5	75.9	0.5	<5	**142**	<0.5
SW16-7	impacted - ZOD	31-Oct-2016	67.4	<0.05	<5	89.6	0.53	5	**89.3**	<0.5
SW16-8	impacted - near	02-Nov-2016	41.1	<0.05	<5	<5	<0.1	<5	<5	<0.5
SW16-9	impacted - near	01-Nov-2016	86.1	<0.05	<5	<5	0.41	<5	**8.3**	<0.5
SW16-10	impacted - near, tributary	02-Nov-2016	77.4	<0.05	<5	<5	0.54	<5	**562**	<0.5
SW16-11	impacted - near, tributary	01-Nov-2016	75.1	<0.05	<5	<5	0.5	<5	<5	<0.5
SW16-12	impacted - near	01-Nov-2016	71	<0.05	<5	<5	0.48	<5	<5	<0.5
SW16-13	impacted - near	01-Nov-2016	69.2	<0.05	<5	29.6	0.44	<5	**75.4**	<0.5
SW16-14	impacted - near	01-Nov-2016	87.4	<0.05	<5	76.6	0.55	<5	**199**	<0.5
SW16-15	impacted - near, tributary	02-Nov-2016	63.6	<0.05	<5	<5	0.23	<5	<5	<0.5
SW16-16	impacted - far	01-Nov-2016	117	<0.05	<5	<5	0.3	<5	<5	<0.5
SW16-17	impacted - far, tributary	01-Nov-2016	24.4	<0.05	<5	<5	<0.1	<5	<5	<0.5
CSR AWF			ns	3	ns	1000	3000	ns	75@H<90 150@H>=90<100 900@H>=100<200 1650@H>=200<300 2400@H>=300<400	ns
BCWWQfw			ns	0.8	ns	ns	8.5	ns	ns	ns
BCWQ AFWg			ns	ns	ns	ns	ns	ns	Refer to Guideline Calculations Tab	ns

Notes:
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Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life

Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life

Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)

Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B9. WATER ANALYTICAL RESULTS - DISSOLVED METALS (ug/L)

Sample ID	Location	Date	pH	Total Hardness (mg/L)	Dissolved Hardness (mg/L)	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Calcium	Cadmium	Chromium, Total	Chromium, Hexavalent
PW16-1	reference, tributary	31-Oct-2016	7.91	80.5	75.4	17.1	0.9	1.36	23.8	<0.1	<1	<50	28200	0.042	<1	---
PW16-2	impacted - ZOD	31-Oct-2016	**3.93**	275	245	**14000**	<0.5	<0.1	14.9	0.45	<1	<50	84200	**197**	1.6	---
PW16-3	impacted - ZOD	31-Oct-2016	**3.15**	269	258	**23200**	<0.5	<0.1	14.3	0.6	<1	<50	82100	**191**	5.4	---
PW16-4	impacted - near, tributary	01-Nov-2016	7.87	75.5	55.8	18.1	<0.5	3.01	17.6	<0.1	<1	<50	20300	<0.01	<1	---
PW DUP1	impacted - near	01-Nov-2016	7.86	66.5	60.8	18.6	<0.5	3.52	18.3	<0.1	<1	<50	22100	<0.01	<1	---
SW16-0	reference - tributary	02-Nov-2016	7.91	64.2	61.3	45.7	0.96	1.6	15.2	<0.1	<1	<50	23400	**1.01**	<1	---
SW16-1	reference - main	31-Oct-2016	7.6	41.7	33.6	30.5	<0.5	0.37	18.5	<0.1	<1	<50	11300	<0.01	<1	---
SW16-2	reference - main	31-Oct-2016	7.44	50.9	43.8	29.9	<0.5	0.5	22.6	<0.1	<1	<50	15000	<0.01	<1	---
SW16-3	reference - main	02-Nov-2016	7.66	62.1	54.3	4.9	<0.5	0.17	39.3	<0.1	<1	<50	17200	<0.01	<1	---
SW16-4	impacted - ZOD	01-Nov-2016	**3.3**	228	200	**10700**	<0.5	3.02	25.6	0.4	<1	<50	67600	**189**	1.2	---
SW16-DUP2	impacted - ZOD	01-Nov-2016	**3.31**	237	260	**11600**	<0.5	3.26	30.4	0.37	<1	<50	90500	**205**	1.3	---
SW16-5	impacted - ZOD	31-Oct-2016	7.23	107	99.8	**363**	<0.5	0.77	31.5	<0.1	<1	<50	34400	**39.7**	<1	---
SW16-DUP1	impacted - ZOD	31-Oct-2016	**4.73**	157	137	**2870**	<0.5	<0.1	24	0.11	<1	<50	47300	**91.8**	<1	---
SW16-6	impacted - ZOD	31-Oct-2016	7.65	51.3	43	39.7	<0.5	0.38	21.8	<0.1	<1	<50	14700	**0.604**	<1	---
SW16-7	impacted - ZOD	31-Oct-2016	7.65	45.9	41.1	36.1	<0.5	0.38	20.3	<0.1	<1	<50	14000	**0.216**	<1	---
SW16-8	impacted - near	02-Nov-2016	7.79	51.5	49.8	13.8	<0.5	1.7	14.3	<0.1	<1	<50	18900	<0.01	<1	---
SW16-9	impacted - near	01-Nov-2016	7.86	71.1	62.4	12.7	0.64	0.73	46.1	<0.1	<1	<50	22300	0.108	<1	---
SW16-10	impacted - near, tributary	02-Nov-2016	7.82	59.6	52.3	12.7	<0.5	3.56	16	<0.1	<1	<50	19000	<0.01	<1	---
SW16-11	impacted - near, tributary	01-Nov-2016	7.7	58.4	56.5	13.5	<0.5	4.12	19.9	<0.1	<1	<50	20400	<0.01	<1	---
SW16-12	impacted - near	01-Nov-2016	7.69	58.1	57.3	13.3	<0.5	4.1	17	<0.1	<1	<50	20700	<0.01	<1	---
SW16-13	impacted - near	01-Nov-2016	7.7	50.8	52.5	22.6	<0.5	0.7	29.5	<0.1	<1	<50	18200	**0.294**	<1	---
SW16-14	impacted - near	01-Nov-2016	7.66	56.3	46.8	26.6	<0.5	0.44	25.8	<0.1	<1	<50	15700	**0.65**	<1	---
SW16-15	impacted - near, tributary	02-Nov-2016	7.6	56.4	49.6	12.2	<0.5	**5.59**	12.9	<0.1	<1	<50	18600	<0.01	<1	---
SW16-16	impacted - far	01-Nov-2016	8.06	124	108	3	<0.5	1.66	78.9	<0.1	<1	<50	39600	0.034	<1	---
SW16-17	impacted - far, tributary	01-Nov-2016	7.25	24	23.3	26.1	<0.5	1.09	29.8	<0.1	<1	<50	8340	0.024	<1	---
CSR AWF			ns	ns	ns	ns	200	50	10000	53	ns	50000	ns	0.1@H<30 0.3@H>=30<90 0.5@H>=90<150 0.6@H>=150<210 0.8@H>=210<270 0.9@H>=270<330 1.1@H>=330<390 1.2@H>=390<450 1.3@H>=450<500	10	10
BCWWQfw			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	8.9 (5); 1 (3)	ns
BCWQ AFWg			>6.5<=9.0	ns	ns	Refer to Guideline Calculations Tab	ns	5	ns	ns	ns	1200	ns	Refer to Guideline Calculations Tab	ns	ns

Notes:
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< - less than analytical detection limit indicated
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Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life

Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life

Exceeds BCWQ AFWmq: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)

Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B9. WATER ANALYTICAL RESULTS - DISSOLVED METALS (ug/L)

Sample ID	Location	Date	Chromium, Trivalent	Cobalt	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Selenium
PW16-1	reference, tributary	31-Oct-2016	---	<0.5	2.8	25.5	<0.2	<5	1220	<1	<1	<1	---	637	0.11
PW16-2	impacted - ZOD	31-Oct-2016	---	**9.86**	**9820**	143	170	13.8	8470	522	<1	15.1	---	1300	0.22
PW16-3	impacted - ZOD	31-Oct-2016	---	**14.2**	**8400**	2600	109	20.2	12800	710	<1	23.8	---	1070	0.25
PW16-4	impacted - near, tributary	01-Nov-2016	---	<0.5	0.68	<5	<0.2	<5	1230	1.2	<1	<1	---	313	0.34
PW DUP1	impacted - near	01-Nov-2016	---	<0.5	0.29	<5	<0.2	<5	1390	1.2	<1	<1	---	361	0.37
SW16-0	reference - tributary	02-Nov-2016	---	<0.5	**29.5**	13.7	0.3	<5	685	1.7	<1	<1	---	367	0.1
SW16-1	reference - main	31-Oct-2016	---	<0.5	0.29	13.1	<0.2	<5	1280	3.7	2.6	<1	---	968	0.21
SW16-2	reference - main	31-Oct-2016	---	<0.5	0.28	6.5	<0.2	<5	1570	12.5	2.3	<1	---	789	0.2
SW16-3	reference - main	02-Nov-2016	---	<0.5	<0.2	<5	<0.2	<5	2720	<1	2.3	<1	---	1300	0.46
SW16-4	impacted - ZOD	01-Nov-2016	---	**8.39**	**9110**	6300	131	11.1	7590	429	<1	12.5	---	864	0.2
SW16-DUP2	impacted - ZOD	01-Nov-2016	---	**9.28**	**9300**	7540	139	11.8	8380	478	<1	12.8	---	1030	0.23
SW16-5	impacted - ZOD	31-Oct-2016	---	1.81	**1500**	385	5.35	<5	3400	107	1.6	3.4	---	1120	0.31
SW16-DUP1	impacted - ZOD	31-Oct-2016	---	3.76	**3760**	319	31.3	5.8	4540	210	<1	5.9	---	921	0.26
SW16-6	impacted - ZOD	31-Oct-2016	---	<0.5	**10.7**	34.7	<0.2	<5	1550	12.4	2.2	<1	---	788	0.25
SW16-7	impacted - ZOD	31-Oct-2016	---	<0.5	**6.22**	9.5	<0.2	<5	1510	10.7	2.1	<1	---	769	0.22
SW16-8	impacted - near	02-Nov-2016	---	<0.5	0.2	<5	<0.2	<5	611	<1	<1	<1	---	297	0.22
SW16-9	impacted - near	01-Nov-2016	---	<0.5	0.72	<5	<0.2	<5	1650	5.2	2.1	<1	---	849	0.21
SW16-10	impacted - near, tributary	02-Nov-2016	---	<0.5	0.22	<5	<0.2	<5	1170	<1	<1	<1	---	277	0.33
SW16-11	impacted - near, tributary	01-Nov-2016	---	<0.5	0.23	<5	<0.2	<5	1340	<1	<1	<1	---	335	0.35
SW16-12	impacted - near	01-Nov-2016	---	<0.5	<0.2	<5	<0.2	<5	1340	<1	<1	<1	---	332	0.35
SW16-13	impacted - near	01-Nov-2016	---	<0.5	**3.9**	<5	<0.2	<5	1730	4.8	2.2	<1	---	911	0.29
SW16-14	impacted - near	01-Nov-2016	---	<0.5	**7.52**	<5	<0.2	<5	1820	12.9	2.5	<1	---	925	0.25
SW16-15	impacted - near, tributary	02-Nov-2016	---	<0.5	0.31	171	<0.2	<5	767	22	<1	<1	---	483	<0.1
SW16-16	impacted - far	01-Nov-2016	---	<0.5	0.41	278	<0.2	<5	2230	690	1.2	1.2	---	1040	<0.1
SW16-17	impacted - far, tributary	01-Nov-2016	---	<0.5	1.7	373	<0.2	<5	599	25.4	<1	<1	---	634	<0.1
CSR AWF			90	40	20@H<50 30@H>=50<75 40@H>=75<100 50@H>=100<125 60@H>=125<150 70@H>=150<175 80@H>=175<200 90@H>=200	ns	40@H<50 50@H>=50<100 60@H>=100<200 110@H>=200<300 160@H>=300	ns	ns	ns	10000	250@H<60 650@H>=60<120 1100@H>=120<180 1500@H>=180	ns	ns	10
BCWWQfw			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BCWQ AFWg			ns	4	Refer to Guideline Calculations Tab	ns	Refer to Guideline Calculations Tab	ns	ns	Refer to Footnotes Tab	1000	ns	ns	ns	2

Notes:
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H - Hardness in mg/L CaCO3
< - less than analytical detection limit indicated
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Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life

Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life

Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)

Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B9. WATER ANALYTICAL RESULTS - DISSOLVED METALS (ug/L)

Sample ID	Location	Date	Silver	Sodium	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Zirconium
PW16-1	reference, tributary	31-Oct-2016	<0.02	821	65.6	<0.05	<5	<5	0.14	<5	6.9	<0.5
PW16-2	impacted - ZOD	31-Oct-2016	0.044	3360	346	0.175	<5	<5	7.56	<5	**54400**	<0.5
PW16-3	impacted - ZOD	31-Oct-2016	0.077	4170	332	0.248	<5	<5	6.22	<5	**49700**	<0.5
PW16-4	impacted - near, tributary	01-Nov-2016	<0.02	732	62.2	<0.05	<5	<5	0.41	<5	7.1	<0.5
PW DUP1	impacted - near	01-Nov-2016	<0.02	832	77.4	<0.05	<5	<5	0.47	<5	<5	<0.5
SW16-0	reference - tributary	02-Nov-2016	<0.02	723	51	<0.05	<5	<5	0.11	<5	**217**	<0.5
SW16-1	reference - main	31-Oct-2016	<0.02	733	54.5	<0.05	<5	<5	0.29	<5	<5	<0.5
SW16-2	reference - main	31-Oct-2016	<0.02	1150	78.9	<0.05	<5	<5	0.42	<5	<5	<0.5
SW16-3	reference - main	02-Nov-2016	<0.02	1150	64.4	<0.05	<5	<5	0.35	<5	<5	<0.5
SW16-4	impacted - ZOD	01-Nov-2016	0.033	3340	299	0.279	<5	<5	5.94	<5	**54800**	<0.5
SW16-DUP2	impacted - ZOD	01-Nov-2016	0.055	4190	386	0.246	<5	<5	6.4	<5	**51300**	<0.5
SW16-5	impacted - ZOD	31-Oct-2016	<0.02	2210	146	<0.05	<5	<5	0.26	<5	**11100**	<0.5
SW16-DUP1	impacted - ZOD	31-Oct-2016	<0.02	2160	191	0.075	<5	<5	2.28	<5	**23700**	<0.5
SW16-6	impacted - ZOD	31-Oct-2016	<0.02	731	64.9	<0.05	<5	<5	0.35	<5	**153**	<0.5
SW16-7	impacted - ZOD	31-Oct-2016	<0.02	689	65.1	<0.05	<5	<5	0.36	<5	**52.5**	<0.5
SW16-8	impacted - near	02-Nov-2016	<0.02	668	34.9	<0.05	<5	<5	<0.1	<5	<5	<0.5
SW16-9	impacted - near	01-Nov-2016	<0.02	1110	75.7	<0.05	<5	<5	0.45	<5	6.4	<0.5
SW16-10	impacted - near, tributary	02-Nov-2016	<0.02	714	61.2	<0.05	<5	<5	0.44	<5	<5	<0.5
SW16-11	impacted - near, tributary	01-Nov-2016	<0.02	1280	75.2	<0.05	<5	<5	0.48	<5	<5	<0.5
SW16-12	impacted - near	01-Nov-2016	<0.02	858	74	<0.05	<5	<5	0.47	<5	<5	<0.5
SW16-13	impacted - near	01-Nov-2016	<0.02	1190	84.7	<0.05	<5	<5	0.41	<5	**68.4**	<0.5
SW16-14	impacted - near	01-Nov-2016	<0.02	1290	83.5	<0.05	<5	<5	0.34	<5	**159**	<0.5
SW16-15	impacted - near, tributary	02-Nov-2016	<0.02	1120	51.6	<0.05	<5	<5	0.2	<5	<5	<0.5
SW16-16	impacted - far	01-Nov-2016	<0.02	1150	96	<0.05	<5	<5	0.26	<5	<5	<0.5
SW16-17	impacted - far, tributary	01-Nov-2016	<0.02	1360	23.9	<0.05	<5	<5	<0.1	<5	<5	<0.5
CSR AWF			0.5@H<=100 15@H>100	ns	ns	3	ns	1000	3000	ns	75@H<90 150@H>=90<100 900@H>=100<200 1650@H>=200<300	ns
BCWWQfw			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BCWQ AFWg			0.05@H<=100 1.5@H>100	ns	ns	ns	ns	ns	ns	ns	Refer to Guideline Calculations Tab	ns

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
H - Hardness in mg/L CaCO3
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed

Exceeds CSR AWF: BC Contaminated Sites Regulation, Schedule 6 Generic Numerical Water Standards, Freshwater Aquatic Life

Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life

Exceeds BCWQ AFWmg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (short term maximum)

Exceeds BCWQ AFWg: BC Approved Water Quality Guidelines - Aquatic Life Freshwater Aquatic Life (long term average)

TABLE B10. PORE WATER AND SURFACE WATER OBSERVATION RESULTS

Location ID	PW16-1	PW16-2	PW16-3	PW16-4	SW16-0	SW16-1	SW16-2	SW16-3	SW16-4	SW16-5	SW16-6	SW16-7	SW16-8	SW16-9	SW16-10	SW16-11	SW16-12	SW16-13	SW16-14	SW16-15	SW16-16	SW16-17
Duplicate ID	---	---	---	PWDUP1	---	---	---	---	SW DUP2	SW DUP1	---	---	---	---	---	---	---	---	---	---	---	---
Sediment ID	---	---	---	---	---	SE16-1	---	---	---	SE16-5	---	---	---	---	---	---	SE16-12	---	SE16-14	SE16-15	---	SE16-17
Sample Date	31-Oct-16	31-Oct-16	31-Oct-16	1-Nov-16	2-Nov-16	30-Oct-16	30-Oct-16	2-Nov-16	1-Nov-16	30-Oct-16	30-Oct-16	30-Oct-16	1-Nov-16	1-Nov-16	2-Nov-16	1-Nov-16	1-Nov-16	1-Nov-16	1-Nov-16	2-Nov-16	1-Nov-16	1-Nov-16
Northing	580824	580907	580930	581461	580837	580237	580546	580262	580881	580926	580998	580845	581406	581397	581751	581524	581380	581345	581255	581620	581498	581664
Easting	6511684	6511348	6511317	6510343	6511653	6512380	6511792	6511796	6511402	6511307	6511142	6511170	6510709	6510423	6510414	6510343	6510181	6510135	6510064	6509934	6519109	6509247
Elevation (m)	nm	39	37	36	41	nm	nm	42	46	nm	33	nm	46	44	47	51	37	nm	36	43	37	40
Acc. (+/-)	nm	2	3	4	3	nm	nm	2	2	3	3	nm	8	1	27	8	2	nm	4	15	4	5
Depth of water (m)	---	---	---	---	0.4	0.7	0.35	0.35	0.15	0.55	0.65	0.45	0.2	0.5	0.5	0.2	0.6	0.3	0.4	0.3	0.3	0.3
Temp	nm	5.4	6	3.2	3.9	1.8	1.7	3.2	3.3	4.5	2.3	1.8	3.2	3.7	1.8	1.4	1.6	3.1	1.5	3.9	6.2	3.8
pH	7.51	4.01	3.2	8.21	8.17	7.76	7.71	8.1	3.29	4.64	6.45	6.9	8.13	7.99	8.06	6.65	7.65	8.19	7.81	7.72	7.57	7.81
pH (mV)	-45.9	146.2	189.9	84.8	-80.5	-58.2	-55.5	-76.8	6.65	110	12	-14.1	nm	-71	-74	nm	nm	-81.4	-60.8	-55.8	-48.5	-60.3
DO	10.52	11.52	12.04	123.62	12.91	13.06	13.13	12.97	13.25	11.61	12.7	12.9	12.91	11.36	13.6	13.25	13.32	11.33	13.13	8.32	5.05	10.36
Tur	nm	nm	nm	nm	nm	100-140	40-60	1.3	40-50	40-50	75	58	1.8	3	1.2	0.9	1.2	16.1	40-60	3	4.2	5.4
SPC	164.1	842	1245	133.1	140.3	82.4	101	143.2	561	506	109.7	103.8	111.5	153.7	128.4	128.4	128.6	130.8	111.3	119	247.1	53.9
Cond	115.6	528	796	77.8	83.8	46.5	56.1	83.5	9.7	307.5	62.2	57.8	65	91.1	71.4	76	71.2	76.1	61.4	71.1	158.2	32.1
ORP	164.1	385.9	541.3	238.2	139.5	293	211.6	190.8	509.5	383	386.8	359.2	214.8	264.8	184.5	342.8	321.2	253.3	225.4	210.1	39.6	235.9
mmHg	692.4	750.9	749.9	747.4	752.1	748.6	749.1	752.1	nm	750	749.8	749.7	nm	747.6	750.6	nm	nm	747.9	749.8	752	747.8	747.6

Notes:
nm - no tmeasured

TABLE B-11: RELATIVE PERCENT DIFFERENCE - GENERAL CHEMISTRY AND INORGANICS (mg/L)

Sample ID	Date	pH	Hardness	Conductivity	Alkalinity (total as CACO23)	Total Suspended Solids (TSS)	Dissolved Sulphur	Dissolved Sulphate
Porewater								
PW16-4	01-Nov-2016	7.87	75.5	131	54.4	124	3.7	14.2
PW DUP1	01-Nov-2016	7.86	66.5	131	51.9	78.8	4.3	14.1
Surface Water								
SW16-4	01-Nov-2016	3.30	228	905	< 0.50	23.6	120	373
SW16-DUP2	01-Nov-2016	3.31	237	901	< 0.50	90.0	139	368
SW16-5	31-Oct-2016	7.23	107	196	30.2	35.5	33.2	64.2
SW16-DUP1	31-Oct-2016	4.73	157	449	< 0.50	39.0	61.3	194
RPD (%)[1,2,3]								
	LMDL	0.5	0.5	1	0.5	1	3	5
PW DUP1 (PW16-4)		0.13	12.68	0.00	4.70	44.58	15.00	0.71
SW16-DUP2 (SW16-4)		0.30	3.87	0.44	nc	116.90	14.67	1.35
SW16-DUP1 (SW16-5)		41.81	37.88	78.45	193.49	9.40	59.47	100.54

Notes:
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
RPD - relative percent difference

[1] - acceptable RPD for metals in water is 30%
[2] - acceptable RPD for conductivity in water is 20%
[3] - acceptable RPD for alkalinity in water is 20%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
RPDs exceeds the acceptable level

TABLE B-12: RELATIVE PERCENT DIFFERENCE - SALINITY PARAMETERS (mg/L)

Sample ID	Date	pH	Calcium	Dissolved Calcium	Magnesium	Dissolved Magnesium	Potassium	Dissolved Potassium	Sodium	Dissolved Sodium
Porewater										
PW16-4	01-Nov-2016	7.87	26.4	20.3	2.33	1.23	0.534	0.313	0.959	0.732
PW DUP1	01-Nov-2016	7.86	23.2	22.1	2.08	1.39	0.498	0.361	0.840	0.832
Surface Water										
SW16-4	01-Nov-2016	3.30	77.2	67.6	8.54	7.59	1.01	0.864	4.06	3.34
SW16-DUP2	01-Nov-2016	3.31	80.6	90.5	8.71	8.38	1.06	1.03	3.69	4.19
SW16-5	31-Oct-2016	7.23	37.1	34.4	3.52	3.40	1.09	1.12	2.07	2.21
SW16-DUP1	31-Oct-2016	4.73	52.9	47.3	6.08	4.54	1.29	0.921	2.55	2.16
RPD (%)[1]										
LMDL		0.5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
PW DUP1 (PW16-4)		0.13	12.90	8.49	11.34	12.21	6.98	14.24	13.23	12.79
SW16-DUP2 (SW16-4)		0.30	4.31	28.97	1.97	9.89	4.83	17.53	9.55	22.58
SW16-DUP1 (SW16-5)		41.81	35.11	31.58	53.33	28.72	16.81	19.50	20.78	2.29

Notes:
mg/L - milligrams per litre
< - less than analytical detection limit indicated
"---" - sample not analyzed for parameter indicated
RPD - relative percent difference
[1] - acceptable RPD for metals in water is 30%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
RPDs exceeds the acceptable level

TABLE B-13: RELATIVE PERCENT DIFFERENCE - OTHER PARAMETERS (mg/L)

Sample ID	Date	pH	Hardness	Conductivity (uS/cm)	Alkalinity	Total Suspended Solids (TSS)	Dissolved Calcium	Dissolved Iron	Dissolved Magnesium	Dissolved Manganese	Dissolved Potassium	Dissolved Sodium
Porewater												
PW16-4	01-Nov-2016	7.87	75.5	131	54.4	124	20.3	<0.005	1.23	0.0012	0.313	0.732
PW DUP1	01-Nov-2016	7.86	66.5	131	51.9	78.8	22.1	<0.005	1.39	0.0012	0.361	0.832
Surface Water												
SW16-4	01-Nov-2016	3.30	228	905	< 0.50	23.6	67.6	6.3	7.59	0.429	0.864	3.34
SW16-DUP2	01-Nov-2016	3.31	237	901	< 0.50	90.0	90.5	7.54	8.38	0.478	1.03	4.19
SW16-5	31-Oct-2016	7.23	107	196	30.2	35.5	34.4	0.385	3.40	0.107	1.12	2.21
SW16-DUP1	31-Oct-2016	4.73	157	449	< 0.50	39.0	47.3	0.319	4.54	0.21	0.921	2.16
RPD (%)[1,2,3]												
LMDL		0.5	0.5	1	0.5	1	0.05	0.005	0.05	0.001	0.05	0.05
PW DUP1 (PW16-4)		0.13	12.68	0.00	4.70	44.58	8.49	nc	12.21	nc	14.24	12.79
SW16-DUP2 (SW16-4)		0.30	3.87	0.44	nc	116.90	28.97	17.92	9.89	10.80	17.53	22.58
SW16-DUP1 (SW16-5)		41.81	37.88	78.45	193.49	9.40	31.58	18.75	28.72	64.98	19.50	2.29

Notes:
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
RPD - relative percent difference
[1] - acceptable RPD for metals in water is 30%
[2] - acceptable RPD for conductivity in water is 20%
[3] - acceptable RPD for alkalinity in water is 20%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
RPDs exceeds the acceptable level

TABLE B-14: RELATIVE PERCENT DIFFERENCE - TOTAL METALS (ug/L)

Sample ID	Date	pH	Hardness (mg/L)	Aluminum	Antimony	Arsenic	Barium	Bismuth	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Magnesium	Manganese
Porewater																				
PW16-4	01-Nov-2016	7.87	75.5	1090	<0.5	5.52	30.8	<1	<0.1	<50	0.022	26400	2.6	0.92	4.75	1680	0.39	<5	2330	65.2
PW DUP1	01-Nov-2016	7.86	66.5	1020	<0.5	4.96	26.7	<1	<0.1	<50	0.016	23200	2.4	0.79	2.95	1540	0.28	<5	2080	47.6
Surface Water																				
SW16-4	01-Nov-2016	3.3	228	11500	3	80.6	26.9	<2*	0.37	<100*	211	77200	<2*	9.4	9710	18300	142	<10*	8540	474
SW16-DUP2	01-Nov-2016	3.31	237	12200	6.33	151	35.5	<1	0.44	<50	217	80600	2.3	9.7	9920	42500	157	13.3	8710	488
SW16-5	31-Oct-2016	7.23	107	2530	0.66	7.78	27.1	<1	<0.1	<50	51	37100	<1	2.19	2240	2360	30.6	5.1	3520	121
SW16-DUP1	31-Oct-2016	4.73	157	6710	1.46	23.2	56.2	<1	0.21	<50	96.4	52900	3.9	6	4430	8060	68.2	6.9	6080	303
RPD (%)[1]																				
LMDL		0.5	0.5*	3	0.5*	0.1	1	1*	0.1	50*	0.01	50*	1*	0.5	0.2	10	0.2	5*	50	1
PW DUP1 (PW16-4)		0.13	12.68	6.64	nc	10.69	14.26	nc	nc	nc	nc	12.90	nc	nc	46.75	8.70	nc	nc	11.34	31.21
SW16-DUP2 (SW16-4)		0.30	3.87	5.91	71.38	60.79	27.56	nc	nc	nc	2.80	4.31	nc	3.14	2.14	79.61	10.03	nc	1.97	2.91
SW16-DUP1 (SW16-5)		41.81	37.88	90.48	nc	99.55	69.87	nc	nc	nc	61.60	35.11	nc	93.04	65.67	109.40	76.11	nc	53.33	85.85

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
RPD - relative percent difference
[1] - acceptable RPD for metals in water is 30%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
* - RDL raised due to sample matrix interference
RPDs exceeds the acceptable level

TABLE B-14: RELATIVE PERCENT DIFFERENCE - TOTAL METALS (ug/L)

Sample ID	Date	pH	Hardness (mg/L)	Mn guideline	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Zirconium
Porewater																		
PW16-4	01-Nov-2016	7.87	75.5	937	<1	2.3	534	0.34	<0.02	959	82.8	<0.05	<5	37.1	0.46	<5	<5	<0.5
PW DUP1	01-Nov-2016	7.86	66.5	898	<1	2.1	498	0.35	<0.02	840	76.3	<0.05	<5	42.4	0.43	<5	<5	<0.5
Surface Water																		
SW16-4	01-Nov-2016	3.3	228	1608	<2*	13	1010	0.22	<0.04*	4060	378	0.11	<10*	<10*	6.32	<10*	54700	<1*
SW16-DUP2	01-Nov-2016	3.31	237	1648	<1	13.9	1060	0.36	0.214	3690	369	0.533	<5	7.8	6.39	<5	55400	<0.5
SW16-5	31-Oct-2016	7.23	107	1076	2.1	3.4	1090	0.29	<0.02	2070	161	<0.05	<5	<5	1.93	<5	13700	<0.5
SW16-DUP1	31-Oct-2016	4.73	157	1296	1.9	12.8	1290	0.48	0.087	2550	234	0.282	<5	40.5	3.52	<5	26700	<0.5
RPD (%)[1]																		
LMDL		0.5	0.5*	1	1*	1	50*	0.1	0.02*	50*	1	0.05*	5*	5*	0.1	5*	5	0.5*
PW DUP1 (PW16-4)		0.13	12.68	4.32	nc	nc	6.98	nc	nc	13.23	8.17	nc	nc	13.33	6.74	nc	nc	nc
SW16-DUP2 (SW16-4)		0.30	3.87	2.43	nc	6.69	4.83	nc	137.01	9.55	2.41	131.57	nc	24.72	1.10	nc	1.27	nc
SW16-DUP1 (SW16-5)		41.81	37.88	18.55	nc	116.05	16.81	nc	125.23	20.78	36.96	139.76	nc	156.04	58.35	nc	64.36	nc

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
RPD - relative percent difference
[1] - acceptable RPD for metals in water is 30%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
* - RDL raised due to sample matrix interference
RPDs exceeds the acceptable level

TABLE B-15: RELATIVE PERCENT DIFFERENCE- DISSOLVED METALS (ug/L)

Sample ID	Date	pH	Total Hardness (mg/L)	Dissolved Hardness (mg/L)	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Calcium	Cadmium	Chromium, Total	Cobalt	Copper	Iron	Lead	Lithium	Magnesium
Porewater																				
PW16-4	01-Nov-2016	7.87	75.5	55.8	18.1	<0.5	3.01	17.6	<0.1	<1	<50	20300	<0.01	<1	<0.5	0.68	<5	<0.2	<5	1230
PW DUP1	01-Nov-2016	7.86	66.5	60.8	18.6	<0.5	3.52	18.3	<0.1	<1	<50	22100	<0.01	<1	<0.5	0.29	<5	<0.2	<5	1390
Surface Water																				
SW16-4	01-Nov-2016	3.3	228	200	10700	<0.5	3.02	25.6	0.4	<1	<50	67600	189	1.2	8.39	9110	6300	131	11.1	7590
SW16-DUP2	01-Nov-2016	3.31	237	260	11600	<0.5	3.26	30.4	0.37	<1	<50	90500	205	1.3	9.28	9300	7540	139	11.8	8380
SW16-5	31-Oct-2016	7.23	107	99.8	363	<0.5	0.77	31.5	<0.1	<1	<50	34400	39.7	<1	1.81	1500	385	5.35	<5	3400
SW16-DUP1	31-Oct-2016	4.73	157	137	2870	<0.5	<0.1	24	0.11	<1	<50	47300	91.8	<1	3.76	3760	319	31.3	5.8	4540
RPD (%)[1]																				
	LMDL	0.5	0.5	0.5	3	0.5	0.1	1	0.1	1	50	50	0.01	1	0.5	0.2	5	0.2	5	50
PW DUP1 (PW16-4)		0.13	12.68	8.58	2.72	nc	15.62	3.90	nc	nc	nc	8.49	nc	nc	nc	nc	nc	nc	nc	12.21
SW16-DUP2 (SW16-4)		0.30	3.87	26.09	8.07	nc	7.64	17.14	7.79	nc	nc	28.97	8.12	nc	10.07	2.06	17.92	5.93	nc	9.89
SW16-DUP1 (SW16-5)		41.81	37.88	31.42	155.09	nc	154.02	27.03	nc	nc	nc	31.58	79.24	nc	70.02	85.93	18.75	141.61	nc	28.72

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
RPD - relative percent difference
[1] - acceptable RPD for metals in water is 30%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
RPDs exceeds the acceptable level

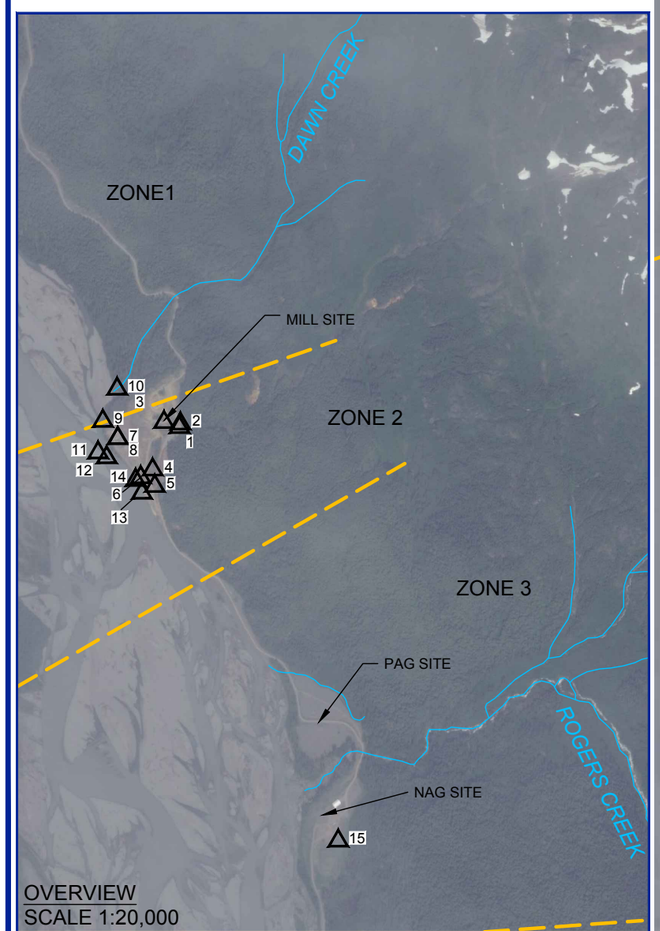
TABLE B-15: RELATIVE PERCENT DIFFERENCE- DISSOLVED METALS (ug/L)

Sample ID	Date	pH	Total Hardness (mg/L)	Dissolved Hardness (mg/L)	Manganese	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Zirconium
Porewater																			
PW16-4	01-Nov-2016	7.87	75.5	55.8	1.2	<1	<1	313	0.34	<0.02	732	62.2	<0.05	<5	<5	0.41	<5	7.1	<0.5
PW DUP1	01-Nov-2016	7.86	66.5	60.8	1.2	<1	<1	361	0.37	<0.02	832	77.4	<0.05	<5	<5	0.47	<5	<5	<0.5
Surface Water																			
SW16-4	01-Nov-2016	3.3	228	200	429	<1	12.5	864	0.2	0.033	3340	299	0.279	<5	<5	5.94	<5	54800	<0.5
SW16-DUP2	01-Nov-2016	3.31	237	260	478	<1	12.8	1030	0.23	0.055	4190	386	0.246	<5	<5	6.4	<5	51300	<0.5
SW16-5	31-Oct-2016	7.23	107	99.8	107	1.6	3.4	1120	0.31	<0.02	2210	146	<0.05	<5	<5	0.26	<5	11100	<0.5
SW16-DUP1	31-Oct-2016	4.73	157	137	210	<1	5.9	921	0.26	<0.02	2160	191	0.075	<5	<5	2.28	<5	23700	<0.5
RPD (%)[1]																			
	LMDL	0.5	0.5	0.5	1	1	1	50	0.1	0.02	50	1	0.05	5	5	0.1	5	5	0.5
PW DUP1 (PW16-4)		0.13	12.68	8.58	0.00	nc	nc	14.24	nc	nc	12.79	21.78	nc	nc	nc	nc	nc	nc	nc
SW16-DUP2 (SW16-4)		0.30	3.87	26.09	10.80	nc	2.37	17.53	nc	50.00	22.58	25.40	12.57	nc	nc	7.46	nc	6.60	nc
SW16-DUP1 (SW16-5)		41.81	37.88	31.42	64.98	nc	53.76	19.50	nc	nc	2.29	26.71	nc	nc	nc	159.06	nc	72.41	nc

Notes:
ug/L - micrograms per litre
mg/L - milligrams per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
RPD - relative percent difference
[1] - acceptable RPD for metals in water is 30%
LMDL - laboratory method detection limit
n.c.- RPDs are not calculated for non-detect results or results within 5X of detection limit.
RPDs exceeds the acceptable level

Location ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Date	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	29-Oct-16	2-Nov-16
Northing	581049	581052	580997	580959	580966	580919	580842	580842	580792	580840	580776	580805	580923	580902	581581
Easting	6511525	6511537	6511542	6511383	6511328	6511357	6511488	6511488	6511546	6511654	6511440	6511424	6511305	6511348	6510139
Elevation (m)	105	104	85	50	64	40	nm	nm	27	45	41	43	43	nm	61
Temp (˚C)	8.1	5.5	4.8	5.3	6	5.1	4.4	4.3	3.6	4	1.9	3.2	3.1	5.7	4
pH	8.58	3.61	3.54	3.48	3.44	3.44	5.65	6.22	6.86	7.37	8.12	7.71	7.69	3.56	8.13
DO (mg/L)	11.2	12	8.68	12.32	11.9	12.24	12.69	12.89	11.14	12.68	10.94	11.74	11.37	12.2	10.94
Turbidity (NTU)	0.5	29.3	3.5	13.2	20-35	16.3	0.9	2.7	1.3	0.6	nm	1.3	2.5	13.5	2.1
SPC (µS)	368.9	864	728	830	961	963	472.5	466	146.5	136.9	114.9	131.7	157.5	919	201.5
Cond (µS)	249.6	542	447.8	518	614	598	286.4	281.7	86.6	81.7	64.1	77	91.7	581	201.5
ORP	96.5	512.8	442.3	518.7	499.6	511.2	437.1	405.5	337	356.9	nm	349	208.7	507.5	120.8
Staining present	N	Y	Y	Y	Y	Y	Y*	Y*	N	N	N**	N	Y	Y	N

Notes:
N- no staining observed
Y - staining observed
* - Algal growth on floor and sides of pond.
** - some other staining or algal growth present yellow, not orange
nm - not measured



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LEGEND:

- ZONE BOUNDARY
- △ SURFACE WATER SAMPLE
- NAG NON-ACID GENERATING WASTE ROCK
- PAG POTENTIALLY ACID GENERATING WASTE ROCK

0 25 50 100 150 m

SCALE 1:3,000
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 9 U

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

MINISTRY OF ENVIRONMENT
TULSEQUAH CHIEF MINE SITE
ATLIN, BC

2016 TULSEQUAH CHIEF MINE SITE AERA

2016 TULSEQUAH CHIEF MINE SITE SURFACE WATER FIELD OBSERVATIONS

Date: January 20, 2017
Project No. 201.88687.00000
Drawing No. B-1

SLR global environmental solutions

Cadfile name: S_201-88687-00000-A2.dwg

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LEGEND:

	ZONE BOUNDARY
	BOREHOLE COMPLETED AS A MONITORING WELL (OTHERS)
NAG	NON-ACID GENERATING WASTE ROCK
PAG	POTENTIALLY ACID GENERATING WASTE ROCK

0 0.25 0.5 1.0 km

SCALE 1:15,000
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 9 U

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

MINISTRY OF ENVIRONMENT
TULSEQUAH CHIEF MINE SITE
ATLIN, BC

2016 TULSEQUAH CHIEF MINE SITE AERA

2016 TUSLEQUAH CHIEF MINE SITE HISTORICAL MONITORING WELL LOCATIONS

Date: January 20, 2017
Project No. 201.88687.00000
Drawing No. B-2

SLR global environmental solutions

Cadfile name: S_201-88687-00000-A2.dwg

Photo B-1: Portal 5400 at top of diversion channel

Photo B-2: Surface flow of water originating from mouth of Portal 5400

Photo B-3: Stained ditch on North side of access road to Portal 5400

Photo B-4: Surficial flow in ditch originating from Portal 5400

Photo B-5: Surface flow of water originating from mouth of Portal 5200

Photo B-6: Exfiltration Pond, surface flow from Portal 5200

Photo B-7: Water Treatment Plant pond

Photo B-8: Riverside North of Water Treatment Plant Sludge Pit

Photo B-9: 10 m west of confluence of Dawn Creek and Tulsequah River side channel

Photo B-10: Surface water monitoring locations 11 and 12

Photo B-11: Confluence of Exfiltration Pond overflow and side channel

Photo B-12: On shoreline, prior to surface runoff from Exfiltration Pond reaching Tulsequah side channel

Photo B-13: Pooled water in the non-acid generating site excavation

Photo B-14: Monitoring Well MW11-3 viewed from the west

Photo B-15: Monitoring well MW11-5 viewed from the south

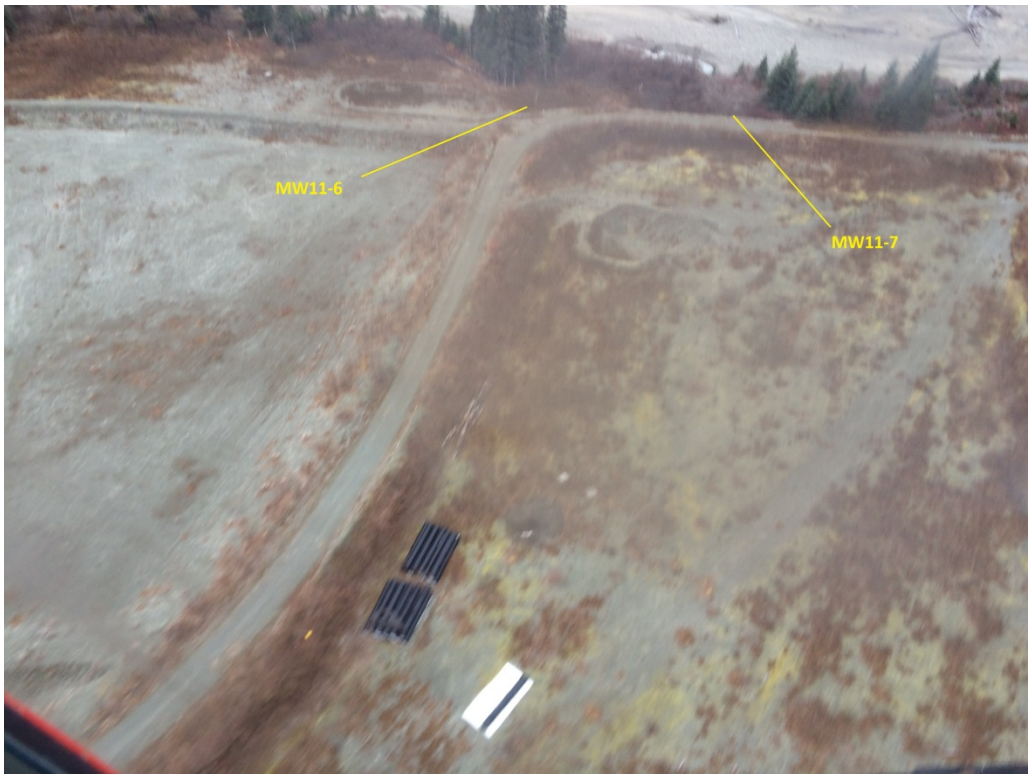

Photo B-16: Monitoring well MW11-6 and 11-7 viewed from the helicopter

Photo B-17: Monitoring well MW11-7 Viewed from the east

Photo B-18: Monitoring Well BH-P-07-4 viewed from the south

Photo B-19: PW16-1 drive point location viewed from the northwest

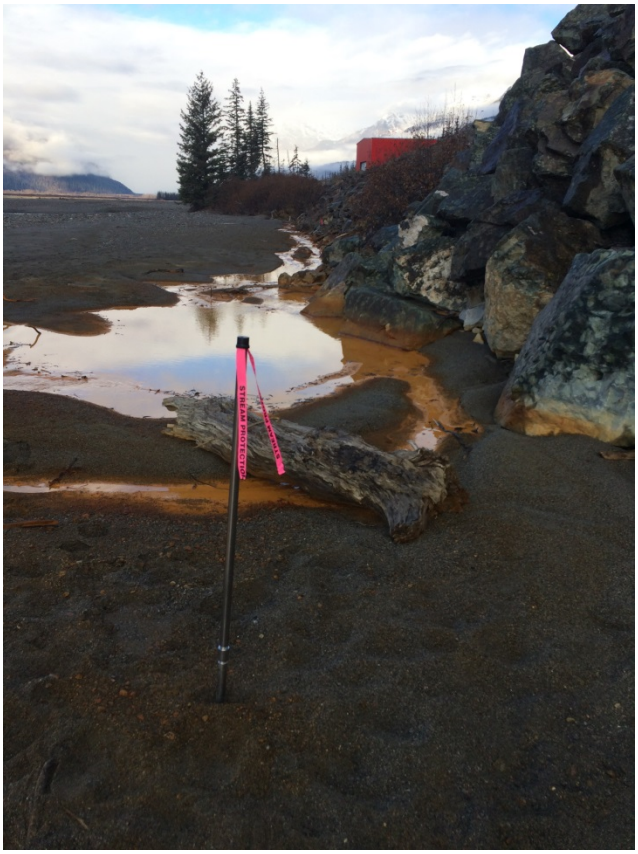

Photo B-20: PW16-2 drive point location viewed from the south

Photo B-21: PW16-3 drive point location viewed from the south

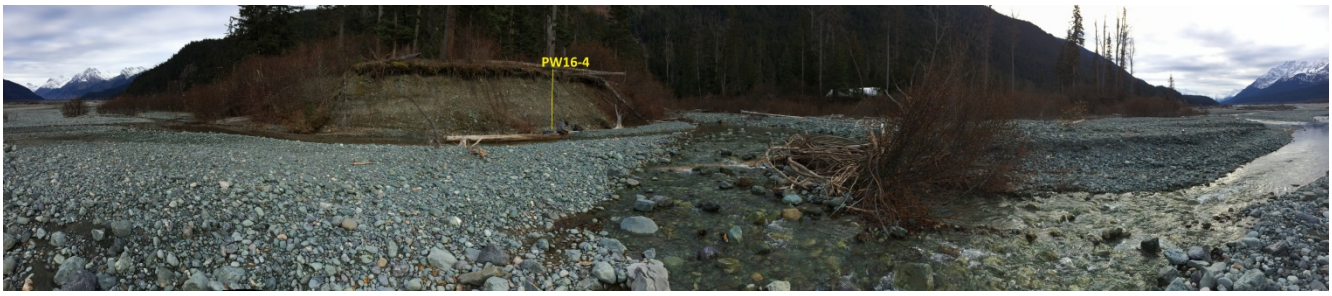

Photo B-22: PW16-4 drive point location viewed from the south

Photo B-23: 30m N of Confluence of Dawn Creek and in side channel – SW16-0

Photo B-24: Tulsequah River, upstream of Dawn Creek side channel – SW16-1

Photo B-25: Mainstem adjacent to Dawn Creek viewed from south – SW16-2

Photo B-26: Upstream of Dawn Creek - Riffle area viewed from north – SW16-3

Photo B-27: Where the overland flow from the pond crests the bank leading to the side channel , viewed from the north – SW16-4

Photo B-28: Confluence of Exfiltrant overflow with Tulsequah side channel - mixing zone – SW16-5

Photo B-29: Confluence of side channel and main reach of Tulsequah – SW16-6

Photo B-30: Split of main stem and side channel, confluence with exfiltration pond – SW16-7

Photo B-31: Trauna Creek at NW corner of PAG - collects all surface water flow off of mountain to east, viewed from the east – SW16-8

Photo B-32: PAG discharge in side channel , viewed from south - SW16-9

Photo B-33: At pool below falls on Roger Creek - 80m from bridge – SW16-10

Photo B-34: 100m E of Rogers Creek confluence, in creek, viewed from west – SW16-11

Photo B-35: At Confluence of side channel from Main Site and main stem, Viewed from north – SW16-12

Photo B-36: Below confluence of Rogers Creek, in main stem, downstream of PAG, viewed from north – SW16-13

Photo B-37: Downstream of PAG site, viewed from south – SW16-14

Photo B-38: In pond south of NAG, viewed from south – SW16-15

Photo B-39: South of Rogers Slough, where drainage from slough ran to ground , viewed from north – SW16-16

Photo B-40: South end of slough on Eastern bank, viewed from south – SW16-17

Photo B-41: NAG Waste Rock Pile

Photo B-42: PAG Waste Rock Pile

APPENDIX C
2016 Fisheries Habitat Assessment

2016 Tulsequah Chief Mine
Aquatic Ecological Risk Assessment
SLR Project No.: 201.88687.00000

APPENDIX C:
2016 TULSEQUAH CHIEF MINE SITE AERA: FISH HABITAT ASSESSMENT

1.0 INTRODUCTION

SLR Consulting (Canada) Ltd. was retained by the British Columbia Ministry of the Environment (BC MOE) to complete a 2016 Aquatic Ecological Risk Assessment (AERA) for the Tulsequah Chief Mine Site (hereafter referred to as the "Site"). The purpose of the 2016 AERA was to provide a current state assessment of potential impacts to aquatic receptors within the Tulsequah mainstem and tributary side-channels surrounding the Site.

In order to assess potential risks to aquatic receptors within the Tulsequah system, appropriate receptors need to be identified. To support the identification of receptors, a preliminary fish habitat assessment was completed between October 29th to November 2nd, 2016. The information presented summarizes the 2016 fish habitat assessment, in addition to available existing fish habitat and community data, most of which predates to 2007.

Additional detailed habitat and community information should be gathered during all biologically relevant seasons to inform a comprehensive understanding of the aquatic ecosystem in the Tulsequah River.

1.1 Purpose

The purpose of the fish habitat assessment was to:

- Review available reports prepared by private consultants and government agencies regarding fish and fish habitat existing conditions within the Tulsequah River;
- conduct a preliminary fish habitat assessment within the Study Area between October 29 and November 2nd concurrent with site assessment activities;
- correlate habitat information obtained from field investigations with species utilization by resident and migratory fish known to occur within Tulsequah River; and
- provide information and recommendations in support of on-going environmental management associated with the project.

2.0 STUDY LOCATION

The Tulsequah River is located in northwestern British Columbia and is within the Taku River watershed. The Tulsequah River confluences with the Taku River approximately 5 kilometres upstream of the Canada-United States border. From the toe of the Tulsequah Glacier to the confluence with the Taku River, the river is approximately 20 km in length and drops approximately 110 m in elevation over this distance. The Tulsequah River drains an area of 737 km^2, approximately 35% of which is glaciated. Tulsequah Lake and Lake No Lake are dammed by the Tulsequah glacier and only once or twice a year the glacial dams fail and flood the Tulsequah River (jökulhlaups) (AERA, 2013).

The Tulsequah Chief Mine is located on the east bank of the Tulsequah River, approximately 100 km south of the town of Atlin, BC.

For the purpose of the AERA investigation, the Study Area was divided into four exposure zones; one reference and three impacted zones. Zone 1 - Reference, is located directly upstream of the Site, and Zone 2 - Zone of Discharge, is located adjacent to the Site. Zone 3 - Impacted Near, is located approximately 1 km downstream of the Site. Zone 4- Impacted Far, is located approximately 2.5 km downstream of the Site. Figures 1, 2 and 3 of the AERA show the sampling zones in the Tulsequah River.

3.0 FISHERIES HABITAT ASSESSMENT APPROACH

3.1 Desktop Analysis

SLR complied and reviewed a database of relevant information from supplemental reports listed below. These sources are referenced throughout the report.

- Core6 Environmental, Palmer Environmental Consulting Group Inc., and Triton Environmental Consultants LTD. 2013. Aquatic Ecological Risk Assessment – Tulsequah Chief Mine.
- Fisheries Information Summary System (FWISS), British Columbia. Available at: http://www.env.gov.bc.ca/fish/fiss/maps/fissfish2ftp.html
- Gartner Lee Limited. 2007. Tulsequah River Valley Fisheries Compilation Maps.
- Gartner Lee Limited 2008. Tulsequah Chief Mine: Environmental Effects Monitoring Program for the Tulsequah River – 2007 Baseline Data Collection.
- Rescan Environmental Services Ltd., 1997: Environmental Assessment for the Tulsequah Chief Mining Project.

In addition to querying these digital sources, the following individuals from resource organizations were contacted for fish and fish habitat information within this Study Area.

- Taku River Tlingit First Nation
    - Mark Connor, Fisheries Coordinator
    - Shauna Yeomans, Land Guardian
    - Trevor Williams, Land Guardian

3.2 Onsite Fish Habitat Assessment

The objective of the 2016 onsite fish habitat assessment was to document existing aquatic habitat conditions within the Study Area including channel type and special habitat features. Particular focus was placed on qualifying fish habitat. Between October 29, 2016 to November 2, 2016, SLR mapped major channel types in the Tulsequah River exposure zones, with a focus on the left bank, facing downstream. The locations of the four exposure zones are shown in Figure 1 of the AERA.

Habitat parameters investigated included:

a) general channel dimension and flow;
b) morphology;
c) substrate classification;
d) in-stream and riparian vegetation;
e) bank stability and cover;
f) areas of critical habitat (spawning, nursery, feeding);and
g) presence of fish barriers and system connectivity.

Habitat mapping was recorded on base maps with the most recent available aerial imagery of the Study Area. In addition, digital photographs of each sampling location were taken. Fish collection was not part of this scope of work.

A complete list of species with the potential to occur in Tulsequah River was compiled prior to the on-site field investigation. The life-cycle behaviours for these species were reviewed to make appropriate species-habitat connections while documenting existing fish habitat features. Based on a review of life-cycle behaviours, previous reports, and consultation with the Taku River Tlingit First Nation biologist, fish with the potential to occur within the Study Area have been categorized as migratory and resident species. This information is presented below in Table C-1.

Fish typically occur in three different forms; a lake resident form, a migratory form that moves, usually for spawning, between ocean, large rivers and tributaries, and a non-migratory stream-resident form. Multiple strategies may be observed within a single river basin and even within a single population. Species listed in Table C-1 were classified as resident, migratory, or both.

For the purpose of this report, resident species were classified as non-anadromous species. These fish do not migrate from the ocean to freshwater to feed or spawn. Resident fish may undertake localized movements into smaller tributaries for spawning, feeding, or rearing purposes. Migratory fish were classified as those that undertake migrations to feed in highly productive coastal waters during the summer and/or returning in the fall/spring to their natal streams to spawn or overwinter.

Through direct correspondence with Mark Connor, he identified additional species that have the potential to occur in Tulsequah River, but their presence was either unconfirmed or they are likely to only occur on the Alaska side of the Taku River. These species include Prickly Sculpin (*Cottus asper*), Longfin Smelt (*Spirinchus thaleichthys*), Eulachon (*Thaleichthys pacificus*), Green Sturgeon (*Acipenser medirostris*), White Sturgeon (*Acipenser transmontanus*), and Burbot (*Lota lota*) (Mark Connor, pers. comm,).

Table C-1: Desktop Information Compiled to Identify Typical Habitat Features and Life-cycle for Fish with the Potential to Occur Within the Study Area

Common Name	Scientific Name	Habitat Preferences/Life History Strategies*	Resident	Migratory
Cutthroat Trout	*Oncorhynchus clarkii*	• gravelly lowland coastal streams and lakes, inland alpine lakes and small rivers, and estuaries or the sea near shore • spawn in gravel streams • stay close to the shore and the estuaries they came from • time spend in ocean in unpredictable, couple weeks to half a year. • can live for many years (up to 10)	✓	✓
Rainbow Trout	*Oncorhynchus mykiss*	• small to moderately large, but shallow rivers of the pool-riffle type with moderate flow and gravel bottoms	✓	✓
Steelhead	*Oncorhynchus mykiss*	• migratory form of Rainbow Trout that spawns in freshwater and reaches adult stage in the sea • requires passage from sea to fine gravel spawning habitat in riffle areas above pools • spend 1 to 3 years in freshwater before smolting and entering ocean • unlike pacific salmon, some individuals can spawn many times (kelts) • long-live species (up to 10 years)		✓
Chinook Salmon	*Oncorhynchus tshawytscha*	• spawn over gravel and require clean, cool, oxygenated, sediment-free fresh water for egg development • Juvenile salmon grow in clean, productive estuarine environments • juveniles may spend up to a year in freshwater before migrating • Adults live in a rich, open ocean habitat		✓
Chum Salmon	*Oncorhynchus keta*	• spawn over gravel in small streams and intertidal zones • In coastal stream, young move directly to ocean, in larger rivers young may spend several months in freshwater before migrating to sea where they stay until returning to streams to spawn		✓
Coho Salmon	*Oncorhynchus kisutch*	• spawning occurs in swifter water of shallow, gravelly areas of river tributaries • the emergent fry occupy shallow stream margins, and, as they grow, establish territories which they defend from other salmonids. • Coho fry live in ponds, lakes, and pools within streams and rivers, usually among submerged, woody debris- in quiet areas free of current. • most migrate to the open ocean after one year of growth in freshwater		✓
Sockeye Salmon	*Oncorhynchus nerka*	• typically spawn in pea-size gravel in the inlet stream to a lake/large river in late summer or early fall • The main stem spawning life history of sockeye (the variety found in the Tulsequah valley) are known to head directly to the ocean and generally do not spend a year resident. However, on occasion some Sockeye reside (or get stuck) in beaver ponds		✓

Common Name	Scientific Name	Habitat Preferences/Life History Strategies*	Resident	Migratory
Dolly Varden (Bull Trout)	*Salvelinus malma*	• entire populations of freshwater-resident Dolly Varden may spend their entire life cycle within a single stream, and during the winter, the entire population may reside at a single spring. • Anadromous fish may spend 3-4 years in freshwater • Deep runs and pools	✓	✓
Pink Salmon	*Oncorhynchus gorbuscha*	• spawn in rivers and streams with clean course gravel • challenged with velocity barriers, tend to spawn closer to sea than other Pacific salmon • Pink Salmon as young or adults do not remain in freshwater long enough to be said to "have habitat there" - spend a few months in freshwater before migrating to sea • fixed two year lifespan		✓
Round Whitefish	*Prosopium cylindraceum*	• shallow water in clear streams • migration limited to upstream movements associated with spawning	✓	
Coastrange Sculpin	*Cottus aleuticus*	• spawns in spring in downstream reaches of rivers (or estuaries) • eggs are deposited on underside of rocks in adhesive masses • prefer flowing water environments on gravel bottom • upstream migration of yearlings and adults occur in late summer to early winter, from August to December	✓	
Slimy Sculpin	*Cottus cognatus*		✓	
Threespine Stickleback	*Gasterosteus aculeatus*	• usually inhabits coastal waters or freshwater bodies well connected (or once well connected) to the coasts • prefers slow-flowing water with areas of emerging vegetation • can be found in ditches, ponds, lakes, backwaters, quiet rivers, sheltered bays, marshes, and harbors	✓	
Lake Chub	*Couesius plumbeus*	• gravel-bottomed pools and runs of creeks and rivers; moves to deeper waters in the summer; preferred water temperature <27°C • spawn in spring	✓	
River Lamprey	*Lampetra fluviatilis*	• anadromous - migrate to freshwater for courtship and spawning • adults spawn only once • April to July lamprey construct gravel nests • Ammocoetes (larval Lamprey) burrow into muddy or silty river bottoms are remain inactive for months. When they emerge, lampreys head to sea.		✓
Pacific Lamprey	*Lamptera tridentata*			✓
Longnose Sucker	*Catostomus catostomus*	• clear, cold, deep water (up to 55 m) of tributary streams; occasionally brackish water; preferred water temperature range 8-17°C • spawn in spring	✓	

*Adapted from Scott and Crossman, 1973; Lamb and Edgell, 2010; Froese and Pauly, 2016.

4.0 FISH HABITAT ASSESSMENT FINDINGS – EXISTING FISH AND FISH HABITAT

This section summarizes the existing fish habitat within the Study Area. This information was compiled using a combination of a desktop analysis (review of existing available documentation), consultation with resource agencies, and a 2016 onsite fish habitat assessment.

4.1 General Fish Habitat Features

Data collected as part of the fish habitat assessment indicate that within the Study Area, the Tulsequah River exhibits four major habitat types:

1) Mainstem
2) Side Channels
3) Tributaries
4) Slough

The 2016 fall field investigation occurred during a low-water event. The following discussion provides a general description of the major habitat features observed at this time. Refer to the Photolog at the end of this document for representative photos.

Mainstem flow was generally turbid in all exposure zones and continually split into braided channels of varying depth and velocity. Throughout the Study Area, clear water segments and/or large deep pools occurred in the mainstem, and are likely a result of parafluvial springs (clear water) or mixing with flow from tributaries. Typically these features were several degrees warmer than temperatures measured elsewhere in the mainstem. Channel morphology was typified by glide and riffle habitat. The river bed primarily consisted of gravels and sands with cobbles and boulders. Instream cover in the mainstem was minimal, except for cover provided by depth or turbidity and woody debris.

Side channels were typified by areas of varying depth and velocity, usually dominated by gravels. As a result of surface water from valley sides and/or groundwater input, channels throughout the Study Area exhibited clear water conditions and warmer water temperatures, compared to the mainstem.

Tributary confluences with mainstem and side channel habitat offered complex substrate types including cobbles and gravels, vegetative cover, and flow variations. Dawn Creek is located in Zone 1, and Rogers Creek and an Unnamed Tributary are located in Zone 3. The locations of these tributaries are presented on Drawing 1 of the AERA. These tributaries were typified by riffle, run and pool morphology. Substrate composition was dominated by gravels with cobbles and boulders. Undercut banks, woody debris and overhanging vegetation offer instream cover. In all tributaries, upstream migration was limited by impassable falls.

Sloughs offer backwater areas with minimal velocity and deep pool habitat. Roger's Slough is located in Zone 4. Substrate composition was dominated by fines and instream cover was provided by overhanging tall grasses. A causeway was constructed adjacent to the Slough during the operations phase of the Site. Equalization culverts and one clear span bridge maintain connection between the Slough and Tulsequah River side channels.

4.2 Pertinent Field Measurements Impacting Fish Habitat

pH and turbidity measurements are important non-chemical parameters that can have adverse impacts on fish and fish habitat. Both pH and turbidity measurements were documented at 18 sampling locations during the 2016 AERA field investigation. This information is presented in Appendix B Table B-10 and below in Table C-2.

Field measured pH in Zone 2 (Discharge Zone) ranged from 3.29 to 4.64, directly downstream from the Site and 6.45 to 6.9 downstream from the Site. Field pH within zones 1, 3 and 4 were less variable and ranged from 6.9 to 8.2. Fish tolerant to degraded habitat conditions, such as Creek Chub and Stickleback have been observed in systems with pH levels as low as 5.4 and 3.7, respectively. Sensitivity of other freshwater fish to pH is as follows (Robertson & Bryan 2004):

- pH range tolerated by Trout: 4.1 to 9.5
- Toxic limits for Perch: <4.6 to >9.5
- Toxic limits for Sticklebacks: ≤5
- Fish avoidance beyond range <5.4 and >11.4

In summary, most freshwater fish populations begin to disappear as pH approaches 5 and at a pH level of 4.5 most freshwaters are devoid of fish (Robertson & Bryan 2004). Given the low field measured pH adjacent to the Site within Zone 2, and the sensitivity of freshwater fish to pH, fish are not likely to persist within this area.

In addition to pH, suspended sediments can adversely affect aquatic organisms. Turbidity levels are naturally elevated during rain events and snowmelt. During the 2016 field investigation field measured turbidity ranged from 1.5 to 140 Nephelometric Turbidity Units (NTU) in Zone 1, 40 to 75 NTU in Zone 2, 1 to 60 NTU in Zone 3, and 4 to 5.5 NTU in Zone 4.

Generally fish can tolerate elevated concentrations of suspended sediments associated with short duration events. When exposure to high concentrations of suspended sediment is long-term, juvenile and adult fish can move to avoid these conditions. This is likely the case for both adult resident and migratory fish within the Tulsequah mainstem. However, for fish that cannot move from exposure areas (yearlings), elevated turbidity concentrations can negatively impact fish health. In general, turbidity should not exceed background levels at a comparable location by 50 NTU instantaneously or 25 NTU for 10 days (Harvey 1989).

Sublethal responses in juvenile and adult fish for short-term exposure (days to 1 week) can occur when laboratory suspended sediment concentration range from 10-20 NTU (Robertson et al. 2006) and include:

- Increased cardiac output at 10 NTU
- Reduced respiratory function at >20 NTU
- Growth rates decrease >10-25 NTU
- Alarm reaction – erratic swimming >40 NTU
- Sight feeding is restricted above 50 NTU, consequently salmonid displacement occurs at this level

Table C-2: *In Situ* Surface Water Monitoring Field Observations

Parameter	Zone 1				Zone 2				Zone 3								Zone 4	
	SW 16-0	SW 16-1	SW 16-2	SW 16-3	SW 16-4	SW 16-5	SW 16-6	SW 16-7	SW 16-8	SW 16-9	SW 16-10	SW 16-11	SW 16-12	SW 16-13	SW 16-14	SW 16-15	SW 16-16	SW 16-17
Sample Date	2-Nov-16	30-Oct-16	30-Oct-16	2-Nov-16	1-Nov-16	30-Oct-16	30-Oct-16	30-Oct-16	1-Nov-16	1-Nov-16	2-Nov-16	1-Nov-16	1-Nov-16	1-Nov-16	1-Nov-16	2-Nov-16	1-Nov-16	1-Nov-16
Depth of water (m)	0.4	0.7	0.35	0.35	0.15	0.55	0.65	0.45	0.2	0.5	0.5	0.2	0.6	0.3	0.4	0.3	0.3	0.3
Temp	3.9	1.8	1.7	3.2	3.3	4.5	2.3	1.8	3.2	3.7	1.8	1.4	1.6	3.1	1.5	3.9	6.2	3.8
pH	8.17	7.76	7.71	8.1	3.29	4.64	6.45	6.9	8.13	7.99	8.06	6.65	7.65	8.19	7.81	7.72	7.57	7.81
pH (mV)	-80.5	-58.2	-55.5	-76.8	6.65	110	12	-14.1	nm	-71	-74	nm	nm	-81.4	-60.8	-55.8	-48.5	-60.3
DO	12.91	13.06	13.13	12.97	13.25	11.61	12.7	12.9	12.91	11.36	13.6	13.25	13.32	11.33	13.13	8.32	5.05	10.36
Tur	nm	100-140	40-60	1.3	40-50	40-50	75	58	1.8	3	1.2	0.9	1.2	16.1	40-60	3	4.2	5.4
SPC	140.3	82.4	101	143.2	561	506	109.7	103.8	111.5	153.7	128.4	128.4	128.6	130.8	111.3	119	247.1	53.9
Cond	83.8	46.5	56.1	83.5	9.7	307.5	62.2	57.8	65	91.1	71.4	76	71.2	76.1	61.4	71.1	158.2	32.1
ORP	139.5	293	211.6	190.8	509.5	383	386.8	359.2	214.8	264.8	184.5	342.8	321.2	253.3	225.4	210.1	39.6	235.9
mmHg	752.1	748.6	749.1	752.1	nm	750	749.8	749.7	nm	747.6	750.6	nm	nm	747.9	749.8	752	747.8	747.6

Sub-lethal and lethal responses for newly emergent fish are much lower than the concentrations listed above. During salmon spawning, a low sediment load is required for successful egg incubation. Deposition of transported sediment on spawning beds can reduce oxygenation and suffocate eggs (NSCU, 2016).

All surface water sampling locations in Zone 2 exceeded 40 NTU. Field pH measurements were low at three of the four sampling locations within Zone 2. Due to high turbidity coupled with low pH observed within Zone 2 both adult resident and migratory fish are not likely to occupy this habitat for long periods of time, but may utilize the area for transitory purposes.

4.3 Fish Habitat and Timing Window Summary Tables

Table C-3 is presented below and was developed to summarize the habitat observed within each of the four exposure zones. SLR biologists linked habitat features to potential life-cycle stages, functions, and dependencies. Using background documents, field observations, and direct correspondence with Mark Connor (Taku River Tlingit First Nation), confirmed and inferred use of the habitat by migratory and resident species was summarized; this information is presented in the reference column of Table C-3. Species that have the potential to exist as both migratory and resident populations are accounted for Table C-3 (e.g. in zone 3 side channel habitat, migratory and resident Dolly Varden are listed in the reference columns).

Table C-4 provides approximate timing for migration and life-cycle stages for migratory salmonid species in the Tulsequah watershed. These timing windows indicate the approximate duration of freshwater residence of migratory species and help determine the potential periods of exposure to mine discharge.

Table C-3: Fish Habitat and Distribution in the Study Area

Exposure Zone (SLR Sample Locations)	Habitat Type	Habitat Features (SLR)	Habitat Functionality (SLR)	Habitat Utilization					Habitat Utilization				
				Migratory					Resident				
				Refuge/ Rearing	Overwintering	Spawning	Migration	References	Refuge/ Rearing	Overwintering	Spawning	Local movements	References
Zone 1-Reference (SW16-0, SW16-1, SW16-2, SW16-3; PW16-1; SED16-1)	Mainstem	• Braided morphology • Glides and riffles • Swift current • Pool habitat • Gravels and boulders • Woody debris • Undercut banks • Turbidity ranged from 40 to 140 NTU • **Adult salmonids** were observed congregating in a large clear pool during the fall field investigation	Migratory corridor Fish cover provided by woody debris Turbidity offers some degree of fish cover Low gravel compaction, high turbidity and shifting channel boundaries are not likely to offer stable incubation conditions for successful egg incubation.		✓	✓	✓	Salmonids (GLL, 2007) Coho overwintering in parafluvial springs on mainstem (Mark Connor, pers. comm.)	✓	✓	✓	✓	Dolly Varden (GLL, 2007) Inferred Round Whitefish (SLR, 2016) Dolly Varden juveniles overwintering in parafluvial springs (Mark Connor, pers. comm.)
	Side Channels	• Pool, riffle glide habitat types • Clear water pools • water temperature 2°C warmer than measured in mainstem • Low turbidity (1.3 NTU) • Gravel substrates • Low water velocity	Warm water may provide overwintering habitat due to inputs from groundwater sources Potential rearing habitat Refuge habitat	✓	✓	✓		Coho & Sockeye spawning, high abundance of yearling Cohos in side water channels (Rescan 1997) Salmonids (SLR, 2016)	✓	✓	✓		Dolly Varden (GLL, 2007) Inferred Round Whitefish juveniles (SLR, 2016) Inferred Sculpin (SLR, 2016)
	Tributary - Dawn Creek	• Riffle, pool, glide • Gravel and large cobbles • Woody debris	Offers flow variations and instream cover suitable for rearing or spawning habitat	✓				Coho (GLL, 2007) YOY Sockeye (Rescan, 1997)	✓		✓		Inferred Dolly Varden (GLL, 2007) Round Whitefish (Rescan 1997) Inferred Sculpin (2016, SLR)
Zone 2-Zone of Discharge (SW16-4, SW16-5, SW16-6; SW16-7; PW16-2, PW16-3; SE16-5)	Mainstem	• Braided • Pool habitat • Gravels and boulders • Undercut banks • High turbidity in fall low-flow event (58 - 75 NTU) • Neutral field pH	Fish cover provided by woody debris Low gravel compaction, high turbidity, and shifting channel boundaries are not likely to offer stable incubation conditions for successful egg incubation.			✓	✓	Coho and Chum (Mark Connor, pers. comm.) Sockeye (spring migrants) (Mark Connor, pers. comm.)			✓	✓	Dolly Varden, Round Whitefish (GLL, 2007)

Exposure Zone (SLR Sample Locations)	Habitat Type	Habitat Features (SLR)	Habitat Functionality (SLR)	Habitat Utilization					Habitat Utilization				
				Migratory					Resident				
				Refuge/ Rearing	Overwintering	Spawning	Migration	References	Refuge/ Rearing	Overwintering	Spawning	Local movements	References
	Side Channels	• Deep pool habitat • Gravels and boulders • Overall, low field measured pH recorded at: SW 16-4 (3.29) and SW 16-5 (4.64) • Field turbidity ranged from 40-50 NTU	Potential rearing and refuge habitat in pool habitat	✓		✓		SLR observation, 2016	✓			✓	SLR observation, 2016
Zone 3-Impacted Near (SW16-8, SW16-9, SW16-10, SW16-11, SW16-12, SW16-13, SW16-14; SW16-15, PW16-4; SE16-12, SE16-14, SE16-15)	Tributary - Unnamed Tributary	• Wetted width = 1 m, 15 – 25 cm water depth • Organic detritus overlaying cobble and gravel substrate with boulders • Riffle, pool run morphology • Woody debris and undercut banks	Offers flow variations and instream cover suitable for rearing or spawning habitat	✓				Inferred Coho and Sockeye (SLR, 2016)	✓		✓	✓	Inferred Stickleback & Sculpin (SLR, 2016)
	Side Channels (PAG)	• Side channels and isolated pools with low turbidity • Low to moderate water velocity • Fines and gravels	Offers flow variations and instream cover potentially suitable for rearing or spawning habitat Under low water level conditions, some pools were disconnected from braided channel	✓				Inferred Coho (GLL, 2007)	✓		✓		Inferred Dolly Varden (SLR, 2016)
	Mainstem	• Braided morphology • Glides and riffles • Pool habitat • Gravels and boulders • Woody debris • High turbidity in low-flow event (40 – 60 NTU) • Undercut banks	Migratory corridor Fish cover provided by woody debris Low gravel compaction, high turbidity and shifting channel boundaries are not likely to offer stable incubation conditions for successful egg incubation.		✓	✓	✓	Salmonids (GLL, 2007) Coho overwintering in parafluvial springs (Mark Connor, per comm.)	✓	✓	✓	✓	Dolly Varden and Round Whitefish (GLL, 2007) Dolly Varden juveniles overwintering in parafluvial springs
	Tributary - Rogers Creek	• Reach below falls is approximately 500 m long • Riffle, pool, and glide morphology • Gravel and large cobbles	Offers flow variations and instream cover suitable for rearing or spawning habitat Flow is likely permanent and suitable to support spawning activities	✓			✓	Inferred Dolly Varden (GLL 2007) Inferred Coho and Sockeye (SLR, 2016)	✓		✓	✓	Round Whitefish refuge (Rescan 1997) Inferred Sculpin (SLR, 2016)

Exposure Zone (SLR Sample Locations)	Habitat Type	Habitat Features (SLR)	Habitat Functionality (SLR)	Habitat Utilization					Habitat Utilization				
				Migratory					Resident				
				Refuge/ Rearing	Overwintering	Spawning	Migration	References	Refuge/ Rearing	Overwintering	Spawning	Local movements	References
		• Woody debris • Low turbidity											
	Side Channels (NAG)	• Clear water side channel with drainage from Roger's Creek • Directly connected to mainstem channel	Salmonid rearing Warm water may provide overwintering habitat due to inputs from groundwater sources High abundance of yearling Cohos in side water channels Suitable spawning habitat	✓	✓	✓		Coho, Dolly Varden fry and juveniles (Rescan) Inferred Coho, Sockeye and Chum spawning	✓				Inferred Dolly Varden (SLR, 2016)
Zone 4-Impacted Far (SW16-16, SW16-17; SE16-17)	Side Channels	• Isolated pools of water • Intergravel flow • Slow water velocity • Low turbidity (10-15 NTU) • **Juvenile salmonids** (n=>50) were observed in a small isolated pool with no connection to upstream or downstream habitat during the fall field investigation.	Limited side channel habitat with connectivity to mainstem or tributaries – water levels very low during fall field visit	✓				Observed rearing salmonids in isolated pool (SLR, 2016)					
	Rogers Slough	• Roger's slough • Low water velocity • Substrate composition was primarily fines • Overhanging vegetation • Deep pool habitat • Low turbidity (10-15 NTU) • **Threespine Stickleback** were observed during the fall field investigations	Potential rearing/refuge habitat and spawning habitat	✓	✓	✓		Known rearing (GLL 2007) Coho & Sockeye spawning downstream of Slough Coho, Dolly Varden, (GLL, 2007) Coho spawning and Coho and Cutthroat rearing (Mark Connor, pers. comm.)	✓	✓	✓		Observed stickleback (SLR, 2016) Inferred Sculpin (SLR, 2016) Yearling and sub-adult Dolly Varden

Bold – indicates incidental fish observed during the 2016 on-site fish habitat assessment.

Table C-4: Approximate Timing of Migratory Salmonid Species Presence by Life-Stage in the Tulsequah River (adapted from DFO 2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon												
Adult Migration[1]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Sockeye Salmon												
Adult Migration[1]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Coho Salmon												
Adult Migration[1]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Dolly Varden/Bull Trout												
Adult Migration[1,2]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Cutthroat/Rainbow Trout (Steelhead)												
Adult Migration												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pink Salmon												
Adult Migration												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												

5.0 CONCLUSIONS AND RECOMMENDATIONS

An onsite fish habitat assessment was completed in four exposure zones within the Tulsequah River, in proximity to the Tulsequah Chief Mine Site. The purpose of this study was to correlate habitat information obtained from field investigations with species utilization by resident and migratory fish that have the potential to occur within Tulsequah River.

Key habitat types observed in the four exposure zones include mainstem, side channel, tributary and slough habitat.

Although the side channel habitat in the Zone of Discharge appear suitable for spawning, refuge, and localized movements, resident and migratory fish are not likely to utilize this area for short or long term durations due to elevated concentrations of suspended sediment and source pulses of low pH levels. It is likely that within Zone 2 mainstem habitat is primarily used as a migratory corridor for Sockeye in the spring and Coho and Dolly Varden in the fall.

Zones 3 and 4 provided the highest quality of habitat. In addition to migratory corridor functions, critical rearing habitat was observed in Zone 3. This habitat appears suitable for Coho, Dolly Varden and Sockeye rearing during the spring, summer and fall. Fall spawners such as Coho, Sockeye and Chum are likely to utilize side channel habitat in Zone 3, which received flow from tributaries and groundwater sources. Suitable habitat for resident species including Stickleback, Sculpin and Dolly Varden was widely distributed throughout Zone 3. These resident species are likely to undertake localized spring movements into tributaries for spawning and rearing functions.

Adult salmonids were observed congregating in a large clear pool, likely a parafluvial spring, in Zone 1. Through direct correspondence with Mark Connor, parafluvial springs are dispersed throughout mainstem habitat in the Tulsequah River and are utilized by Coho for overwintering habitat. The mainstem habitat in Zone 3 is likely to support parafluvial springs, utilized by salmonids from November to late April.

The habitat observed in Zone 4 is suitable to support Coho, Dolly Varden and Cutthroat rearing (Mark Connor, pers. comm.). It is expected that these juvenile fish will occupy Zone 4 in spring, summer and fall. In the fall, Coho have been documented spawning directly downstream of Roger's Slough. Zone 4 contained habitat suitable for year round residency of Stickleback.

It is recommended that the information contained in this report is used to plan representative locations for fish and benthic invertebrate collections in 2017. This will provide information related to the level of impact to fish and fish habitat and assist with the delineation of longer

term monitoring stations in reference and exposure zones. This information should be used to update the fisheries compilation maps developed by Gartner Lee Limited (2007).

6.0 REFERENCES

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Photo 1: Mainstem habitat – braided morphology observed throughout exposure zones

Photo 2: Zone 1 - Mainstem habitat – Zone 1 large deep clear pool (potential parafluvial spring); adult salmonids observed congregating

Photo 3: Zone 1 - Side Channel habitat

Photo 4: Zone 1 – Tributary habitat - Dawn Creek confluence with side channel habitat

Photo 5: Zone 1 – Instream habitat cover, woody debris

Photo 6: Zone 2 - Mainstem habitat and Side Channel habitat

Photo 7: Zone 2 - Side Channel habitat

Photo 8: Zone 3- Tributary habitat – Unnamed Tributary

Photo 9: Zone 3 - Tributary habitat – Rogers Creek, Zone 3

Photo 10: Zone 3 - PAG Side Channel and pool habitat, facing downstream

Photo 11: Zone 3 – Mainstem habitat at confluence with side channel, facing downstream

Photo 12: Zone 3 - Tributary habitat; Roger's Creek

Photo 13: Zone 3 - Tributary habitat; riffle and glide habitat in Roger's Creek, facing downstream

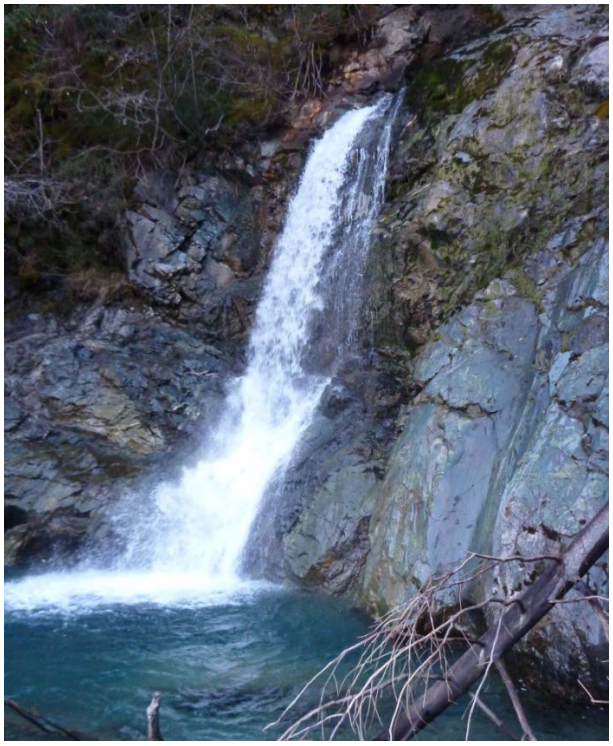

Photo 14: Zone 3 - Tributary habitat; Roger's Creek falls

Photo 15: Zone 3 – Side Channel habitat adjacent to NAG

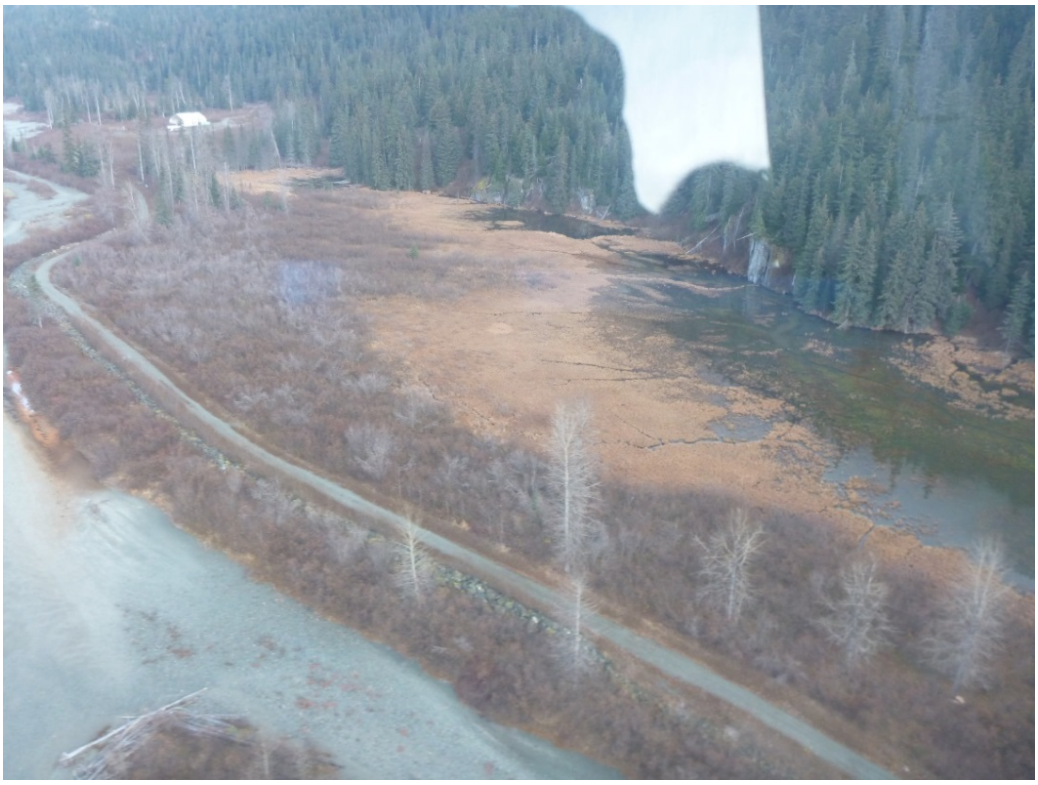

Photo 16: Zone 4 - Roger's Slough and adjacent causeway

Photo 17: Zone 4 - Roger's Slough habitat

Photo 18: Zone 4 - Roger's Slough clear span bridge supporting causeway and maintaining connectivity between slough and mainstem habitat

Photo 19: Zone 4 - Side Channel habitat – isolated pool with juvenile salmonids

Photo 20: Zone 4 - Juvenile salmonid observed in Side Channel habitat

Photo 21: Zone 4 - Threespine Stickleback observed utilizing habitat in Roger's Slough

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