RED MOUNTAIN UNDERGROUND GOLD PROJECT
VOLUME 3 | CHAPTER 17
AQUATIC RESOURCES EFFECTS ASSESSMENT

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17 AQUATIC RESOURCES EFFECTS ASSESSMENT

17.1 Introduction

The proposed Red Mountain Underground Gold Project (the Project) is an underground gold mine in the Bitter Creek valley, located near Stewart, in northwest British Columbia (BC).

This Environmental Impact Statement (Application/EIS) chapter presents the effects assessment for the Aquatic Resources valued component (VC), which is represented by Benthic Invertebrates and Periphyton. The purpose of this assessment is to comprehensively evaluate the potential changes to Aquatic Resources that may result from the Project.

The introduction summarizes why Aquatic Resources was selected as a VC, what it encompasses, and linkages to other VCs. The remainder of the chapter covers: the scope of the assessment, existing aquatic conditions (*i.e.,* baseline data), potential effects, mitigation measures, residual effects and their significance, cumulative effects, follow-up strategy, and conclusions.

Aquatic Resources was selected as a VC based on input and consultation with the Project's technical Working Group, which is composed of Nisga'a Nation, as represented by the Nisga'a Lisims Government (NLG), provincial government, and federal government representatives. Aquatic Resources encompasses benthic invertebrates, periphyton, and the aquatic habitat that supports these organisms.

Primary and secondary producers such as periphyton and benthic invertebrates are important components of the aquatic food web foundation. They provide food sources for higher trophic levels (*e.g.*, fish and birds), and are useful as indicators of overall aquatic health due to their sedentary life histories. Accordingly, the Aquatic Resources VC is closely linked to the Surface Water Quality, Sediment Quality and is considered a pathway component to Fish, and Fish Habitat VCs. Benthic invertebrates support the assessment of potential effects on benthivorous fish health and fish habitat. Periphyton supports the assessment of potential effects on fish habitat via effects on Benthic Invertebrates. Benthic invertebrate success is often based on an abundant and diverse periphyton community. Therefore, periphyton is a representative indicator of benthic invertebrate health and, in turn, fish, fish health, and habitat integrity.

The results of the Aquatic Resources Effects Assessment show that there will be no effects to Aquatic Resources outside of Canada.

17.2 Regulatory and Policy Setting

The Application Information Requirements (AIR) for the Project, approved by the British Columbia Environmental Assessment Office (EAO) in March 2017, outlines the requirements of the Aquatic Resources Effects Assessment to meet both the provincial and federal environmental assessment (EA) requirements under the BC Environmental Assessment Act (2002) and *Canadian Environmental Assessment Act, 2012* (CEAA 2012), respectively.

Federal and provincial regulations and policies which guide protection to Aquatic Resources during the mine development process are summarized in Table 17.2-1.

The Canadian Council of Ministers of Environment (CCME) Water and Sediment Quality Guidelines, and the BC Approved Water Quality Guidelines cover protection of freshwater aquatic life. Guidelines are not regulatory instruments but can be defined as targets or triggers for action if not met and can be used as the basis of regulatory limits. Generally, the BC guidelines are used where BC and CCME guidelines differ, as the BC guidelines are intended to represent more closely the conditions in BC waters, while the CCME (federal) guidelines are more general in nature.

In addition to the guidelines and legislation outlined in Table 17.2-1, BC MOE's Water and Air Baseline Monitoring Guidance Document (BC MOE, 2016) outlines and defines the baseline study requirements for mining projects in BC. Information requirements for water quality (including physical and chemical parameters, aquatic sediments, tissue residues, and aquatic life), fish and fish habitat, and initial environmental impact assessment are included.

Table 17.2-1: Summary of Applicable Legislation, Regulations, and Guidelines for Aquatic Resources Effects Assessment, Red Mountain Project

Legislation/Regulation/Policy	Level of Government	Administered by	Description
Fisheries Act (1985)	Federal	Fisheries and Oceans Canada (DFO)	The *Fisheries Act* prohibits the carrying out of any work, undertaking or activity that results in serious harm to fish that are part of a commercial, recreational, or Aboriginal (CRA) fishery, or to fish that support such a fishery. 'Serious harm' is defined as: "the death of fish or the permanent alteration to, or destruction of, fish habitat". While the act does not directly protect benthic invertebrates and periphyton, these aquatic organisms are afforded protection because they support fish and are a constituent of fish habitat.
Metal Mining Effluent Regulations	Federal	Environment and Climate Change Canada (ECCC)	The Metal Mining Effluent Regulations (MMER) are administered under section 36(3) of the *Fisheries Act*. MMER allows proponents to deposit deleterious substances into waters frequented by fish, if the Schedule 2 of the MMER is amended to designate these waters as a Tailings Impoundment Area. In addition, discharge of effluent from metal mines to surface waters is regulated through the MMER. Under MMER, if mine discharge into the receiving environment exceeds 50 m^3 per day the mine shall conduct environmental effects monitoring (EEM) studies of the potential effects of effluent on the fish populations, on fish tissue and on the benthic invertebrate community.
Species at Risk Act (2002)	Federal	DFO (for Schedule 1 aquatic species)	The *Species at Risk Act* (SARA; 2002) prohibits killing, harming, capturing, or harassing species listed (in schedule 1 of the Act) as endangered, threatened or extirpated and provides protection for habitat that supports these species. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses and identifies species at risk. An activity that affects an aquatic species at risk in a way that is prohibited by the federal *Species at Risk Act* (SARA), requires approval from Fisheries and Oceans Canada (DFO).

Legislation/Regulation/Policy	Level of Government	Administered by	Description
British Columbia Conservation Data Centre (BC MOE, 2010)	Provincial	BC Ministry of Environment (BC MOE)	The CDC assigns species at risk to one of three ranked lists: red-, blue-, and yellow-lists. These lists help to identify species (and ecosystems) that can be considered for designation as Endangered or Threatened either provincially under the British Columbia *Wildlife Act*, or nationally by the COSEWIC. Red-listed species have, or are candidates for, Extirpated, Endangered, or Threatened status in British Columbia. Blue-listed species are considered to be of Special Concern (formerly Vulnerable) in British Columbia. Blue-listed species are at risk, but are not Extirpated, Endangered or Threatened.
Environmental Management Act (2003)	Provincial	BC MOE	The *Environmental Management Act* (EMA) prohibits pollution of water, land, and air in BC. Mines require authorization under the EMA to discharge mining effluent to receiving waters, and are required to register (or include on the permit) sewage discharges greater than 100 persons. The EMA specifies environmental monitoring requirements for EMA permit holders, which should enable ongoing evaluation of waste management performance, receiving environment condition, and evaluation of impact predictions made during the permit application.
Water Sustainability Act (2016)	Provincial	BC Ministry of Forests, Lands and Natural Resource Operations (BC MoFLNRO)	The *Water Sustainability Act* (WSA) regulates the diversion and use of water resources. Under the WSA, a license or use approval is required to make changes in and about a stream. Changes in and about a stream are defined as: • Any modification to the nature of the stream, including any modification of the land, vegetation and natural environment of a stream or the flow of water in a stream, or • Any activity or construction within a stream channel that has or may have an impact on a stream or stream channel.
CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life	Federal	CCME	Water quality guidelines are intended to provide protection of freshwater life from anthropogenic stressors such as chemical inputs or changes to physical components. Guideline values are meant to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive stage of the most sensitive species for the long term.

Legislation/Regulation/Policy	Level of Government	Administered by	Description
CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life	Federal	CCME	The CCME Sediment Quality Guidelines cover protection of freshwater aquatic life by providing scientifically-derived benchmarks for evaluating the potential for observing adverse biological effects in aquatic systems. CCME's Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels (PELs), are associated with occasional and frequent adverse biological effects, respectively.
CCME Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota	Federal	CCME	The CCME Canadian Tissue Residue Guidelines address those substances for which aquatic food sources are the main route of exposure. The tissue residue guidelines (TRGs) refer to the maximum concentration of a chemical substance in the tissue of aquatic biota that is not expected to result in adverse effects in wildlife. TRGs can apply to any aquatic species consumed by wildlife, including fish, shellfish, other invertebrates, or aquatic plants.
BC Water Quality Guidelines: • Working Water Quality Guidelines (2015) • Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture (2017)	Provincial	BC MOE	In BC, the definition of water quality includes sediments, therefore the Approved Water Quality Guidelines also includes sediment quality values for some parameters. These guidelines serve as benchmarks for the protection of benthic aquatic life in freshwater and marine environments. BC MOE (2015) also has Working Water Quality Guidelines (WWQGs), and Working Sediment Quality Guidelines (WSQGs), which provide benchmarks for those substances that have not yet been fully assessed and formally endorsed by BC MOE and are obtained from other jurisdictions, including the CCME. Most WSQGs have a 'Lower WSQG' and an 'Upper WSQG', which are equivalent to CCME's Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels (PELs), respectively.

17.3 Scope of the Assessment

17.3.1 Information Sources

The information sources used to assess potential Project effects on Aquatics Resources included baseline reports, the Project Overview (Volume 2, Chapter 1), and the effects assessments for the Surface Water Quality and Sediment Quality VCs (Chapters 13 and 14, respectively). Information gathered during consultation with NLG, as well as meetings and discussion with the Project's working group was also incorporated.

Baseline characterization of Aquatic Resources within the Project area is summarized in Section 17.4.4. The baseline studies included detailed review of historical and background information, data gap analysis, and field surveys. Baseline field surveys on Aquatic Resources were conducted in 1993 (Rescan 1994), and from 2014 to 2016. These efforts are detailed in Volume 8, Appendix 18-A, Baseline Fisheries and Aquatic Resources.

As outlined in Chapter 6 (Effects Assessment Methodology), IDM has not conducted primary traditional use or traditional ecological knowledge (TEK) surveys in support of the Project due to the preferences of Nisga'a Nation, as represented by NLG, and EAO's and the Agency's direction for comparatively low levels of engagement with the other Aboriginal Groups potentially affected by the Project. IDM has committed to using TEK where that information is publicly available. As no TEK relevant to this effects assessment was publicly available at the time of writing, no TEK has been incorporated.

17.3.2 Input from Consultation

IDM is committed to open and honest dialogue with regulators, Aboriginal Groups, community members, stakeholders, and the public.

IDM conducted consultation with regulators and Aboriginal Groups through the Working Group co-led by EAO and the Agency. Where more detailed and technical discussions were warranted, IDM and Working Group members, including sometimes NLG representatives, held topic-focused discussions, the results of which were brought back to EAO and the Working Group as a whole.

Further consultation with Aboriginal Groups, community members, stakeholders, and the public has been conducted as outlined by the Section 11 Order and EIS Guidelines issued for the Project. More information on IDM's consultation efforts with Aboriginal Groups, community members, stakeholders, and the public can be found in Chapter 3 (Information Distribution and Consultation Overview), Part C (Aboriginal Consultation), Part D (Public Consultation), and Appendices 27-A (Aboriginal Consultation Report) and 28-A (Public Consultation Report). A record of the Working Group's comments and IDM's responses can be found in the comment-tracking table maintained by EAO.

Table 17.3-1 provides a summary of the consultation feedback and input that was received and that was specifically relevant to and affected issues scoping and VC selection for Aquatic Resources.

Table 17.3-1: Consultation Feedback

Topic (VC, IC, Sub-Component)	Feedback by*				Consultation Feedback	Response
	NLG	G	P/S	O		
Aquatic Resources Fish Fish Habitat Groundwater Quality Hydrogeology Hydrology Sediment Quality Surface Water Quality	X				NLG requested a conceptual Aquatic Effects Monitoring Program (AEMP) design be included in the Application.	A conceptual AEMP has been included in Volume 5, Chapter 29 of the Application/EIS.
Aquatic Resources	X				NLG requested that benthic invertebrates be included in the effects assessment as a VC.	IDM has included benthic invertebrates as an Aquatic Resources VC.
Aquatic Resources	X				NLG requested that baseline for Periphyton and the benthic invertebrate community be characterized in Bitter Creek, Goldslide Creek, Otter Creek, Bear River, and American Creek. NLG recommended that three years of data from multiple sampling sites on each waterbody be taken.	Baseline conditions for Periphyton and benthic invertebrate communities have been characterized for the waterbodies recommended by NLG. Spatial and temporal variability and standard metrics, including abundance and diversity of Periphyton communities and benthic invertebrate communities, were evaluated based on two years of data.
Aquatic Resources		X			ECCC recommended that invertebrate species, specifically molluscs and arthropods, be added as VCs, and that each federally listed, COSEWIC–assessed, or provincially listed invertebrate species that is likely to occur within the Local and Regional Study Area be included as a separate VC (*i.e.,*	No mollusks are known to occur within the Project area that would help to inform the effects assessment. Benthic invertebrates are the most likely arthropod group to interact with the Project. They have been

Topic (VC, IC, Sub-Component)	Feedback by*				Consultation Feedback	Response
	NLG	G	P/S	O		
					not representing a larger species group).	assessed as a VC under Aquatic Resources. Federal and provincial species databases were reviewed, and no listed species were identified in the LSA or RSA. Baseline studies did not detect any federally listed, COSEWIC–assessed, or provincially listed invertebrate species.
Aquatic Resources	X				NLG requested a conceptual AEMP design be included in the Application.	A conceptual AEMP has been included in the Application/EIS.

*NLG = Nisga'a Lisims Government; G = Government - Provincial or federal agencies; P/S = Public/Stakeholder - Local government, interest groups, tenure and license holders, members of the public; O = Other

17.3.3 Valued Components, Assessment Endpoints, and Measurement Indicators

There are several potential pathways through which the Project could result in effects on Aquatic Resources. Potential effects pathways start with Project activities (*e.g.*, mine water discharge, instream works), which can cause changes to the physical and chemical habitat of aquatic organisms.

The primary measurement indicators for the Aquatic Resources VC are changes in abundance and diversity of periphyton and benthic invertebrates, changes in water and sediment quality, and changes in hydrology (Table 17.3-2). Changes in sediment quality, water quality, or physical habitat conditions (*e.g.,* flow regimes) represent potential stressors that, in turn, could lead to effects on Aquatic Resources.

Groundwater Quality (Volume 3, Chapter 11), Hydrology (Volume 3, Chapter 12), Surface Water Quality (Volume 3, Chapter 13) and Sediment Quality (Volume 3, Chapter 14), are pathways of effects to Aquatic Resources. Aquatic Resources is an effect pathway to the Fish and Fish Habitat VCs (Volume 3, Chapter 18).

Intermediate Components (ICs) represent the pathway of potential effect between a Project component or activity and a VC. Groundwater Quality is an IC and is linked to the Aquatic Resources VC via the Surface Water Quality and Sediment Quality VCs.

Table 17.3-2: Assessment Endpoints and Measurement Indicators for Aquatic Resources

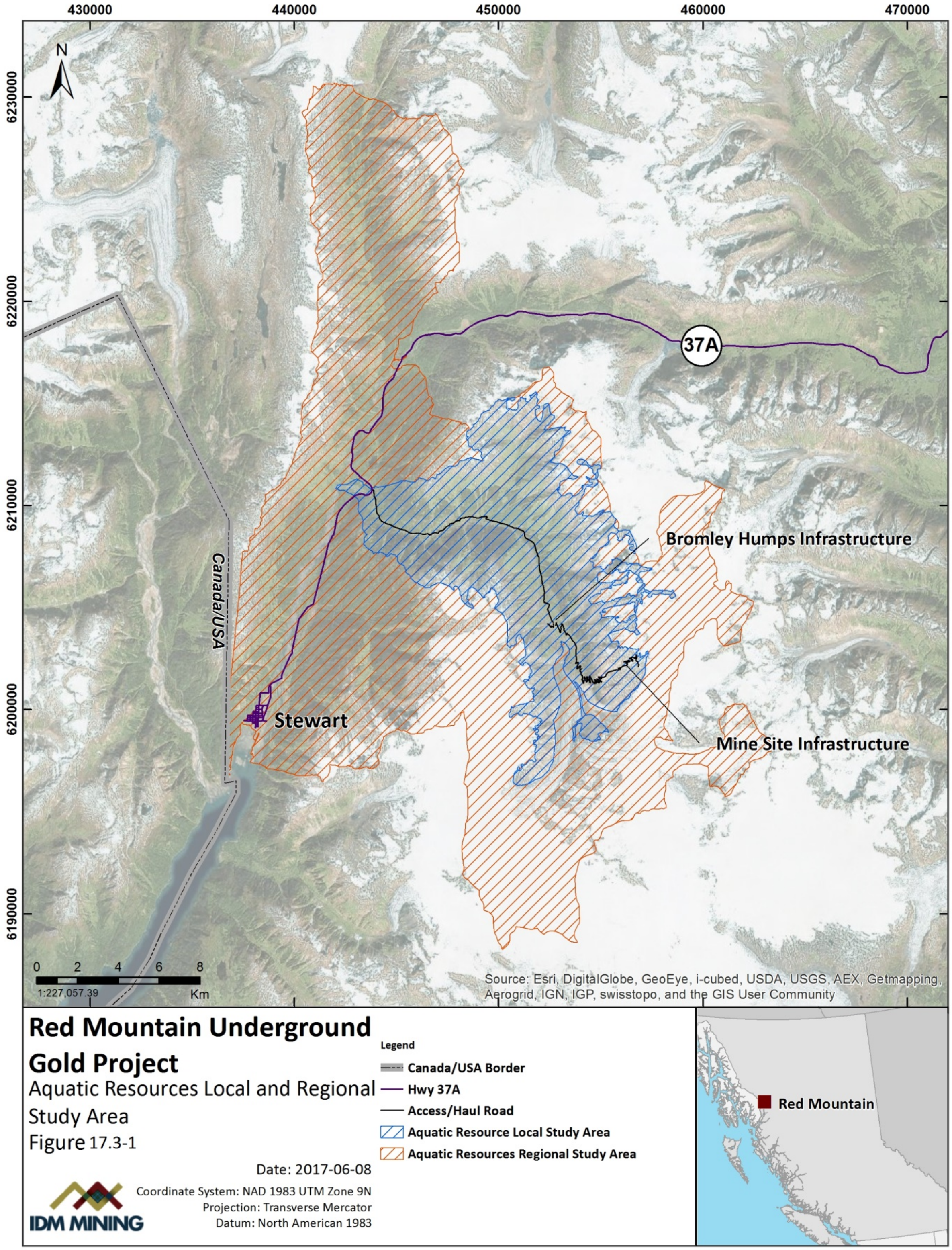
VC	Primary Measurement Indicators	Assessment Endpoint
Aquatic Resources represented by: • Periphyton • Benthic Invertebrates	• Abundance and diversity of periphyton and benthic invertebrates • Change in water quality parameter concentrations • Change in hydrology (timing, flows and volume) • Change in sediment quality parameter concentrations	The maintenance of ecological conditions that support populations relative to existing baseline.

17.3.4 Assessment Boundaries

17.3.4.1 Spatial Boundaries

The spatial boundaries for assessment of the Aquatic Resources VC consist of two spatial boundaries: the Local Study Area (LSA) and the Regional Study Area (RSA). The study area boundaries were based on the likely geographic extent of potential direct and indirect effects to Aquatic Resources from the Project (Figure 17.3-1). The LSA encompasses the zone of influence of the Project, covering the area within which there is a reasonable potential for adverse Project-specific effects to occur. For Aquatic Resources, the LSA includes the Bitter Creek watershed up to the Bromley Glacier. The RSA is larger, and provides context for the assessment of potential Project effects. The RSA was used for assessment of direct and indirect Project effects and for assessment of potential cumulative effects. The RSA surrounds the LSA, and also contains the Bear River watershed, from American Creek to Stewart and the northern end of the Portland Canal.

Figure 17.3-1 Local and Regional Study Areas for Aquatic Resources



17.3.4.2 Temporal Boundaries

The temporal boundaries for Aquatic Resources VC has been defined as “Life of Project”, which covers the period from construction through to the Post-Closure Phase of the Project (Table 17.3-3). These boundaries capture the time periods within which a reasonable expectation of interaction with components of the freshwater environment can be predicted.

Table 17.3-3: Temporal Boundaries for the Effects Assessment of Aquatic Resources

Phase	Project Year	Length of Phase	Description of Activities
Construction	Year -2 to Year 1	18 months	Construction activities and construction of: Access Road, Haul Road, Powerline, declines, Power supply to the underground, water management features, water treatment facilities, Tailings Management Facility (TMF), Process Plant, ancillary buildings and facilities; underground lateral development and underground dewatering; ore stockpile and ore processing start-up; and receiving environmental monitoring.
Operation	Year 1 to Year 6	6 years	Ramp up to commercial ore production and maintain a steady state of production, underground dewatering, tailings storage, water treatment, gold dore shipping, environmental monitoring, and progressive reclamation.
Closure and Reclamation	Year 7 to Year 11	5 years	Underground decommissioning and flooding; decommissioning of infrastructure at portals, Process Plant, TMF, ancillary buildings and facilities; reclamation, water treatment; removal of water treatment facilities.
Post-Closure	Year 12 - 21	10 years	Receiving environment monitoring to ensure closure objectives are satisfied.

17.3.4.3 Administrative and Technical Boundaries

Administrative boundaries refer to the limitations imposed on the assessment by political, economic, or social constraints, and consider the jurisdiction in which the Project is located. The Project falls within the resource management area boundaries of DFO’s Pacific Region, BC MFLNRO’s Skeena Region (Region 6), and the Regional District of Kitimat-Stikine.

The Project is located within the Nass Area and Nass Wildlife Area, as set out in Nisga’a Final Agreement (NFA). Pursuant to the NFA, Nisga’a Nation, as represented by NLG, has Treaty rights to the management and harvesting of fish, wildlife, and migratory birds within the

Nass Area and Nass Wildlife Area. The Project is also within the asserted traditional territories of Tsetsaut Skii km Lax Ha (TSKLH) and Métis Nation BC (MNBC).

Technical boundaries refer to the constraints imposed on the assessment by limitations in the ability to predict the effects of a Project. Technical boundaries for the assessment of potential effects to Aquatic Resources include:

- Limitations in current knowledge;
- Limitations imposed by the constraints of the data collection methods, study design, and data coverage; and
- Assumptions required in the predictive models, specifically the Water and Load Balance Model Report (Appendix 14-C).

17.4 Existing Conditions

17.4.1 Overview of Existing Conditions

The Project area is characterized by rugged, steep terrain with weather conditions typical of the northern coastal mountains. Temperatures are moderated year-round by the coastal influence. The mean annual air temperature (MAAT) at an elevation of 1514 meters is −0.8°C, with monthly mean values ranging between −6.4°C in December and January and 6.9°C in August (Appendix 12-A: Baseline Climate and Hydrology Report). Precipitation is significant throughout the year; October is typically the wettest month and there is significant snow accumulation in the winter (JDS 2016). The snowfall, steep terrain, and frequently windy conditions present blizzard and avalanche hazards during the winter (JDS 2016). The climatic conditions at the Project site are described in the baseline climate and hydrology report (Appendix 12-A).

A deactivated logging road extends e from Highway 37A for approximately 13 km along the Bitter Creek valley; however, it is currently impassable for heavy equipment due to washouts caused by Bitter Creek, and at other creek crossings (JDS 2016).

The proposed underground mine is situated at the top of the Red Mountain cirque, a short, westerly trending hanging valley above the Bromley Glacier. The cirque is drained by Goldslide Creek. Goldslide Creek flows southwest into the east side of Bromley Glacier, which extends about 1 km to the Bitter Creek headwaters. Flows in Goldslide Creek peak during freshet (typically in June) and Goldslide Creek is not glacially-influenced. Goldslide and Rio Blanco Creeks are the two uppermost tributaries to Bitter Creek. Other Bitter Creek tributaries relevant to the baseline Aquatic Resources evaluation are Otter Creek, Roosevelt Creek, and two small unnamed tributaries to Bitter Creek that drain Bromley Humps. Otter Creek is glacially-influenced and its discharge peaks during summer (typically in July) because of glacial melt. The winter low flow period in Otter Creek is from November to April. Like Otter Creek, Bitter Creek is glacially-influenced and its flows peak in summer (typically in July), and are low during November to April. Bitter Creek is a tributary to the

Bear River, which then discharges into the Portland Canal, near Stewart (Figure 17.4-1). Flows peak in summer (July/August) in Bear River.

The proposed Project is composed of two main areas with interconnecting access roads (Figure 17.4-1): the Mine Site with an underground mine and three portals (Upper Power, Lower Portal and Vent Portal) at the upper elevations of Red Mountain (1950 metres above sea level [masl]) (Figure 17.4-2); and Bromley Humps situated in the Bitter Creek valley (500 masl), with a Process Plant and TMF (Figure 17.4-3).

Figure 17.4-1: Project Overview

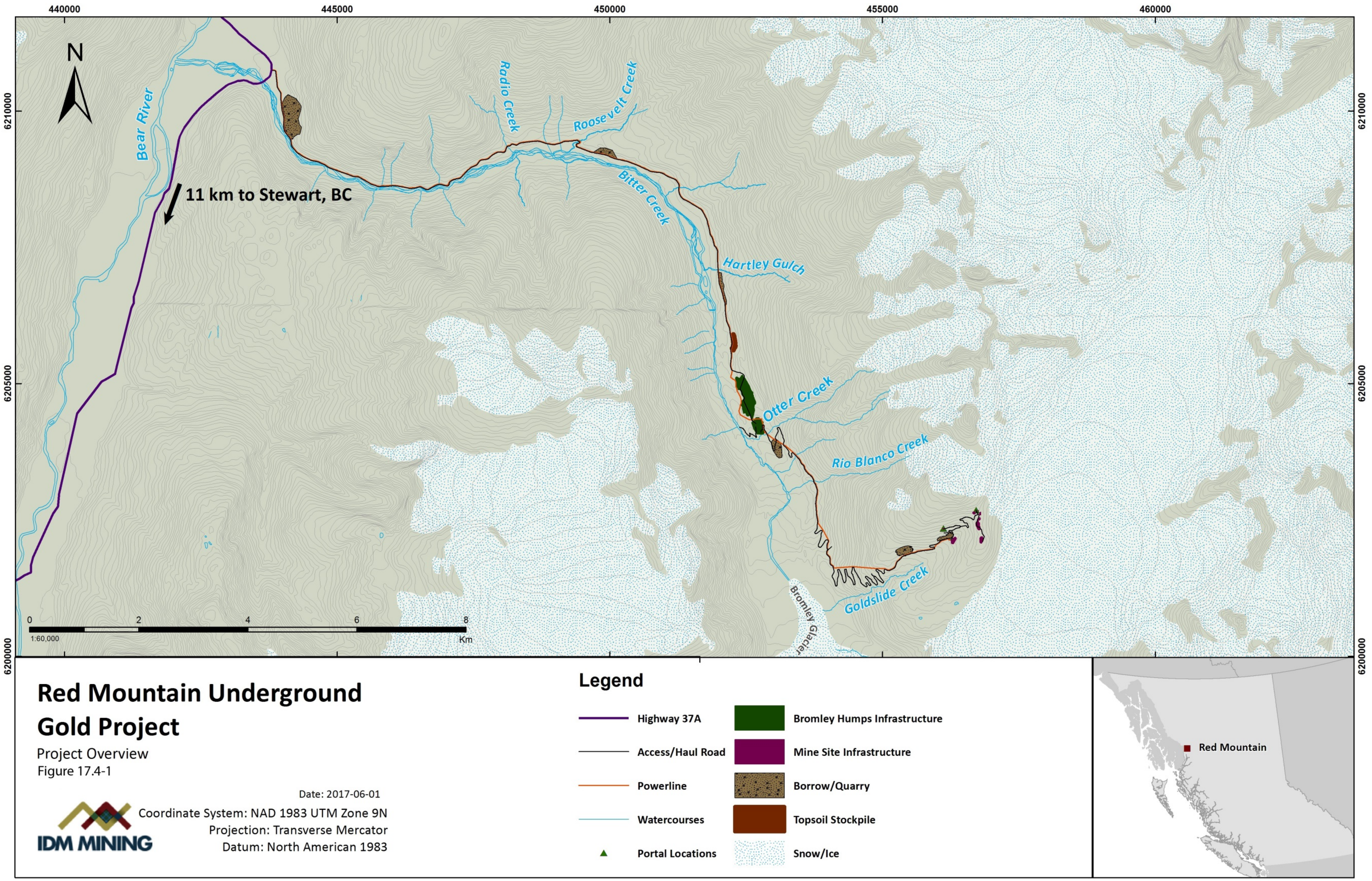


Figure 17.4-2: Project Footprint – Mine Site

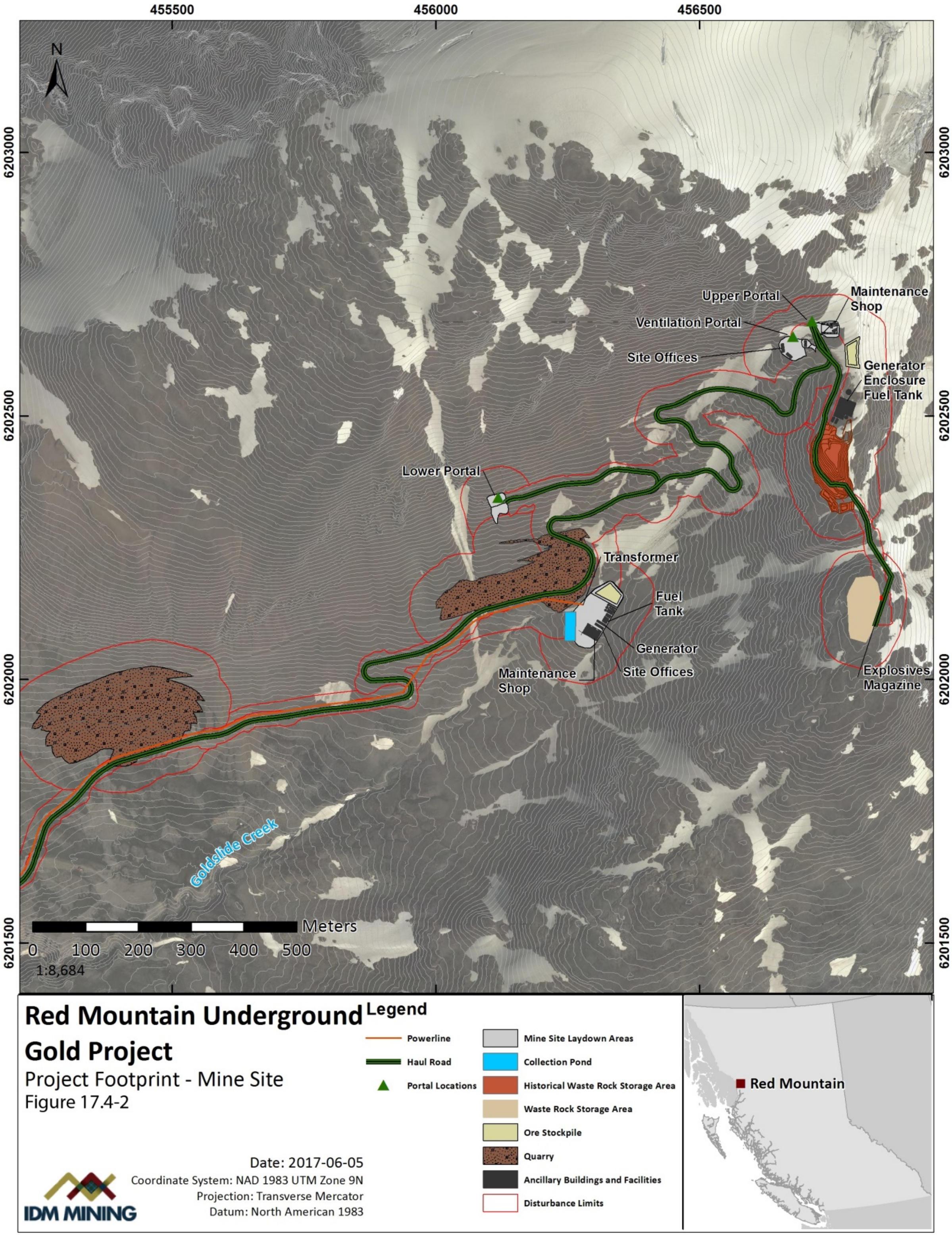
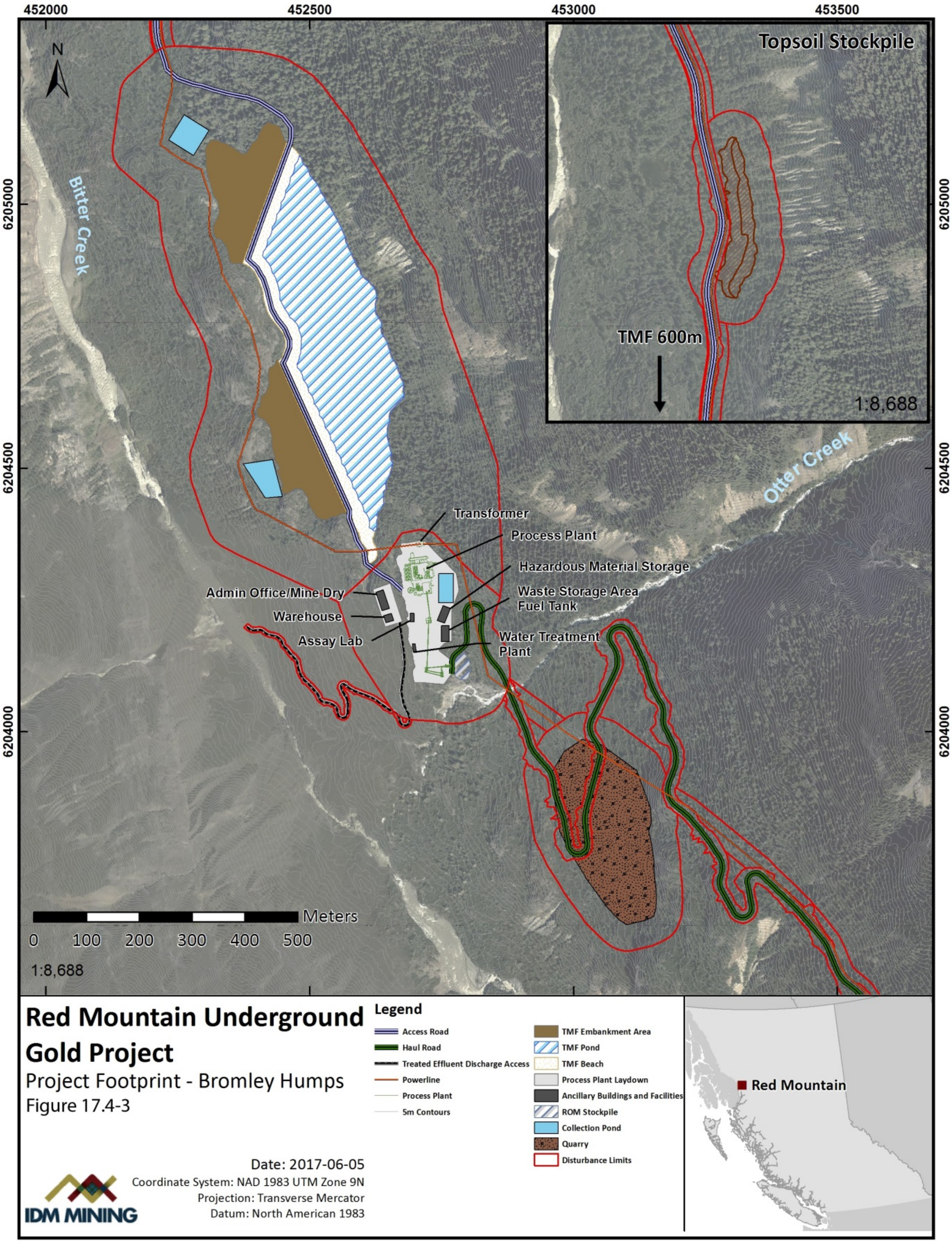


Figure 17.4-3: Project Footprint – Bromley Humps



17.4.2 Past and Current Projects and Activities

Placer mining commenced in Bitter Creek at the base of Red Mountain at the turn of the 20th century. In 1989, gold mineralization was discovered and surface drilling was conducted from 1991 to 1994.

Existing infrastructure on the site includes an underground decline and drift development that was developed in 1993 and 1994 for bulk sampling the mineralized Marc zone, a 50,000 tonne (t) waste rock pile, a surface tote road network, camp buildings, helipads, and used mobile equipment (JDS 2016).

Current activities include environmental baseline studies in the Bitter Creek watershed. Between 2015 and 2016, a surface and underground drilling program at Red Mountain was launched, which included the dewatering of the underground mine and obtaining material for engineering and resource studies.

The exploration and dewatering program is the only significant anthropogenic activity that may have resulted in a human-caused alteration to the environmental setting of the project, namely the aquatic environments of Goldslide and Bitter Creeks. Human disturbances through mining exploration may have affected aquatic resources in Goldslide Creek, but are unlikely to have resulted in any measurable changes to the benthic invertebrate or periphyton community because of the small-scale nature of these activities, and limited interaction with Goldslide Creek.

The discharge water from dewatering, bypassed Goldslide Creek, as it was pumped to the Cambria Icefield. The discharge followed an eight-kilometer pathway before potentially entering the headwaters of Bitter Creek, formed by Bromley Glacier meltwater (IDM, 2017).

Water quality monitoring during the dewatering program was conducted at BC08 (referred to as “CP2” in 2016 Dewatering Report (IDM, 2017)). The monitoring results indicated that the mine discharge was not influencing water quality in Bitter Creek, as there were no fluctuations in water quality parameters that were outside of the natural variability. It follows that there were no effects on Aquatic Resources in Bitter Creek from the mine dewatering.

17.4.3 Project-Specific Baseline Studies

17.4.3.1 Data Sources

The baseline studies included detailed review of historical and background information, data gap analysis, and field surveys. Initial baseline field surveys for Aquatic Resources (periphyton and benthic invertebrates) were conducted in 1993 to 1994 (Table 17.4-1; Rescan, 1994). The recent baseline programs to support the Application/EIS were carried out from 2014 to 2016 (Table 17.4-1; Appendix 18-A). The 2014 sampling event also included benthic tissue sampling of periphyton, benthic invertebrates, and macrophytes.

Table 17.4-1: Baseline Benthic Invertebrate and Periphyton Sampling, 1990-2017

Year	1993		2014		2015		2016	
Sampling Agency	**Rescan**		**SNC-Lavalin**		**Northlink Consultants LP**		**Northlink Consultants LP**	
Sampling Component	Periphyton	Benthic Invertebrates	Periphyton	Benthic Invertebrates	Periphyton	Benthic Invertebrates	Periphyton	Benthic Invertebrates
Sampling Method	syringe/brush apparatus	Hess/Surber/ Corer	brush apparatus	CABIN (kicknet)	-	CABIN (kicknet)	brush apparatus	CABIN (kicknet)
Laboratory	Unknown	Unknown	Biologica Ltd.	Biologica Ltd.	-	Biologica Ltd.	Biologica Ltd.	Biologica Ltd.
Bitter Creek	4 sites	3 sites	4 sites	4 sites	-	3 sites	3 sites	3 sites
Roosevelt Creek	2 sites	2 sites	-	-	-	-	-	-
American Creek	-	-	1 site	1 site	-	1 site	1 site	1 site
Goldslide Creek	-	-	1 site	1 site	-	2 sites	1 site	1 site (GSC02)
Otter Creek	-	-	1 site	1 site	-	-	1 site	1 site
Bear River	1 site	1 site	2 sites	2 sites	-	2 sites	2 sites	2 sites
Hartley Gulch	-	-	-	-	-	1 site	-	-

17.4.3.2 Primary Data Collection and Analysis Methods

17.4.3.2.1 1993 Sampling Locations

The 1993 Aquatic Resources sampling program covered Bitter Creek (four sites), Roosevelt Creek (two sites), and Bear River (one site) (Table 17.4-2; Figure 17.4-2). All sites were located within fish bearing areas. The most downstream site on Bitter Creek (F4) was located immediately below the Highway 37A crossing, and the most upstream site (F8) was located just downstream of Hartley Gulch. The sites are not co-located with the 2014-2016 sites.

Table 17.4-2: Aquatic Resources sampling sites, 1993

Watercourse	Site Name	Site Description	Location
Bitter Creek	F8	Spring Fed Channel	Approximately 200 m downstream of Hartley Gulch confluence, on north side of Bitter Creek
Bitter Creek	F1	Spring Fed Channel	Approximately 400 m upstream of Roosevelt Creek confluence
Bitter Creek	F2	Spring Fed Creek	Approximately 500 m downstream of Radio Creek confluence
Bitter Creek	F4	Side Channel	Downstream of Highway 37A bridge
Roosevelt Creek	F7	Mainstem Edgewater	Approximately 1.3 km upstream from Bitter Creek
Roosevelt Creek	F6	Side Channel	Approximately 250 m upstream from Bitter Creek
Bear River	F5	Side Channel	Approximately 1.4 km downstream from Bitter Creek confluence

17.4.3.2.2 2014-2016 Sampling Locations

2014-2016 monitoring locations in the LSA (Table 17.4-3; Figure 17.4-2) included: BC02, BC04, BC013.4, and BC08 (Bitter Creek); GSC02 and GSC05 (Goldslide Creek); OC04 (Otter Creek); and UN2.0 (Hartley Gulch). Additional monitoring sites in the RSA included BR08 and BR06 (Bear River) and AC02 (American Creek). The 2014-2016 sites (Table 17.4-2) are not co-located with the 1993 sites.

Table 17.4-3: Baseline Aquatic Resources sampling sites, 2014-2016

Watershed	Site Name	Site Description	Fish Bearing	Location relative to closest 1993 site
Bitter Creek	BC13.4	Bromley Humps Near Field Impact Site. Approximately 1.5 km downstream first fish barrier on Bitter Creek.	Yes	BC13.4 is upstream of F8
	BC02	Bromley Humps Mid Field Impact Site. Immediately upstream of Highway 37A bridge.	Yes	BC02 is upstream of F4
	BC04	Bromley Humps Mid Field Impact Site. Downstream of Roosevelt Creek confluence.	Yes	BC04 is downstream of F1
	BC08	Mine Area Mid Field Impact Site. Downstream of the Bromley Glacier, upstream of Rio Blanco Creek inflow.	No	BC08 is upstream of F8
Goldslide Creek	GSC02	Mine Area Near Field Impact Site. Downstream of GSC05.	No	n/a
	GSC05	Mine Area Near Field Impact Site. Upstream of GSC02, near camp.	No	n/a
Otter Creek	OC04	Mine Area Mid Field Reference Site. Bromley Humps Near Field Reference Site. Upper Otter Creek.	No	n/a
Hartley Gulch	UN2.0	Mine Area Mid Field Reference Site. Upper Hartley Gulch.	Yes	n/a
Bear River	BR06	Bromley Humps Far Field Impact Site. Approximately 2.5 km downstream of Bitter Creek inflow.	Yes	BR06 is downstream of F5
	BR08	Bromley Humps Far Field Reference Site. Approximately 2.0 km upstream of Bitter Creek inflow.	Yes	BR08 is upstream of F5
American Creek	AC02	Bromley Humps Far Field Reference Site. American Creek just upstream of confluence with Bear River.	Yes	n/a

The 2014-2016 sites cover areas that could be affected by physical locations of Project infrastructure. Sites were established upstream and downstream of potential mine influences, and at far-field locations where downstream and/or cumulative effects could be assessed. Reference sites were also established.

Where possible, Aquatic Resources sampling was co-located with sediment and water quality sampling. Sites were named according to their associated water quality sampling location; for sites having no associated water quality site, the site name was derived from its distance upstream from its confluence (*e.g.*, BC 13.4 is 13.4 km upstream on Bitter Creek). Some sampling locations differed from water quality locations as conditions were not ideal for sampling benthic invertebrates or periphyton. Sampling locations within each site were chosen based on the presence of riffle habitat (for benthic invertebrates).

In addition to the named streams listed in Table 17.4-3, there are two small unnamed watercourses, located in Bromley Humps where the TMF is proposed. Both watercourses drain into Bitter Creek. There are no baseline sampling sites for Aquatic Resources located on those watercourses. Listed below are the watercourses and associated sampling locations from the 2014 to 2016 baseline program.

Bitter Creek

Bitter Creek flows for 18.1 km from the toe of the Bromley Glacier to its confluence with the Bear River. Bitter Creek sites (BC02, BC04, BC08, and BC13.4) are all downstream of the proposed mining facilities. There are no monitoring locations on Bitter Creek upstream of the Goldslide Creek confluence and thus no upstream reference location, because the creek is overlain by Bromley Glacier at, and, upstream of Bitter Creek's confluence with Goldslide Creek.

Goldslide Creek

Goldslide Creek drains the Mine Site cirque. The creek is confluent with the right margin of the Bromley Glacier, out of which Bitter Creek flows. There are two sites on Goldslide Creek (GSC02, GSC05), downstream of the proposed mining facilities.

Otter Creek

Otter Creek is a right bank tributary of Bitter Creek. The site on Otter Creek (OC04) is upstream of Bromley Humps where the TMF and Process Plant are proposed.

Hartley Gulch

Hartley Gulch is another right bank tributary of Bitter Creek, downstream of Otter Creek. Mine infrastructure is not proposed within the area drained by this watercourse. There is one site on Hartley Gulch (UN2.0).

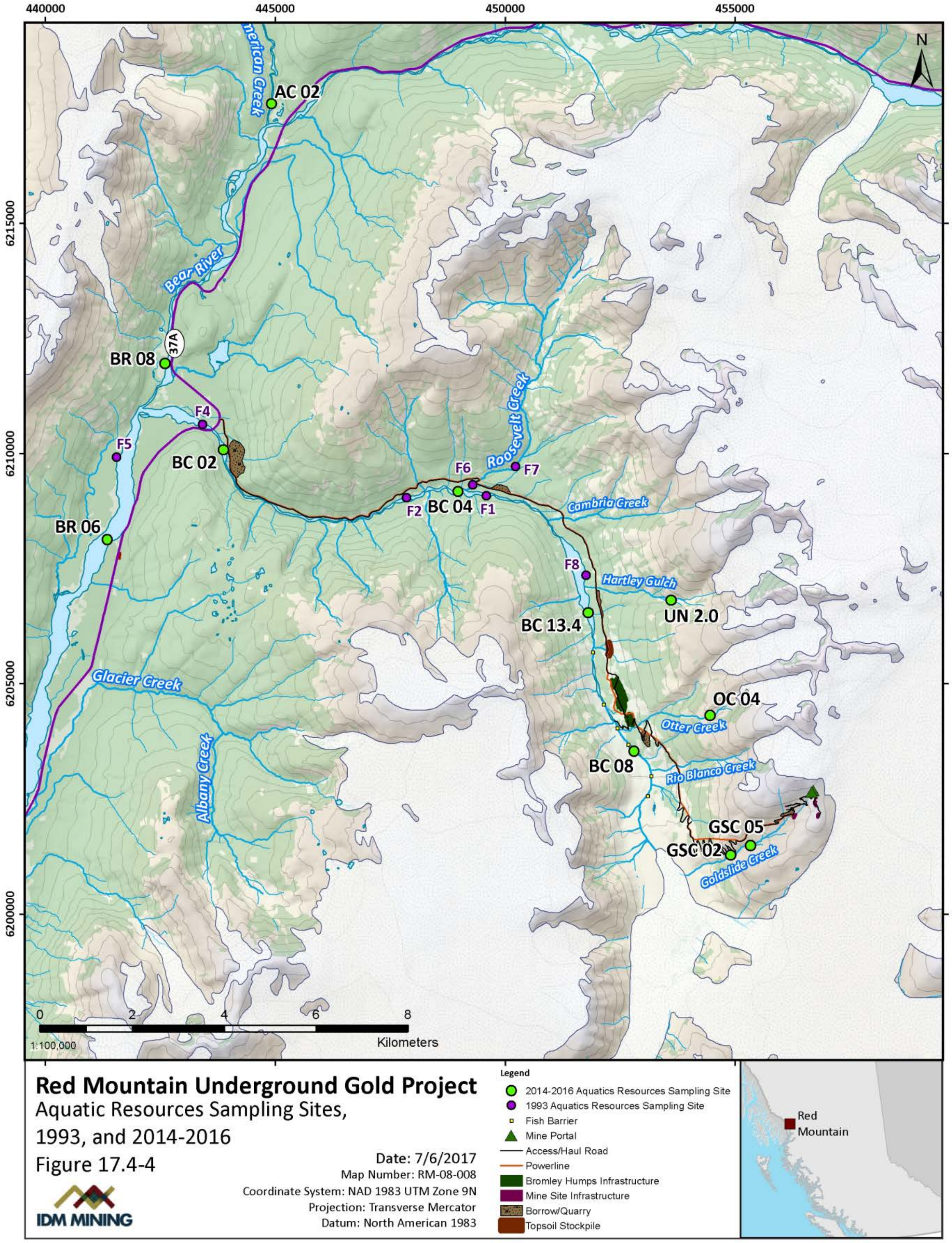
Bear River

Bitter Creek flows into the Bear River. Bear River has one site upstream of the confluence with Bitter Creek (BR08) and one site downstream of the confluence (BR06).

American Creek

American Creek flows into the Bear River upstream (north) of Bitter Creek. There is one site on American Creek (AC02).

Figure 17.4-4: Aquatic Resources Sampling Sites, 1993, and 2014-2016



17.4.3.3 Field Sampling Methods

17.4.3.3.1 1993 Sampling Program

Benthic invertebrate and periphyton sampling was conducted at six sites in the summer (late June and early July) and fall (late September) of 1993 (Table 17.4-4). A seventh site (F8, the most upstream site on Bitter Creek) was sampled for periphyton in the fall of 1993 only. The fall 1993 sampling event also included drift invertebrate sampling at two sites on Bitter Creek (F1 and F4), and one site on Roosevelt Creek (F6).

Table 17.4-4: Baseline Aquatic Resources Sampling, 1993

Monitoring Site	Watercourse	Early July		Late September		
		Periphyton	BI	Periphyton	BI	DI
F8	Bitter Creek	×	×	✓	×	×
F1	Bitter Creek	✓	✓	✓	✓	✓
F2	Bitter Creek	✓	×	✓	✓	×
F4	Bitter Creek	✓	✓	✓	✓	✓
F7	Roosevelt Creek	✓	✓	✓	✓	×
F6	Roosevelt Creek	✓	✓	✓	✓	✓
F5	Bear River	✓	✓	✓	✓	×

BI = Benthic Invertebrates, DI = Drift Invertebrates
✓= Site/component sampled
× = Site/component not sampled

Periphyton

Samples of periphyton were collected at each site using a combination syringe/brush apparatus (Rescan, 1994). Five replicate composite samples were collected from each site. Each sample was composed of three rock scrapings (total surface area sampled was 14.7 cm^2 per sample). Samples were preserved with Lugol's iodine solution and submitted to an unknown laboratory for analysis.

Benthic Invertebrates

Benthic invertebrates were collected with either a 253 µm mesh Hess sampler (0.096 m^2 area), a 0.093 m^2 Surber sampler, or a 0.003 m^2 corer, depending on size and composition of the substrate and water depth. Five replicate samples were collected at each site, except at site F1 in the fall, when only three replicates were collected because low flows limited the availability of suitable habitat for sampling. Samples were preserved with 10% buffered formalin and submitted to an unknown laboratory for analysis.

Drift Invertebrates

Samples of drift invertebrates were collected using a vertically fixed drift net with the opening of the net facing into the stream flow (*i.e.,* facing upstream). A net was deployed at each site for 15-24 hours. After the time period had elapsed, the net was recovered and organisms contained in the cod-end were transferred to a labelled jar. Organisms were preserved with 10% buffered formalin and submitted to an unknown laboratory for analysis.

17.4.3.3.2 2014-2016 Sampling Program

Sampling was conducted in late September of 2014, and in early September of 2015 and 2016 (Table 17.4-5). The 2014 sampling event also included collection of benthic tissue (periphyton, benthic invertebrates, and macrophytes), for metals analysis (Table 17.4-6).

Table 17.4-5: Baseline Benthic Invertebrate and Periphyton Sampling, 2014-2016

Watercourse	Site Name	2014 (late Sept)		2015 (early Sept)		2016 (early Sept)	
		BI	Periphyton	BI	Periphyton	BI	Periphyton
Bitter Creek	BC13.4	✓	✓	✗	✗	✓	✓
Bitter Creek	BC02	✓	✓	✓	✗	✓	✓
Bitter Creek	BC04	✓	✓	✓	✗	✗	✗
Bitter Creek	BC08	✓	✓	✓	✗	✓	✓
Goldslide Creek	GSC02	✗	✗	✓	✗	✓	✓
Goldslide Creek	GSC05	✓	✓	✓	✗	✗	✗
Otter Creek	OC04	✓	✓	✗	✗	✓	✓
Hartley Gulch	UN2.0	✗	✗	✓	✗	✗	✗
Bear River	BR06	✓	✓	✓	✗	✓	✓
Bear River	BR08	✓	✓	✓	✗	✓	✓
American Creek	AC02	✓	✓	✓	✗	✓	✓

BI = Benthic Invertebrates
✓= Site/component sampled
✗ = Site/component not sampled

Table 17.4-6: Baseline Benthic Tissue Sampling (Benthic Invertebrates, Macrophytes, and Periphyton) 2014

Watercourse	Site Name	2014 (late Sept)		
		BI	Macrophytes	Periphyton
Bitter Creek	BC13.4	✗	✓	✓
Bitter Creek	BC02	✗	✓	✓
Bitter Creek	BC04	✓	✗	✓
Bitter Creek	BC08	✗	✗	✓
American Creek	AC02	✗	✓	✓

Watercourse	Site Name	2014 (late Sept)		
		BI	Macrophytes	Periphyton
Goldslide Creek	GSC02	Site not sampled for benthic tissue		
Goldslide Creek	GSC05	✓	✓	✓
Otter Creek	OC04	✓	✓	✓
Bear River	BR06	×	✓	✓
Bear River	BR08	×	✓	✓
Hartley Gulch	UN2.0	Site not sampled for benthic tissue		

✓ = Tissue sample collected, and metals analysis was conducted for this site and type of tissue.
× = Tissue sample collected, but did not yield sufficient material for metals analysis

Periphyton

Periphyton sampling was conducted in 2014 (SNC-Lavalin) and 2016 (Northlink) (Table 17.4-5). Periphyton samples were collected from a known surface area of rock using a brush apparatus. In 2014, a single composite sample was collected from each site (*i.e.*, no replication). Each composite sample was composed of five rock scrapings from within the site. Each individual rock scraping was collected from a fixed area. The area was isolated using a bottle lid having known area. The remainder of the rock outside the lid was scrubbed clean. The remaining disc of periphyton (where the lid had been placed) was then scraped and brushed clean from the rock and collected in a sample jar using distilled water. Brushings and cleanings were repeated until cleansing water ran clear. Samples were preserved with Lugol's iodine solution (for taxonomic analysis), frozen (for chlorophyll *a* analysis), and submitted to Biologica Environmental Services for taxonomic and chlorophyll *a* (biomass) analysis.

In 2016, five replicate composite samples were collected at each site; each replicate sample was composed of five rock scrapings from within the site. A sixth composite sample was collected at each site for taxonomic analysis. Samples were preserved with Lugol's iodine solution and submitted to Biologica Environmental Services for taxonomic analysis, and measurement of biomass as ash-free dry mass.

In addition to periphyton sample collection, field surveys in early September 2015 and 2016 included observational qualitative ranking of periphyton.

Benthic Invertebrates

In 2014 (SNC-Lavalin), 2015, and 2016 (Northlink), benthic invertebrate sampling followed the Canadian Aquatic Biomonitoring Network (CABIN, Environment Canada 2012) field sampling protocol. The CABIN method entails kick-net sampling for benthic invertebrates in the erosional zone (riffle, straight run, or rapid) of a representative watercourse reach.

At each site, a single benthic invertebrate sample was collected using D-ring shaped kicknet with a <400 µm mesh. Sampling was timed for 3 minutes, during which the collector walked backward in the upstream direction, tracing a zig zag pattern, and dragging the net along the bottom. Sampling was conducted in a riffle area within each site, as per CABIN protocols, and to maximize the potential that areas had been continuously wetted for four weeks prior to sampling. Samples were preserved in 10% buffered formalin and submitted to Biologica Environmental Services Ltd. (Victoria, BC) for taxonomic analysis. Habitat characteristics (*e.g.,* surrounding vegetation, substrate composition, slope, channel widths, depths, and velocities), were recorded at each sampling site.

Benthic Tissue

In 2014, benthic tissue samples of benthic invertebrates, macrophytes, and periphyton were collected at each site for laboratory analysis of metals.

Benthic tissue residue sampling was guided by the BC Field Sampling Manual (BC MWLAP 2013) and Water and Air Baseline Monitoring Guidance Document (BC MOE 2014, updated 2016). From each site, a composite sample of each tissue category (*i.e.*, macrophyte, periphyton, and benthic invertebrate tissues) was collected, with exception of site GSC05 on Goldslide Creek, at which five replicates were collected to determine within-site variance.

Macrophyte samples were collected as whole individuals (*e.g.*, roots, leaves, and stem); periphyton was collected by scraping a minimum of three (or more) random rocks, depending on periphyton load); and benthic invertebrates were collected from three separate 3-minute kick net samples. Samples were kept at <4°C in a cooler until delivered to CARO Laboratories in Richmond, BC. CARO Laboratories are a Canadian Association for Laboratory Accreditation (CALA) accredited environmental laboratory.

17.4.3.4 Laboratory and Data Analyses

17.4.3.4.1 1993 Sampling Program

Periphyton

Upon delivery to the laboratory, samples were vigorously shaken and a subsample (usually two milliliters) was transferred to a settling chamber. Samples were permitted to settle for at least 24 hours prior to analysis. An inverted microscope was used to enumerate and identify algae to the species level, where possible, in 40-160 (depending on magnification) random microscopic fields. Densities of algal cells were calculated and expressed as number of cells per square centimeter. Site metrics reported for the 1993 periphyton data included:

- Abundance, as total numbers of cells per site;
- Taxonomic richness (S) calculated as the total number of species present at each site. In cases where species could not be discerned, the lowest possible taxonomic level identified was substituted;
- S(90%): the number of species accounting for 90% of the total number of cells at a site;
- Maximum Dominance (%): percentage of the total number of cells accounted for by the single, most abundant species at that site; and

- Biological indices for each site: the Shannon-Weiner diversity index, the Pielou equitability index, Heip equitability index, and Simpson's diversity index.

Benthic Invertebrates

At the laboratory, all benthic samples were washed in a 150 µm mesh sieve to remove excess sediment and formalin. Organisms were then sorted, enumerated, and identified to the species level, where possible. Density was reported as number of organisms per meter squared. Metrics reported for the 1993 benthic invertebrate data included:

- Abundance, as total numbers of organisms per site;
- Taxonomic richness, calculated as the total number of species present at each site. Where species could not be discerned, the lowest possible taxonomic level identified was substituted;
- S(90%): the number of species accounting for 90% of the total number of organisms at a site;
- Maximum Dominance (%): percentage of the total number of organisms accounted for by the single, most abundant species at that site; and
- Biological indices for each site: the Shannon-Weiner diversity index, the Pielou equitability index, Heip equitability index, and Simpson's diversity index.

Drift Invertebrates

At the laboratory, organisms were rinsed to remove excess formalin and then sorted. All individuals were counted and identified to the species level, where possible. Numbers of organisms reported were the actual number found in the sample due to the paucity of organisms captured. For the 1993 drift invertebrate data, the data were reported as percentage composition of each genus at each site.

17.4.3.4.2 2014-2016 Sampling Program

The 2014-2016 periphyton and benthic invertebrate samples were submitted to Biologica Environmental Services (Victoria, BC), for taxonomic analysis (benthic invertebrates and periphyton) and biomass determination (periphyton only). Biologica has been accredited by the Society for Freshwater Science’s Taxonomic Certification Program (SFSTCP). Standard taxonomic QA/QC protocols were followed. Further detail on laboratory methods used by Biologica can be found in Appendix 1 of the baseline report (Appendix 18-A).

Periphyton

In 2014, biomass of the periphyton samples was determined using chlorophyll *a* analysis, and was reported in micrograms per square centimeter (µg/cm^2), for each taxon. Biomass reported for each taxon at a site was then summed to give the total periphyton biomass (mg/cm^2) as for that site. In contrast, biomass of the 2016 periphyton samples was determined by measuring the ash-free dry-mass, such that the average periphyton biomass is reported for each site (average of the five replicates).

Results of taxonomic analysis were used to characterize the periphyton communities, and the following was reported for each site and year:

- Percentage composition, calculated by dividing the density of dominant (i.e., most abundant) taxa groups by the total density;
- Taxonomic richness, calculated as the total number of species present at each site. Where species could not be discerned, the lowest possible taxonomic level identified was substituted;
- Simpson's Diversity Index defined as: $D = 1 - \sum_{i=1}^{S} (p_i)^2$,where S is taxa richness, and p_i is the total number of individuals in the ith species divided by the total number of organisms in the sample; and
- First, second and third dominant taxon

Benthic Invertebrates

Benthic invertebrates were identified to the lowest possible taxonomic group. Benthic invertebrate density was reported relative to each kick net sampling event. The following community metrics were reported for benthic invertebrates for each site and year:

- Percentage composition, calculated by dividing the density of dominant (i.e., most abundant) taxa groups by the total density;
- Abundance, as total numbers of organisms per site;
- Taxonomic richness, calculated as the total number of species present at each site. Where species could not be discerned, the lowest possible taxonomic level identified was substituted;
- EPT taxa richness, defined as the total number of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) per site. These three orders of aquatic insects are typically most sensitive to habitat disturbance in stream or riverine systems;
- EPT %, calculated by dividing the density of EPT organisms by the total density;
- Chironomid %, calculated by dividing the density of organisms belonging to the family Chironomidae, by the total density;
- Shannon-Wiener diversity index H', defined as: $H' = -\sum_{i=1}^{R} p_i (\ln p_i)$, where R is taxa richness, and p_i is the total number of individuals in the ith species divided by the total number of organisms in the sample;
- Simpson's Diversity Index defined as: $D = 1 - \sum_{i=1}^{S} (p_i)^2$; and

- First, second and third dominant taxon.

The benthic invertebrate taxonomic and habitat data were analysed using the Reference Condition Approach (RCA) as per Environment Canada's CABIN protocols to assess aquatic ecosystem condition relative to an established reference condition.

Benthic Tissue

The benthic tissue samples (collected in 2014 by SNC-Lavalin) were submitted to CARO Laboratories (Richmond, BC) for analysis of metal concentrations.

Laboratory analyses for metal concentrations in benthic tissue samples followed the BC Laboratory Manual (BC MOE 2015). Wet weight metals concentrations were reported in milligrams per kilogram. The laboratory results can be found in Appendix 4 of Baseline Fisheries and Aquatic Resources (Appendix 18-A).

Selenium wet weight concentrations were converted to dry weight to allow comparison with the BC guideline of 4 µg/g (dry weight) for aquatic dietary tissue, *i.e.,* tissue (such as invertebrates) consumed by fish (Beatty and Russo, 2014).

Wet weight concentrations of total mercury in macrophyte and benthic invertebrate tissues samples were compared with CCME methylmercury tissue residue guideline for the Protection of Wildlife Consumers of Aquatic Biota (CCME, 2000). This is a conservative approach as it is being assumed that 100% of the total mercury is methylmercury (*i.e.*, conversion factor of 1.00), when the actual proportion of the total mercury comprising of methylmercury would be less.

For periphyton, a conversion factor of 0.36 (36%) was applied to convert the concentration of total mercury at each site, to methylmercury equivalent. The conversion factor of 36% was based on a literature review by Hamelin *et al.* (2015), where a summary of MeHg/THg concentrations in periphyton from different waterbodies around the globe gave a % MeHg/THg range for periphyton of 0.1 to 36%. Hamelin *et al.* (2015) observed higher ratios of MeHg/THg (74%) in Lake St-Pierre, Quebec; however, this value was not used as a conversion factor due it being observed when temperature and nutrient input were at their greatest, conditions unlikely to be experienced within the Bitter Creek system.

17.4.4 Baseline Characterization

17.4.4.1 1993 Sampling Program

17.4.4.1.1 Periphyton

The key periphyton findings from the 1993 sampling program (Table 17.4-7; Rescan 1994) include:

- Three phyla of benthic algae were found in the Project area: Chlorophyta (green algae), Chrysophyta, (golden-brown algae), and Cyanophyta (blue-green algae);

- The three most dominant and abundant genera, as defined by the McCloskey Biological Index (McCloskey, 1970), were: *Palmodictyon* spp. (Chlorophyta), *Achnanthes* spp. (Chrysophyta), and the *Phormidium/Oscillatoria* spp. Group (Cyanophyta);
- For the Bitter Creek watershed, periphyton abundance decreased while diversity increased at most sites from summer to fall;
- The two sites in Reach 2 of Bitter Creek (F1 and F2, upstream and downstream of the current BC04 site, respectively), and most upstream site on Bitter Creek (F8, in Reach 3 near Hartley Gulch), had similar taxa richness (22 to 25 species recorded at those sites in fall 1993);
- The most downstream site on Bitter Creek (F4, in Reach 1 just below highway 37A) had noticeably lower taxa richness (8 species in fall 1993);
- Sites on Roosevelt Creek (F7 and F6), had lower taxa richness than the nearby sites on the Bitter Creek mainstem (F1, F2, and F8); and
- In the summer (July 1993), F4 had the highest abundance, whereas in fall, that site had the lowest abundance.

Table 17.4-7: Periphyton Community Metrics, 1993

Site	Total # of Cells*		Total # of Species*		S(90%)		Maximum Dominance		Shannon Diversity Index	
	July	Sept	July	Sept	July	Sept	July	Sept	July	Sept
F8	-	386782	-	23	-	7		46.9	-	1.852
F1	215262	278945	19	22	8	8	27.4	23.5	2.127	2.172
F2	498932	284746	25	25	9	11	28	41.6	2.117	2.177
F4	4250346	15158	10	8	1	3	99.5	58.1	0.038	1.156
F7	408132	709904	14	12	4	2	62.2	80.5	1.259	0.768
F6	266741	153182	17	15	6	6	22.1	30.8	1.942	1.875
F5	534727	61708	13	12	1	6	93.5	33.8	0.337	1.872

* Numbers of cells/species within fixed area (same for each site, so numbers are comparable).

17.4.4.1.2 Benthic Invertebrates

Key benthic invertebrate findings from the 1993 sampling program (Table 17.4-8; Rescan 1994) include:

- Diptera was the dominant order at all sites in the Bitter Creek watershed, and Plecoptera was subdominant;
- The two sites in Reach 2 of Bitter Creek (F1 and F2, upstream and downstream the current BC04 site, respectively), had noticeably higher abundance and taxa richness (approximately 2 to 3 times greater) than the downstream site (F4, in Reach 1 just below highway 37A); and

- The downstream site (Reach 1, below highway 37A) exhibited the highest maximum dominance; 59% of the community was comprised of a single taxon.

Table 17.4-8: Benthic Invertebrate Community Composition by Site, September 1993

Monitoring Site	Watercourse	Method	Diptera	Ephemeroptera	Plecoptera	Trichoptera	Other
F1	Bitter Creek	Surber	74.13	2.80	15.38	6.29	1.40
F2	Bitter Creek	Surber	59.58	13.17	14.07	11.08	2.10
F4	Bitter Creek	Hess	64.71	2.84	32.35	0.00	0.10
F7	Roosevelt Creek	Hess	29.81	10.10	54.97	0.32	4.80
F6	Roosevelt Creek	Hess	38.40	5.20	40.80	2.00	13.60
F5*	Bear River	Core grab	50.00	0.00	0.00	0.00	50.00

*The other 50% of the sample from site F5 was composed of organisms from the order Oligochaeta

17.4.4.1.3 Drift Invertebrates

Drift samples were collected at three sites on Bitter Creek in the fall of 1993 and yielded the larval stages from the orders Ephemoptera (mayflies), Plecoptera (stoneflies), and Diptera (two-winged flies). Larval *Diamesa*, a genus belonging to the Chironomidae family (Diptera), were the most abundant in all three samples (Rescan 1994). However, the number of organisms captured was low, supporting the observation that September is past the optimal breeding season of terrestrial and aquatic insects.

17.4.4.2 2014-2016 Sampling Program

17.4.4.2.1 Periphyton

Periphyton Biomass

Periphyton biomass exhibited high variability across the sites in the two years that sampling was conducted (Table 17.4-9; Appendix 18-A). In 2014, one composite sample was collected from each site and biomass was determined using chlorophyll *a* analysis. In 2016, five replicate composite samples were collected at each site and biomass was determined by measuring ash-free dry mass weights. Therefore, the periphyton biomass results cannot be directly compared across years. In 2014, chlorophyll *a* ranged from 4.17 µg/cm^2 at BC04 to 347.1 µg/cm^2 at BR08. However, the 2014 samples may not have remained fully frozen during transport and shipping (as required for the chlorophyll *a* analysis), which could have affected the accuracy of results. In 2016, the average periphyton ash-free dry mass ranged from 0.423 mg/cm^2 at BC13.4 to 29.73 mg /cm^2 at BC02.

In 2016, when five replicates were collected at each site, intra site variability was typically high (Table 17.4-9), reflecting the different micro-habitats for periphyton within a site. Visual (qualitative) observations in 2015 and 2016 showed that most coarse sediment throughout Bear River and Bitter Creek had been scoured clean of periphyton, with only small areas exhibiting a thicker mat of periphyton. Thicker periphyton mats were typically observed in shallow channel margins.

Table 17.4-9: Periphyton Biomass Results, 2014 and 2016

Site	2014 Biomass* (µg chlorophyll *a*/cm^2)	2016 Biomassǂ (mg/cm^2, ash-free dry weight, mean ± SD)
BC02	4.26	29.73 ± 47.11
BC04	4.17	-
BC13.4	68.7	0.423 ± 0.302
BC08	4.34	5.11 ± 8.97
AC02	53.4	1.20 ± 0.959
BR06	51.6	1.88 ± 0.931
BR08	347.1	0.986 ± 1.065
GSC02	-	0.684 ± 0.510
GSC05	26.3	-
OC04	7.2	0.465 ± 0.084

[*] Sample number, n = 1 (single replicate per site)

[ǂ] Sample number, n = 5 (five replicates per site), SD = standard deviation

Periphyton Community Composition

Qualitative comparison of the periphyton taxonomic data shows that the community composition was highly variable between sampling years. Full taxonomic results for periphyton samples collected in 2014 and 2016 are available in Appendix 18-A.

In 2014, blue-green algae (cyanophyta) was the most dominant algal group in the periphyton samples. Of the blue-green algae, the species *Chamaesiphon incrustans* (a photosynthetic cyanobacterium) was the most common species in the periphyton samples. This species was the first, second, or third dominant taxon in every sample, with the exception of site OC04. *C. incrustans* was the first dominant taxon for five of the nine sites. The cyanobacterium *Gloeocapsa punctata* was dominant at the Bear River sites. The genus *Gloeothece* dominated at the high-elevation site OC04, and *Leptolyngbya limnetica* dominated site BC13.4. At all sites the dominant periphyton taxon made up more than 60% of the community.

The 2016 periphyton samples were not dominated by *Chamaesiphon incrustans* nor were they heavily dominated by any single taxon. Community composition was similar across high elevation sites. The Bear River sites also had similar communities. Conversely, sites in Bitter Creek exhibited high variability in community composition, likely reflecting the different habitat conditions at the sites. *Clastidium cylindricum*, a cyanobacterium (blue green algae), was dominant in the samples from Otter Creek and Goldslide Creek. Species from the genus *Clastidium* are known from clear, streaming or stagnant mountains waters (Komárek, 1992). In Bitter Creek, the dominant taxa were *Hydrurus* (BC08), *Ulothrix variabilis* (BC13.4), and

Phormidium sp. (BC02). In North America, the only species of *Hydrurus* (*H. foetidus*) is found in cold clear flowing waters in full sunlight. *Ulothrix* is a genus of green algae (Chlorophyta) that thrives in the low temperatures of spring and winter. *Phormidium* is a genus of blue-green algae. *Chamaesiphon incrustans*, which was the most common species in 2014, was second dominant at BC02. Other taxa that were second or third dominant in the Bitter Creek 2016 samples were *Heteroleibeinia profunda*, *Clastidium cylindricum*, and *Gloeocapsa punctata*, which are types of blue-green algae.

Periphyton Taxonomic Richness and Diversity

In both sampling years, periphyton taxonomic richness and diversity was higher at the Bear River and American Creek sites than at sites in the Bitter Creek watershed (Table 17.4-10).

Periphyton taxa richness and diversity was generally higher in 2016 than in 2014. The difference in periphyton communities between years may due to any one, or a combination of, the following:

- Variability in climatic conditions between years, such that in 2014 conditions may have been favourable for growth of blue-green cyanobacteria;
- Variability within sites *e.g.*, shallow margin habitat versus deeper mid-channel areas; and
- Potential differences in sampling techniques used by the field crews.

Full results for periphyton community metrics are reported in Appendix 18-A.

Table 17.4-10: Periphyton Taxonomic Richness and Diversity, 2014 and 2016

Site	Taxa Richness		Simpson's Diversity Index	
	2014	2016	2014	2016
BC02	9	5	0.459	0.711
BC04	8	-	0.532	-
BC13.4	7	4	0.601	0.423
BC08	7	5	0.308	0.165
AC02	9	12	0.435	0.680
BR06	10	14	0.446	0.717
BR08	8	11	0.227	0.728
GSC02	-	8	-	0.769
GSC05	6	-	0.412	-
OC04	9	10	0.237	0.778

17.4.4.2.2 Benthic Invertebrates

Full results for benthic invertebrate abundance, community composition, and community metrics (*e.g.*, taxa richness, %EPT), can be found in Table 3-9 of Appendix 18-A.

Benthic Invertebrate Abundance

Benthic invertebrate abundance was generally highest at the low-stream order, high-elevation sites, while the higher stream order low-elevation sites had lower abundances. Bitter Creek consistently yielded the lowest numbers of individuals, while Goldslide Creek and Otter Creek had the highest benthic invertebrate abundance. Samples from Goldslide and Otter Creek typically yielded several thousand individuals, whereas the Bitter Creek samples typically contained less than a thousand individuals. These results likely reflect suboptimal habitat conditions in Bitter Creek for supporting benthic invertebrates. Bitter Creek is a dynamic, fast flowing, and turbid stream, with high bedload transport rates, which limits colonization by benthic invertebrates. Conditions in Goldslide Creek and Otter Creek are more suitable for supporting benthic invertebrates. Bear River and American Creek samples also had abundance in the range of hundreds, rather than thousands, of organisms per sample. An exception to this was in 2015, when sites AC02 and BR08 yielded abundances of 1920 and 2576 individuals, respectively (although these abundance values are still lower than those for Goldslide Creek and Otter Creek).

Benthic Invertebrate Community composition

Pollution sensitive (EPT taxa dominated the benthic communities, with Plecoptera forming the majority of the EPT individuals. Densities of chironomids (Diptera family), which are more tolerant of organic pollution, were low. The benthic invertebrate baseline data point to a healthy benthic community, reflective of the habitat conditions. Erosional zones and coarse substrate are preferred by many EPT species, while slow moving areas and finer substrate (sand, silt and organics) generally support more Diptera.

Benthic Invertebrate Taxonomic Richness and Diversity

Benthic invertebrate taxonomic richness was highest at the Bear River and American Creek sites (typically >15 taxa present), and lowest site BC08 in upper Bitter Creek (5 to 7 taxa present over the three years). The other sites on Bitter Creek (BC13.4, BC04, and BC02) had 8 to 14 taxa. Taxa richness at the sites on Goldslide Creek ranged from 6 to 13 taxa. Otter Creek had relatively low taxa richness in both years (6 or 7 taxa present). The site on Hartley Gulch, which was sampled on one occasion only (2015) had a taxonomic richness of 16, the highest of any site on Bitter Creek or its tributaries.

CABIN Analyses

The CABIN analyses of the benthic invertebrate communities showed that the sites belonged to Reference Group 2 or 3 within the BC Central-North Coast Model. The Bray-Curtis analysis (part of the CABIN analyses) showed that the benthic community structure at the sites was more dissimilar than similar to the CABIN reference condition for sites with similar habitat characteristics. The degree of deviation (*i.e.*, divergence) from the reference condition is calculated in CABIN, and can indicate the severity of impairment of site. A site that is highly divergent (furthest condition away from regional reference site conditions) is considered the most stressed. Benthic invertebrate community composition within all sites were at least mildly divergent compared to the reference streams in the CABIN database. These results reflect the low taxonomic richness observed at the sites, which is uncharacteristic of streams with similar habitat conditions. However, in this case the study streams are subject to heavy scour, frequent debris torrents, and low nutrient inputs, which may pose higher limitations to benthic productivity than exist in the reference streams in the CABIN analysis. As such, the sites are not considered impaired or stressed, but rather naturally unsuitable for supporting large and diverse benthic invertebrate communities. Alteration of the site conditions could make them more or less similar to the streams that comprise the CABIN Reference Group.

17.4.4.2.3 Benthic Tissue

Selenium dry weight concentrations in benthic tissue samples exceeded the BC guideline of 4 µg/g (dry weight) at all sites for one or more tissue types. The guideline of 4 µg/g (dry weight) is for dietary tissue (*i.e.*, tissue consumed by fish). Although some of the benthic tissue sampling locations (BC08, 0C04, GSC02 and GSC05) are within non-fish bearing areas, the guideline is still applied for comparison purposes. The samples from sites in upper Bitter Creek and Goldslide Creek had the highest selenium concentrations in benthic tissue, often 2 to 3 times the guideline value.

Wet weight concentrations of total mercury in macrophyte samples were below the methylmercury CCME Guideline (0.033 µg/g wet weight) at all sites that yielded sufficient macrophyte tissue for analysis. For benthic invertebrates, only three sites yielded sufficient sample for analysis (Table 17.4-6). Wet weight concentrations of total mercury in the benthic invertebrate tissue samples were below the laboratory detection limits, which exceeded the guideline value for methylmercury. Periphyton wet weight concentrations for total mercury were converted to methylmercury based on a conversion factor of 0.36 (Section 17.4.3.4.2). The equivalent wet weight concentrations for methylmercury in periphyton exceeded the guideline value at BC04, where the methylmercury equivalent concentration was approximately twice the guideline value, and at BC13.4 (slight exceedance; 0.005 µg/g above the guideline value).

17.4.4.2.4 Aquatic Resources Summary

The aquatic conditions within the Red Mountain LSA and RSA can be described as largely unimpaired from anthropogenic activities. Although baseline sampling results (*e.g.*, CABIN analyses, benthic tissue selenium concentrations) point to stress on the aquatic organisms, this can be attributed to natural factors such as the dynamic nature of the streams, and high background levels of metals.

The recent (2014-2016) baseline sampling data differed from the 1993-1994 baseline data. In particular, in 1993, the dominant benthic invertebrate order in the stream communities was Diptera, whereas in 2014-2016 the dominant order was Plecoptera. However, different sampling locations and methods were employed, which limits the comparability of the results. As such, the baseline conditions are inferred primarily from the 2014-2016 studies, as these indicate the current conditions, and consistent and up-to-date standard sampling methods were used.

The periphyton and benthic communities in the Bitter Creek watershed are reflective of oligotrophic conditions (*i.e.*, low nutrient status). Generally, periphyton communities are composed of taxa that thrive in clean, cool, and fast-flowing water.

Within the benthic invertebrate communities, the dominant taxa are comprised of organisms from the order Plecoptera. These taxa have high sensitivity to disturbance, and low tolerance to organic pollution. They prefer coarse substrate and well-oxygenated, flowing water.

As benthic invertebrates are sedentary, local factors strongly influence their distribution. This is evident in the Bitter Creek watershed, where the tributary streams, namely Goldslide Creek, support higher benthic invertebrate abundance owing to higher stability of the habitat. Benthic habitat in mainstem Bitter Creek is subject to more frequent natural disturbance from scouring, bedload movement, and sediment loading. The mainstem sampling sites had lower abundance values, which is likely attributable to the unstable nature of the benthic habitat.

17.5 Potential Effects

17.5.1 Methods

Activities associated with the Project have the potential to cause adverse effects to Aquatic Resources in the immediate and downstream aquatic environments. Effects were assessed in relation to planned discharges, runoff, atmospheric deposition, and instream works for all mine components using project interaction matrices. Once links between mine components and project interactions were identified, key potential effects were discussed in terms of potential pathways of effects to sediment quality (Section 17.5.3).

This effects assessment for Aquatic Resources assumes that all Project activities will occur within the designed scope of the Project. Any potential risk due to spills, equipment malfunctions, emergencies, or accidents are assessed in Accidents and Malfunctions (Volume 3, Chapter 23), and are not discussed any further in this assessment.

17.5.2 Project Interactions

The physical works and activities to be implemented during the Project have the potential to interact with and lead to effects on the Aquatic Resources VC. Evaluation of the interaction matrix (Table 17.5-1) led to identification of potential effects.. Project interactions and potential effects associated with Aquatic Resources are presented below. IDM's identification of interactions and potential Project effects on Aquatic Resources have been informed by the conceptual site model (CSM) and Screening Level Ecological Risk Assessment conducted for the Project.

Generally, effects to water quality and related VCs, such as Aquatic Resources, have been one of the primary concerns of NLG and other Working Group members, such as ECCC. In response to this level of concern, IDM has made all efforts to identify potential interactions between Aquatic Resources and proposed Project components and activities (as outlined in Table 17.5-1) so that appropriate mitigation measures (see Section 17.6) and follow-up and monitoring programs (see Section 17.9) can be identified and planned. Further information regarding IDM's consultation on Aquatic Resources can be found in Section 17.3.2.

Table 17.5-1: Potential Project Interactions, Aquatic Resources, Red Mountain Project

Project Component/Activity	Periphyton	Benthic Invertebrates	Potential Effect / Pathway of Interaction with Aquatic Resources
Construction Phase			
Construct Access Road and Haul Road from Hwy 37A to the Upper Portal	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition; direct mortality from mine footprint and associated infrastructure; habitat loss from mine footprint development and associated infrastructure; habitat loss from changes to streamflow and channel morphology; direct mortality from increased fishing pressure
Install Powerline from substation tie-in to the Lower Portal laydown area	X	X	Changes to Surface Water Quality as a result of erosion, sedimentation, and dust deposition
Excavate and secure Lower Portal entrance and access tunnel	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Construct Mine Site water management infrastructure including talus quarries and the portal collection ponds, dewatering systems, and water diversion, collection and discharge ditches and swales.	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Discharge of water from underground workings at the Mine Site	X	X	Changes to surface water quality as a result of mine water discharge; habitat loss from changes in streamflow
Construct other Mine Site ancillary buildings and facilities	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Discharge of water from underground workings at the Mine Site	X	X	Erosion and sedimentation; changes in water and sediment chemistry; habitat loss from changes to streamflow
Initiate underground lateral development and cave gallery excavation	X	X	Habitat loss from changes to streamflow
Temporarily stockpile ore at the Mine Site	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition

Project Component/Activity	Periphyton	Benthic Invertebrates	Potential Effect / Pathway of Interaction with Aquatic Resources
Transport and deposit waste rock to the Waste Rock Storage Area(s)	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Water withdrawal for the purposes of dust suppression and construction use (primarily contact water management ponds; secondarily Bitter Creek, Goldslide Creek, and Otter Creek) and to meet freshwater needs (Otter Creek, Goldslide Creek)	X	X	Habitat loss from changes to streamflow
Clear and prepare the TMF basin and Process Plant site pad	X	X	Direct mortality and habitat loss due to mine footprint development and associated infrastructure; changes to water and sediment chemistry from erosion, sedimentation, and dust deposition
Excavate rock and till from the TMF basin and local borrows / quarries for construction activities (e.g. dam construction for the TMF)	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Establish water management facilities including diversion ditches for the TMF and Process Plant	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Construct the TMF	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Construct the Process Plant and Run of Mine Stockpile location	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Construct water treatment facilities and test facilities at Bromley Humps	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Construct Bromley Humps ancillary buildings and facilities	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Commence milling to ramp up to full production	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Operation Phase			
Use Access Road for personnel transport, haulage, and delivery of goods	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition

Project Component/Activity	Periphyton	Benthic Invertebrates	Potential Effect / Pathway of Interaction with Aquatic Resources
Maintain Access Road and Haul Road, including grading and plowing as necessary	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Maintain Powerline right-of-way from substation tie-in to portal entrance, including brushing activities as necessary	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Continue underground lateral development, including dewatering	X	X	Habitat loss from changes in streamflows from dewatering activities
Discharge of water from underground facilities	X	X	Changes in surface water and sediment chemistry from mine discharge; habitat loss from changes to streamflow
Haul waste rock from the declines to the Waste Rock Storage Area(s) for disposal (waste rock transport and storage)	X	X	Changes in water and sediment chemistry from erosion, sedimentation, and dust deposition
Extract ore from the underground load-haul-dump and transport to Bromley Humps to Run of Mine Stockpile (ore transport and storage)	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Freshwater for the Process Plant will be obtained through water withdrawal from Bitter Creek	X	X	Habitat loss from changes to streamflow
Water withdrawal for the purposes of dust suppression along Project roads and to meet freshwater needs (Otter Creek, Goldslide Creek)	X	X	Habitat loss from changes to streamflow
Treat and discharge, as necessary, excess water from the TMF	X	X	Changes in hydrology, and water and sediment chemistry from TMF discharges
Progressively reclaim disturbed areas no longer required for the Project	X	X	Changes in surface water and sediment chemistry from erosion and sedimentation
Closure and Reclamation Phase			
Use and maintain Access Road for personnel transport, haulage, and removal of decommissioned components until road is decommissioned and reclaimed.	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Decommission underground infrastructure	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition

Project Component/Activity	Periphyton	Benthic Invertebrates	Potential Effect / Pathway of Interaction with Aquatic Resources
Flood underground	X	X	Changes in hydrology, and water and sediment chemistry from mine discharges
Decommission and reclaim Lower Portal Area and Powerline	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Decommission and reclaim Haul Road	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Decommission and reclaim all remaining mine infrastructure (Mine Site and Bromley Humps, except TMF) in accordance with Closure Plan	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Construct the closure spillway	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Treat and discharge water from the TMF	X	X	Changes to surface water quality as a result of discharge, erosion,sedimentation, and dust deposition
Conduct maintenance of mine drainage, seepage, and discharge	X	X	Changes in hydrology, and water and sediment chemistry from discharges
Remove discharge water line and water treatment plant	X	X	Changes in surface water and sediment chemistry (due to filling of the TMF and discharge via the closure spillway)
Decommission and reclaim Access Road	X	X	Changes in surface water and sediment chemistry from erosion, sedimentation, and dust deposition
Post-Closure Phase			
Flood underground	X	X	Changes to surface water quality as a result of ML/ARD and groundwater interaction

17.5.3 Discussion of Potential Effects

Potential effects to Aquatic Resources may occur through various pathways during the life of the Project. These pathways, if unmitigated, can lead to adverse effects on Aquatic Resources. The effects through these pathways would vary in terms of severity, with some effects causing direct mortality to organisms, while others cause sub-lethal effects. For the purposes of the Aquatic Resources assessment, the potential effects were classified under the following categories, which represent all of the possible pathways that could lead to reduced abundance and diversity of periphyton and benthic invertebrates. Furthermore, these categories draw on predictive analyses conducted for other VCs, such as Surface Water Quality, to provide quantitative predictions of potential effects on Aquatic Resources. The categories are:

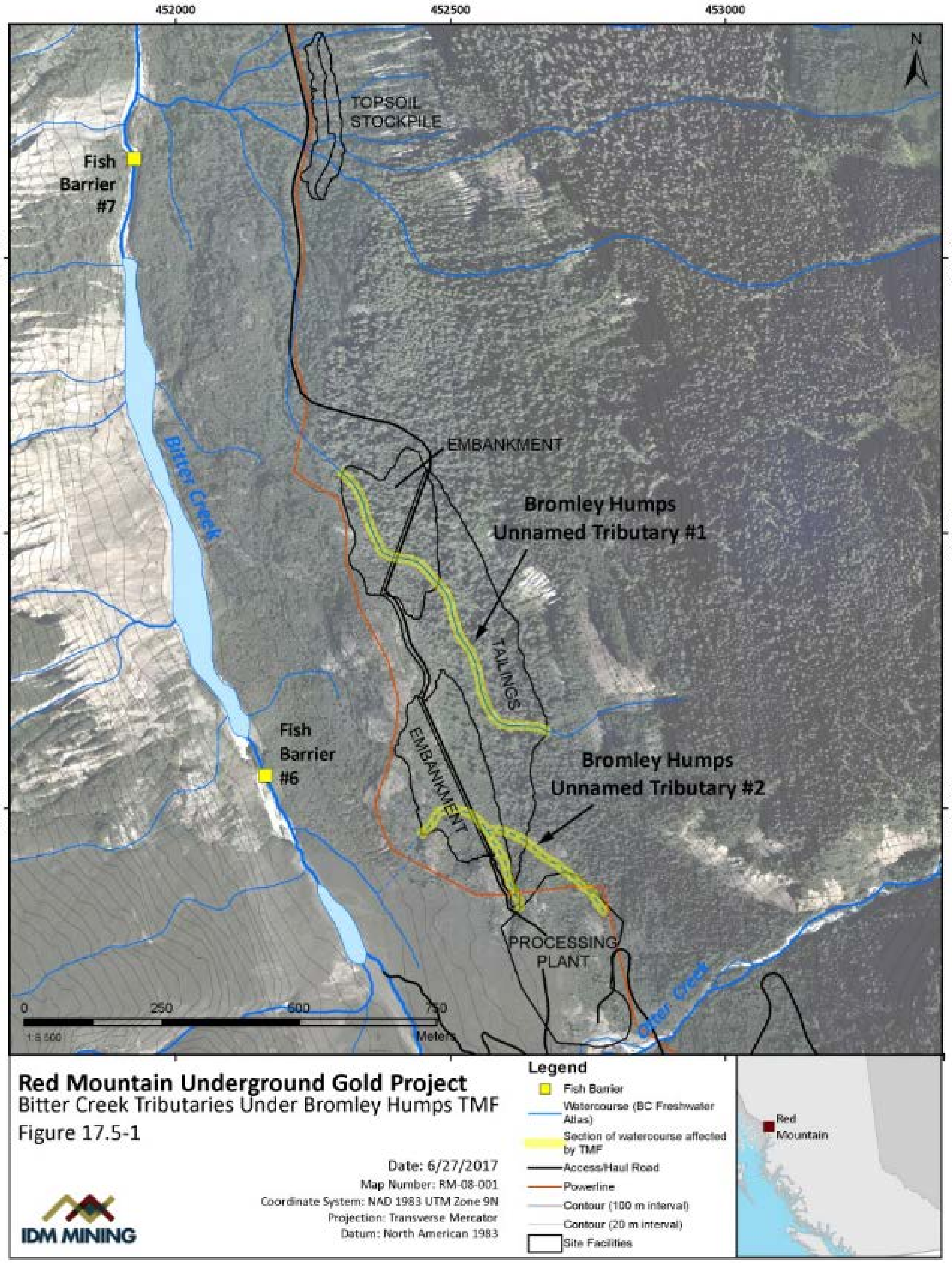
- Habitat loss;
- Change in Surface Water Quality;
- Change in Sediment Quality;
- Changes in Streamflow (water quantity, flow regime); and
- Blasting.

17.5.3.1 Habitat Loss

Habitat loss under the mine footprint (*i.e*., direct loss) occurs where mine infrastructure overlaps with watercourses, and has the potential to cause direct mortality to benthic organisms from habitat infilling.

The TMF footprint overlaps with two small, unnamed watercourses that are connected to Bitter Creek (Figure 17.4-3). Unnamed Bromley Humps Creek 1 is not fish bearing owing to a series of high gradient drops and chutes in the lower section of the creek. Unnamed Bromley Humps Creek 2 flows into Bitter Creek upstream of the series of fish barriers near BC06 on Bitter Creek. Baseline sampling of Aquatic Resources were not conducted in these unnamed watercourses and although they are non-fish bearing, are conservatively assumed to support benthic invertebrates and periphyton. Approximately 520 m^2 of aquatic habitat will be lost under the TMF footprint. This calculation is based on affected stream length and a typical channel width of 0.5 m.

Figure 17.5-1: Location of the TMF Relative to Unnamed Tributaries to Bitter Creek



Other than the TMF, Project infrastructure in Bromley Humps and Mine Site does not overlap with any watercourses.

The proposed Access Road will use existing road for 14 km from Highway 37A to Bromley Humps. An additional 9 km of (new) Haul Road is proposed to link Bromley Humps to the Mine Site.

The existing road alignment follows Bitter Creek along its right bank, and crosses 64 unnamed right bank tributaries of Bitter Creek, as well as 5 named creeks: Lim Creek, Radio Creek, Roosevelt Creek, Cambria Creek, and Hartley Gulch. Only Roosevelt Creek and Hartley Gulch are fish bearing at road crossings. The road crosses each watercourse once. Road crossings along the proposed Access Road will be comprised of: clearspan bridges (Roosevelt Creek, Cambria Creek, and Hartley Gulch), modified ford (Radio Creek), or culverts (remaining crossings). No instream habitat loss is associated with clearspan bridges, as there is no instream infrastructure required for this type of crossing. However, there may be minor losses of riparian habitat. Ford crossings will not result in habitat loss *per se*, but will potentially result in some deterioration of habitat, from erosion and sedimentation. This is discussed under the Sediment Quality pathway. Damaged or undersized culverts along the existing access road will be replaced. New or replacement culverts will be appropriately sized and installed. Site roads will maximize the use of pre-existing crossings; however, at some crossings, the road will be widened and/or raised, which could lead to more infilling and longer culverts, resulting in some habitat loss. Field reconnaissance of crossing sites indicated that most crossings had low to no habitat value for benthic invertebrates and periphyton, as they were classified as no visible channel (NVC) or as a non-classified drainage (NCD), had high gradients, lacked substrate, or were likely ephemeral. These habitat characteristics are unsuitable for supporting high densities of benthic invertebrates or periphyton.

The proposed new Haul Road from the Process Plant to the Mine Site crosses 47 unnamed watercourses and two named creeks: Otter Creek and Rio Blanco Creek. All crossings would occur above non-fish bearing watercourses. The road crosses each watercourse once. Otter Creek and Rio Blanco Creek crossings will be modified fords. Culverts will be installed at the 47 unnamed watercourse crossings. Some crossing sites were identified based on desktop mapping, while others were identified in the field. Habitat loss at the proposed Haul Road crossings is estimated to be minimal, because the majority of watercourses are small and ephemeral (freeze in winter, and/or dry in summer).

A conservative estimate of habitat loss along the Haul Road is 560 m^2, based on a typical culvert footprint of 12 m^2 and assuming that all 47 crossings contain aquatic habitat.

Some aquatic habitat loss is also anticipated along Bitter Creek, where the road alignment overlaps with the main channel of Bitter Creek. Sections of the existing road were washed away during a flood event in 2011, and therefore upgrading of the road along its original alignment requires construction within the channel formed during the 2011 flood. While this means that the road alignment infringes on the Bitter Creek channel, the road will, for the most part, be above the annual high water mark. Road construction will be within the annual high water mark in 4 or 5 locations; however, at these locations, realignment of the creek will be towards the opposite bank, such that here is no net loss of aquatic habitat.

In September 2011, Bitter Creek experienced flows which greatly exceeded typical annual flows, eroding portions of the existing road and washed out the nearby bridge on Highway 37A. During this event, the creek flowed beyond its banks, scouring historical floodplains, overflowed channels, and eliminated any indicators to differentiate between annual floodplain and historic floodplain. The annual high water mark was surveyed around Lim Creek and other sections where an encroachment of the river was obvious. Due to the recent bank erosion from high flows, the annual highwater mark is not always obvious in the field. In sections where road encroachment was not obvious during 2016 fieldwork (conducted by Onsite Engineering), supplied ortho images and LIDAR data were used by Onsite to delineate the highwater mark. The ortho images and LIDAR data were collected on July 30, 2013, and given the channels recent history of flood events, the delineated disturbance area along Bitter Creek is likely an overestimate. Fieldwork is proposed for the 2017 season and will include surveying annual high water levels, present water, and potential side channels of the entire section of river that may be impacted by proposed road works in conjunction with hydrotechnical engineering assessments. The data from this proposed 2017 fieldwork will be used to refine the expected disturbance area within Bitter Creek.

In summary, there will be aquatic habitat loss from the Project footprint; under and upstream of the TMF, at watercourse crossings along proposed roads, and in Bitter Creek where the road alignment is located within the annual highwater mark.

17.5.3.2 Changes in Surface Water Quality

Potential effects to Aquatic Resources from changes in water quality may occur through the chemical and physical alteration of their habitat.

The following pathways to physical and chemical changes to water quality are described in the Surface Water Quality assessment (Volume 3, Chapter 13), and are discussed here in the context of potential effects on the Aquatic Resources VC (Table 17.5-2):

- Mine discharge;
- TMF discharge;
- Road runoff;
- Non-contact water runoff; and
- Aerial deposition.

The above pathways can contribute to changes in water quality, including changes in metal concentrations, nutrient loading, acidity (pH), Total Suspended Solids (TSS), and water hardness. Each of these components of water quality, and the interaction with Aquatic Resources, is summarized in Table 17.5-2. A discussion of each pathway follows.

Table 17.5-2: Water Quality Components and Interactions with Aquatic Resources

Water Quality Component	Description	Project Activity/Pathway	Potential Effect on Aquatic Resources from Change in Water Quality Component
pH	Acid-base balance of water can be altered by inputs of nitrogen oxides and sulphur dioxides. These compounds are released into the atmosphere from burning fossil fuels, and mix with water, increasing its acidity. Sulfates derived from oxidation of metal sulfides are the main cause of acidification at metal mine sites.	Discharge, runoff, aerial deposition	Acidification of surface waters can shift the pH outside the tolerance range of aquatic species. Sudden shifts in pH associated with runoff events can cause direct mortality in aquatic organisms. Acidification of receiving waters can also increase metal mobility and bioavailability in the aquatic environment.
Metals	Metals suspended or dissolved in water. Examples include arsenic, cadmium, chromium, copper, lead, zinc, selenium, and mercury. Metals occur naturally in the environment but can be released through mining activities.	Discharge, runoff, aerial deposition	Increased dissolved metals can cause toxic responses in aquatic organisms. In general, acids and metals introduction into aquatic environments can result in decreased growth and diversities of primary producer and secondary communities.
TSS	Quantity of suspended material in the water column.	Works in or near water, discharge, runoff (*e.g.*, from ford crossings), aerial deposition	Reduction in water clarity and increased suspended particle loads alters light penetration and intensity thereby effecting rates of primary productivity of benthic aquatic organisms.
Nutrients	Chemical compounds that are taken up by periphyton for growth. The primary bioavailable nutrients in surface water are soluble forms of nitrogen and phosphorus, as well as ammonia. These chemicals stimulate the growth of all types of aquatic plants, including periphyton (microscopic algae), although other chemicals (*e.g.*, silica) may limit growth when other nutrients are available in abundance.	Blasting residues, runoff, discharge, aerial deposition	Moderate increases in concentrations of nutrients can increase periphyton growth and food supply for benthic invertebrates. Overabundance of nutrients and resultant periphyton and plant growth can upset the balance of the aquatic environment, degrade physical habitat, and have cascading effects through the food web.
Hydrocarbons	Polycyclic aromatic hydrocarbons (PAHs) are formed during combustion processes, sources include vehicular exhaust, crude oil, and petroleum.	Discharge, runoff, aerial deposition	Several PAHs have been identified as carcinogens or mutagens and can be acutely or chronically toxic to aquatic organisms.

17.5.3.2.1 Mine Discharge

Water from the underground mine may be potentially affected by underground water management, drilling, blasting, excavation, and backfilling activities.

During construction, water from the underground workings will be discharged in accordance with permit conditions, via the Upper Portal into the Cambria Icefield as per the discharge activities during exploration. From the discharge point, the natural drainage path is approximately 8 km to Bitter Creek, via Lost Valley and the Bromley Glacier. Based on the ongoing monitoring results, potential effects on Aquatic Resources from discharge to the Cambria Icefield during construction are not expected, and this interaction is not carried forward in the assessment.

During operations, this water will continue to be pumped to the Cambria Icefield for the first 1.5 years of production until the Lower Portal is commissioned. Water would then be pumped to surface and will combine with other mine contact water in the Portal Collection Pond, within the cirque, before being discharged to the receiving environment. The Portal Collection Pond receives the discharge from underground mine dewatering during construction and operations, as well as runoff from the stockpile and laydown areas. Goldslide Creek receives discharges from the Portal Collection Pond as well as discharge from the sediment ponds servicing two talus quarries.

Discharge will meet MMER requirements prior to discharge to Goldslide Creek. Potential effects on aquatic resources will be greatest in the dilution zone (estimated 100 m long), where the discharge is not yet fully mixed.

Baseline studies showed that Goldslide Creek supports high benthic invertebrate abundance (thousands of individuals in the baseline samples), relative to mainstem Bitter Creek, and the community is heavily dominated by pollution intolerant invertebrate species (namely Plecoptera).

The mine discharge could affect periphyton and benthic invertebrates through increased loading of metals, and alteration of pH (acidity). For benthic organisms, effects could include reduction in growth, recruitment, and reproduction with implications for the overall productive capacity of an aquatic community. If concentrations are high enough, effects can be lethal (direct toxicity and mortality of organisms).

17.5.3.2.2 TMF Discharge

During the Operation Phase, process water, runoff from the Process Plant area, runoff from the tailings beaches, and water used in heavy equipment and truck washing facilities will be directed to the TMF. Discharge of excess TMF water to Bitter Creek will be required at certain times of year, to manage the impounded volume behind the TMF. The discharge will be treated prior to release into Bitter Creek, *i.e.* there will be no direct discharge from the TMF under normal operating conditions.

Excess TMF supernatant water will be treated to meet MMER requirements prior to discharge to Bitter Creek. Potential effects on Aquatic Resources will be greatest in the dilution zone (estimated 100 m long), where the discharge is not yet fully mixed.

Benthic invertebrate colonization in Bitter Creek is limited owing to frequent high-energy, high flow events, which scour the channel and flush substrates downstream.

Bitter Creek has low benthic invertebrate abundance (typically less than a hundred individuals per sample), and the benthic samples taken during baseline were dominated by pollution intolerant invertebrate species. The low benthic invertebrate abundance in Bitter Creek likely reflects the high bedload movement of this stream.

Considering that periphyton and benthic invertebrate abundance in Bitter Creek is generally low, the communities of these organisms may be more sensitive to changes in water quality. If the abundance of organisms were to be reduced, regrowth and recolonization may be slow given that natural conditions are already sub-optimal for growth.

17.5.3.2.3 Blasting residues

Ammonium Nitrate Fuel Oil (ANFO) will be used during construction and operation of the mine. Blasting is anticipated to occur on a daily basis during construction and temporary explosives magazines will be stored at Bromley Humps, as well as at various locations along the road, during construction.

Underground mining and mine development, including excavation of each portal entrance and access tunnel, construction of the TMF and road construction, will require some degree of blasting. Blasting residues contain nitrogen compounds that will remain on the surface of excavated rock and be available for transport to the aquatic environment via runoff. The loading of nitrogen into the freshwater environment can increase primary production, cause the accumulation of primary producer biomass, alter the composition of primary producer and secondary producer communities, and cause cascading trophic effects in the food web. Furthermore, some nitrogen compounds (nitrate, nitrite, and ammonia) can have sublethal and lethal effects on aquatic organisms.

During road construction, blasting residues have the potential to leach from excavated rock to access road watersheds. Runoff from blasting areas adjacent to the road, and aerial deposition, also form a potential pathway for blasting residues to enter watercourses However, the vast majority of the explosives will be used for blasting ore at the mine site. It is expected that nitrogen loading from the excavated rock and blasting residues along the access roads will be negligible.

17.5.3.2.4 Runoff

At the Mine Site and Bromley Humps, surface water runoff to watercourses will be non-contact water, as contact water will be intercepted, and directed to the TMF (Bromley Humps), or to Portal Collection Pond (Mine Site), prior to discharge to the receiving environment. Non-contact water runoff in these areas will be directed away from developed areas by means of natural or man-made diversion channels and routed to receiving environment watercourses. Changes to the existing drainage patterns will be minimized, however the altered runoff routes may increase erosion potential as well as sediment loading. Increased TSS, and turbidity (*i.e.*, physical changes to water quality) reduces light penetration in the water column, which in turn reduces primary (photosynthesis) and secondary production.

The highest potential for increased erosion and sedimentation will be during periods of disturbance of natural surface cover and vegetation, such as during construction and closure and reclamation. During closure, drainage patterns will be returned to pre-Project conditions to the maximum extent possible.

Surface water runoff from the road will be a mix of contact and non-contact water. Road runoff has the potential to occur during construction and subsequent use. This will increase erosion and sedimentation potential, particularly where the road is near a watercourse, or where the road fords a watercourse. Road runoff can also contribute metals and other contaminants (blasting residues, PAHs, road salts from de-icing) to the receiving aquatic environment. This source of potential contamination is not captured as contact water (which is treated and discharged).

17.5.3.2.5 Aerial deposition

Dustfall

Dustfall, or total particulate matter, is generated mainly from blasting (for portal and road construction), ore conveying, crushing and hauling, and traffic and equipment use on the access/haul road. Dustfall on watercourses, at high enough rates, can increase TSS (a physical change to water quality). This in turn can lead to effects on Aquatic Resources from homogenization of stream bed features, reduced pool depths, and decreased habitat quality and quantity for periphyton and benthic invertebrate communities.

Using an air dispersion model, CALPUFF, annual maximum dustfall rates (milligrams per square decimeter per day; mg/dm^2/day) from Project sources, at Aquatic Resources sampling sites, were predicted to occur during operations in Year 3. Predicted increases in dustfall rates compared with background levels were typically small (0 to 7% increase), an exception was site GSC02, where the predicted maximum annual dustfall represented an increase of 32% of background. However, predicted maximum annual dustfall at all sites are below the historical provincial annual air quality standard of 1.7 mg/dm^2/day, and therefore potential effects of dustfall on TSS levels in the LSA are expected to be minor, if not negligible.

Acid Deposition

Acid deposition forms when nitrogen oxides (NOx) and sulphur dioxides (SOx) are emitted from burning fossil fuels. Baseline studies indicated that alkalinity, which determines the buffering capacity of water against acidic inputs, is low in Bitter Creek and Goldslide Creek (Appendix 14-A). Acidification conditions (lower pH) can alter the abundance and community composition of periphyton and benthic invertebrate communities.

CALPUFF modelling indicates that the annual maximum concentrations of SOx, NOx (micrograms per cubic meter of air; µg/m^3), at the aquatic sampling site locations will remain well below the ambient air quality objectives. Based on this, acid deposition is considered negligible.

17.5.3.3 Changes in Sediment Quality

Potential effects to Aquatic Resources from changes in sediment quality may occur through the chemical and physical alteration of the sediment in which they live. Reduced abundance and diversity of periphyton and benthic invertebrates may occur if increases in concentrations of sediment quality parameters exceed guideline (MMER and/or CCME Sediment Quality Guidelines for the Protection of Aquatic Life) or background levels.

Pathways to changes to the Sediment Quality VC are described in Chapter 14, and are discussed here in the context of potential effects on Aquatic Resources.

Chemical changes to sediment quality may occur in Goldslide Creek, and Bitter Creek, from changes in water quality. Accordingly, potential effects to Aquatic Resources from chemical changes in sediment quality occur through the same pathways as changes to water quality, namely discharge, which are discussed above in Section 17.5.3.2 and in Chapter 14.

Other pathways to changes in sediment quality are runoff (non-contact water), aerial deposition, and blasting vibration and shockwaves. Physical alteration of sediment through these pathways includes changes in particle size distribution, and increased sedimentation.

Sediment runoff from the Mine Site will be limited primarily to the Construction Phase. During operations, non-contact water runoff will be directed away from developed areas by means of natural or man-made diversion channels and routed to receiving environment watercourses. Changes to the existing drainage patterns will be minimized, however the altered runoff routes may increase erosion potential and sediment loading.

Road runoff will occur during road construction and subsequent use. This will increase erosion and sedimentation potential, particularly where the road is near a watercourse, or where the road fords a watercourse.

A change in particle size distribution, such as a higher proportion of finer sediments, can reduce benthic habitat quality for invertebrates, as coarse substrate (cobble and gravel) is preferred by most Plecoptera species (the most common taxa in the LSA), and finer substrates (sand, silt and organics) generally support more Diptera and Oligochaeta (pollution tolerant species). Alteration of the particle size distribution can also affect colonization success of primary producers (periphyton). Increased sedimentation can cause direct mortality of benthic organisms through smothering. Rates of adsorption of metals into sediment are also linked to particle sizes, and consequently a change in particle size distribution can increase exposure of benthic organisms to metals contamination.

There is also potential for road runoff containing salts (for de-icing in winter) to enter nearby watercourses. This represents a chemical change to sediment quality. Increased inputs of road salts can alter the concentrations of sodium and chloride ions in sediment pore water, which, if concentrations are high enough, could shift the community structure in the receiving waters toward halophilic species.

17.5.3.4 Changes in Streamflow

Potential activities that are likely to influence surface water flows include the dewatering of the underground mine, construction of surface water management facilities, and the use of water for mine-related activities such as dust suppression and providing freshwater for the Process Plant. Flow changes during construction will be negligible. During post-closure flow changes will not exceed 10%, which is within the natural range of flows and therefore considered to have a low probability of impact. The maximum flow reduction in all watercourses throughout mine life is 2.7%, which occurs in Goldslide Creek in December and February; therefore effects from flow reduction is negligible.

During operations, flow in Goldslide Creek is predicted to greatly increase from baseline conditions (up to 400%) due to the direct discharge from the Portal Collection Pond. Since Goldslide Creek flows into Bromley Glacier, the increased flow in Goldslide Creek would add volume, to a much lesser extent, to Bitter Creek.

Potential effects to Aquatic Resources from changes in flow include alterations to their physical habitat. Riffle habitat is ideal for most species for benthic invertebrates present in Goldslide and Bitter Creeks. The quantity of this habitat type could be reduced with increased flow levels and replaced with deeper run habitat. Changes in stream velocities, water depth, and substrate can cause deviations that result in a deterioration of habitat conditions, which in turn can lead to reduced abundance, diversity, or community composition.

17.5.3.5 Blasting

The potential effects on Aquatic Resources from blasting occur through blasting residues, as well as vibration and shockwaves from detonation of explosives. By-products from the detonation of explosives may include ammonia or similar compounds and may be toxic to aquatic organisms. The potential for increased nitrogen loading to streams from the use of nitrogen-containing explosives is discussed in Section 17.5.3.2.3 (Changes to Surface Water Quality).

Blasting vibration and shockwaves have the potential to impact benthic invertebrates through physical effects on the tissues and organs of organisms. In addition, there is also potential for the disturbance of aquatic habitat, primarily from increased sedimentation.

The detonation of explosives can impact nearby watercourses when ground vibrations propagate into the waterbody causing water overpressures and particle motions at the water substrate interface (Kolden and Aimone-Martin 2013). Water overpressure is the sudden change in water pressure from ambient pressure, and is measured in Pascals (Pa). Ground vibration measurements are typically reported as Peak Particle Velocity (PPV) in millimetres per second (mm/s). Methods for calculating setback distances, based on the total net explosive weight of the blasting charge and delay, have been established for fish (Wright and Hopky, 1998). The setback distances specify the distance from the explosive source at which overpressure and particle velocity levels would fall below thresholds for detrimental impacts on free swimming fishes or fish eggs. There are no established methods to calculate setback distances to avoid impacts on benthic invertebrates. Effects on benthic invertebrates from blasting are not well understood. Possible effects include mortality, physical injury, tissue damage, and decreased egg and larvae viability (Hastings and Popper, 2005).

17.6 Mitigation Measures

17.6.1 Key Mitigation Approaches

Results from the review of best management practices, guidance documents, and mitigation measures conducted for similar projects, as well as professional judgment for the Project-specific effects and most suitable management measures, were considered in determining the mitigation measures. The approach to the identification of mitigation measures subscribed to the mitigation hierarchy, as described in the Environmental Mitigation Policy for British Columbia (http://www.env.gov.bc.ca/emop/). Technical and economic feasibility constraints dictated the highest level on the hierarchy that could be achieved for each potential effect and the identification of mitigation measures for managing these effects. The need for any proposed compensation or offset is identified where required, along with the management plan where the scope of such compensation or offset is described.

Potential Project-related effects to Aquatic Resources will be reduced through mitigation measures, management plans, and adaptive management. If mitigation measures were considered entirely effective, potential Project-related effects to the Aquatic Resources VC were not identified as residual effects.

Specific mitigation measures were identified and compiled for each category of potential effect on Aquatic Resources and presented in this section. For the purposes of this assessment, mitigation measures included any action or project design feature that will reduce or eliminate effects to Aquatic Resources. Key approaches include:

- Design Mitigation;
- Regulatory Requirements;
- Best Management Practices (BMPs); and
- Monitoring.

One key mitigation approach that will be applicable to all potential effects on Aquatic Resources is the implementation of an Aquatic Effects Management and Response Plan (AEMRP) (Volume 5, Chapter 29). This plan outlines the aquatic effects management and response to be carried out during all phases of the Project. The AEMRP will include the following:

- Monitoring streams at locations potentially affected by the Project and at reference areas well away from Project activities;

- Monitoring surface water quality, sediment quality, and aquatic biology;

- Monitoring fish populations and fish tissues; and

- If effluent (as defined in MMER regulations) is proposed for discharge to the environment, then additional sampling per MMER requirements may be conducted (effluent characterization; acute toxicity testing; site characterization studies (including hydrology); sublethal toxicity testing).

17.6.1.1 Mitigation Measures for Habitat Loss

Habitat loss from the mine footprint was minimized by Project design. All major mine components are contained within one watershed and overlap with aquatic habitat is limited to the TMF. The Access Road will follow the existing alignment which results in minimizing habitat disturbance and the number of new stream crossings required. Aquatic habitat loss from the Project will therefore be limited to watercourse crossings and road construction along Bitter Creek. Although the road is designed to minimize impacts to aquatic habitat, habitat loss cannot be avoided or fully mitigated, and is therefore carried forward in this assessment as a residual effect.

17.6.1.2 Mitigation Measures for Changes in Surface Water Quality

The primary mitigation measure for potential changes to Aquatic Resources from changes in water quality will be to sequester all mine and site contact water prior to entering the aquatic environment. Mine Site discharge and contact water will be directed to a collection pond for settling before discharge into Goldslide Creek. At Bromley Humps, excess TMF supernatant and all contact water will be treated to meet MMER requirements, prior to discharge into Bitter Creek. Groundwater seepage from the TMF will be collected in two Seepage Collection Ponds and pumped back to the TMF. Project activities related fuels, oils and other hydrocarbons will employ Best Management Practices for machinery operation, maintenance, refueling, and secondary containment systems.

Management plans in Volume 5, Chapter 29 will include: Explosives Management Plan, Fuel Management Plan, Hazardous Materials Management Plan, Material Handling & ML/ARD Management Plan, Site Water Management Plan, Tailings Management Plan and Spill Contingency Plan.

A complete list of mitigation measures to avoid and mitigate effects to Aquatic Resources from changes in water quality can be found in the effects assessment for the Surface Water Quality (Volume 3, Chapter 13).

Even with the application of the mitigation measures described above, CCME guideline exceedances for some water quality parameters are predicted in Goldslide and Bitter Creeks (Section 17.5.3.2). These exceedances are expected to have the potential to result in reduced abundance and diversity of periphyton and benthic invertebrates. The effects on Aquatic Resources from changes in water quality are therefore carried forward as a residual effect.

17.6.1.3 Mitigation Measures for Changes in Sediment Quality

The mitigation measures for potential effects to Aquatic Resources from chemical changes in sediment quality are the same as those discussed for water quality. Effects on Aquatic Resources associated with sedimentation and erosion will be minimized through adherence to Best Management Practices as outlined in management plans in Volume 5, Chapter 29, including the Site Water Management Plan and Erosion and Sediment Control Plan.

A complete list of mitigation measures to avoid and mitigate effects to Aquatic Resources from changes in sediment quality can be found in the effects assessment for the Surface Water Quality (Volume 3, Chapter 13). Additional mitigation measures to avoid and mitigation effects to sediment quality can be found in the effects assessment for Sediment Quality (Volume 3, Chapter 14).

Even with the application of the mitigation measures, potential changes in sediment quality are expected to result in reduced abundance and diversity of periphyton and benthic invertebrates. The effects on Aquatic Resources from changes in sediment quality are therefore carried forward as a residual effect.

17.6.1.4 Mitigation Measures for Changes in Streamflow

The primary mitigation measures for changes in stream flow hydrology are discussed in the Hydrology Effects Assessment (Volume 3, Chapter 12) and include the construction of site water management infrastructure, limiting withdrawal to no more than 10% of stream flows, and matching the discharge from the TMF to the hydrograph. Monitoring of stream flow during operations will determine whether additional measures are needed as mining continues. A complete list of mitigation measures to avoid and mitigate effects to Aquatic Resources from changes in stream flows can be found in Volume 3, Chapter 12.

However, with these mitigation measures in place, there will be still be potential for residual effects on Aquatic Resources.

17.6.1.5 Mitigation Measures for Blasting

Blasting activities will be limited to the Mine Site during operations, so there is no potential for effects on benthic invertebrates from explosive shockwaves as the blasting zone will not be near any fish-bearing watercourses. The use of explosives and subsequent deposition of blasting residues on surfaces, with subsequent possibility of transport to nearby watercourses will be primarily mitigated by capturing runoff and diverting it to the Portal Collection Pond in the Mine Site or to the TMF in Bromley Humps for treatment prior to discharge. Additional mitigation measures are outlined in the Surface Water Quality Chapter (Volume 3, Chapter 13).

Due to the mitigation measures, including monitoring and adaptive management, no residual effects from blasting residues are predicted on Aquatic Resources.

17.6.2 Environmental Management and Monitoring Plans

In addition to mitigation measures, the following environmental management and monitoring plans will be designed and implemented to monitor water quality, aquatic habitat, and aquatic communities in the LSA.

- Access Management Plan;
- Air Quality and Dust Management Plan;
- Aquatic Effects Management and Response Plan;
- Erosion and Sediment Control Plan;
- Explosives Management Plan;
- Fuel Management Plan;
- Mine Closure and Reclamation Plan;
- Material Handling & ML/ARD Management Plan;
- Spill Contingency Plan;
- Tailings Management Plan;
- Terrain and Soil Management Plan;
- Vegetation and Ecosystems Management Plan; and
- Site Water Management Plan.

17.6.3 Effectiveness of Mitigation Measures

The anticipated effectiveness of mitigation measures to minimize the potential for significant adverse effects is evaluated and classified as follows within this section:

- Low effectiveness: Proposed measure is experimental, or has not been applied in similar circumstances.

- Moderate effectiveness: Proposed measure has been successfully implemented, but perhaps not in a directly comparable situation.

- High effectiveness: Proposed measure has been successfully applied in similar situations.

- Unknown effectiveness: Proposed measure has unknown effectiveness because it has not been implemented elsewhere in a comparable project or environment.

The timing of effectiveness of the mitigation measures varies depending on the type of mitigation. Mitigation measures that are part of the project design or that rely on avoidance or prevention of effect through BMPs or Regulatory Requirements are effective immediately. Mitigation measures that are based on monitoring are dependent on the monitoring schedule. The implementation of all the mitigation measures as a whole will generally provide close to immediate effectiveness.

The proposed mitigation measures include standard measures that are known to be effective (based on relevant/applicable experience with other mining projects), and therefore the uncertainty associated with their use is low. Any further uncertainty associated with the effectiveness of the proposed mitigation trends will be addressed through the AEMRP (Volume 5, Chapter 29.5). If monitoring indicates that effectiveness of mitigation measures is lower than predicted, further mitigation may be required as per adaptive management strategies outlined in the AEMRP.

The key measures proposed for mitigating potential effects on the Aquatic Resources VC, along with mitigation effectiveness and uncertainty are outlined in Table 17.6-1. This table also identifies the residual effects that will be carried forward for residual effects characterization and significance determination.

Table 17.6-1: Proposed Mitigation Measures and Their Effectiveness

VC/IC	Potential Effects	Mitigation Measures	Rationale	Applicable Phase(s)	Effectiveness[1]	Uncertainty[2]	Residual Effect
Aquatic Resources (Periphyton; Benthic Invertebrates)	Direct mortality and habitat loss	Infrastructure (including the Access Road) shall be designed in a manner that minimizes the footprint of disturbance and the number of new stream crossing required.	Directly avoids and minimizes the amount of habitat loss to aquatic resources	Construction	Moderate (Some habitat loss will occur)	Low	Yes
	Reduced abundance and diversity from changes in water quality	All implemented mitigation measures for Hydrology (Chapter 12, Section 12.6.3) and Surface Water Quality (Chapter 13, Section 13.6) will serve as mitigation for Aquatic Resources relative to this effect.					Yes
	Reduced abundance and diversity from changes in sediment quality	All implemented mitigation measures for Sediment Quality will serve as mitigation for Aquatic Resources relative to this effect (Chapter 14, Section 14.6).					Yes
		Culvert maintenance will be conducted following Department of Fisheries and Oceans best practice as outlined as measures for working near water, including maintain original stream flow directions.	Minimizes erosion and alteration of stream flow characteristics.	Construction, Operation, Closure and Reclamation	Moderate (Potential for accidents to affect sediment quality)	Low	
	Reduced abundance and diversity from changes in stream flow	All implemented mitigation measures for Hydrology will serve as mitigation for Aquatic Resources relative to this effect (Chapter 12, Section 12.6).					Yes

VC/IC	Potential Effects	Mitigation Measures	Rationale	Applicable Phase(s)	Effectiveness[1]	Uncertainty[2]	Residual Effect
	Reduced abundance and diversity from blasting and blasting residue	All implemented mitigation measures for Surface Water Quality will serve as mitigation for Aquatic Resources relative to this effect (Chapter 13, Section 13.6).					No
		Capture surface runoff and diverting it to the Portal Collection Pond in the Mine Site or the TMF in Bromley Humps for treatment prior to discharge.	Minimizes the potential for increased nitrogen loading to streams	Construction, Operation, Closure and Reclamation	High	Low	
		Blasting activities will be limited to the Mine Site during operations, so there is no potential for effects on benthic invertebrates from explosive shockwaves as the blasting zone will not be near any fish-bearing watercourses.	Avoidance blasting activities within fish-bearing watercourses.	Construction, Operation, Closure and Reclamation	High	Low	

[1] Effectiveness: Low = measure unlikely to result in effect reduction; Moderate = measure has a proven track record of partially reducing effects; High = measure has documented success (e.g., industry standard; use in similar projects) in substantial effect reduction

[2] Uncertainty: Low = proposed measure has been successfully applied in similar situations; Moderate = proposed measure has been successfully implemented, but perhaps not in a directly comparable situation; High = proposed measure is experimental, or has not been applied in similar circumstances

17.7 Residual Effects Characterization

17.7.1 Summary of Residual Effects

The residual effects after application of mitigation measures are:

- Reduced abundance and diversity of periphyton and benthic invertebrates from habitat loss;
- Reduced abundance and diversity of periphyton and benthic invertebrates from changes in water quality;
- Reduced abundance and diversity of periphyton and benthic invertebrates from changes in sediment quality; and
- Reduced abundance and diversity of periphyton and benthic invertebrates from changes in streamflows.

17.7.2 Methods

Significance of residual effects was evaluated based on several criteria including: magnitude, duration, frequency, reversibility, context, and probability of occurrence, as defined for Aquatic Resources (Table 17.7-1).

17.7.2.1 Residual Effects Criteria

Table 17.7-1: Characterization of Residual Effects on Aquatic Resources

Criteria	Characterization for Aquatic Resources
Magnitude	• Low (L): The magnitude of effect is within the range of natural variation in the abundance or community composition of Aquatic Resources and/or the value of a measurement indicator is less than guideline or threshold value for the protection of aquatic life. • Moderate (M): The magnitude of the effect exceeds by less than 30% of the limits of natural variation and/or the value of the measurement indicator is up to 30% greater than guideline or threshold value for the protection of aquatic life. • High (H): The magnitude of effect exceeds by more than 30% of the limits of natural variation and/or the value of a measurement indicator is more than 30% greater than guideline or threshold value for the protection of aquatic life.
Geographical Extent	• Discrete (D): Effect is limited to the immediate receiving environment in Goldslide Creek watershed (Mine Site) or the immediate freshwater environment in Bitter Creek (Bromley Humps, Access Road). • Local (L): Effect extends beyond the immediate receiving environment of Goldslide Creek and Bitter Creek near the TMF to the entire Bitter Creek watershed. Effects do not extend into the RSA.

Criteria	Characterization for Aquatic Resources
	• Regional (R): Effect extends across the RSA. • Beyond Regional (BR): Effect extends beyond the RSA and beyond the province (transboundary effects).
Duration	• Short-term (ST): Effect lasts less than 18 months (during the Construction Phase of the Project). • Long-term (LT): Effect lasts greater than 18 months and less than 22 years (encompassing Operation, Closure and Reclamation, and Post-Closure Phases). • Permanent (P): Effect lasts more than 22 years.
Frequency	• One time (O): Effect is confined to one discrete event (month). • Sporadic (S): Effect occurs rarely and at sporadic intervals. • Regular (R): Effect occurs on a regular basis. • Continuous (C): Effect occurs constantly.
Reversibility	• Reversible (R): Effect can be reversed. • Partially reversible (PR): Effect can be partially reversed. • Irreversible (I): Effect cannot be reversed, is of permanent duration.
Context	• High: the receiving environment has a high natural resilience to imposed stresses, and can respond and adapt to the effect. • Neutral: the receiving environment has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect. • Low: the receiving environment has a low resilience to imposed stresses, and will not easily adapt to the effect.

17.7.2.2 Analytical Assessment Techniques for Aquatic Resources

Habitat loss under the TMF was calculated as stream length multiplied by an assumed channel width of 0.5 m.

For all watercourse crossings along the road alignment, field data were used to assess whether or not a crossing site constituted aquatic habitat. If the crossing site had no visible channel (NVC), or was a non-classified drainage (NCD, channel with length < 100 m), it was not considered as aquatic habitat. The area of habitat lost at watercourse crossings was then calculated by multiplying the number of crossing containing aquatic habitat with the typical footprint of a culvert installation. A typical culvert was assumed to be 1 m in diameter, and 10 m or 12 m in length for the access road and haul road respectively.

Habitat loss along Bitter Creek was based on the areal extent of aquatic habitat below the annual high water mark that will be infilled as part of road construction.

For other effects, predictions from Appendix 14-C informed the Aquatic Resources residual effects assessment.

17.7.2.3 Assessment of Likelihood

Likelihood is determined per the attributes listed in the Application/EIS Methodology Chapter (Volume 3, Chapter 6).

17.7.2.4 Significance Determination

The evaluation of significance was completed by comparing predicted residual effects against thresholds, standards, trends, or objectives relevant to ecosystems, as defined below.

- Not significant: Residual effects have low or moderate magnitude; local to regional geographic extent; short- or long-term duration; could occur at any frequency, and are reversible or partially reversible in either the short or long-term. The effects on Aquatic Resources are either indistinguishable from background conditions (*i.e.,* occur within the range of natural variation as influenced by physical, chemical, and biological processes), or distinguishable at the individual level.

- Significant: Residual effects have high magnitude; regional or beyond regional geographic extent; duration is permanent; and can occur at all frequencies. Residual effects on Aquatic Resources are consequential (*i.e.*, structural and functional changes in populations, communities, and ecosystems are predicted) and are irreversible.

17.7.2.5 Confidence and Risk

Confidence definitions for the Application/EIS are provided in Volume 3, Chapter 6.

17.7.3 Potential Residual Effects Assessment

17.7.3.1 Reduced Abundance and Diversity of Periphyton and Benthic Invertebrates from Habitat Loss Under the Project footprint

17.7.3.1.1 Residual Effect Analysis

Habitat loss and direct mortality of benthic invertebrates is anticipated under the TMF, at road crossings, and in Bitter Creek where the Access Road will encroach on the stream channel. There will be no habitat loss in Bear River.

17.7.3.1.2 Characterization of Residual Effect

The residual effect to Aquatic Resources (direct mortality leading to a reduced abundance) from habitat loss (from infilling of aquatic habitat) is characterized as follows:

- Magnitude is Low; the total area of habitat loss is relatively small and therefore changes in overall abundance and diversity of benthic invertebrates and periphyton in the Project area will be small;

- Geographical extent is Discrete; the areas of total habitat loss are limited to immediate receiving environments of the access road crossings, and small sections of minor, unnamed watercourses under the TMF, and a short section of Bitter Creek from the access road;
- Duration is Short-term; habitat loss occurs once during the Construction Phase; benthic invertebrate and periphyton populations will recover once conditions return to their pre-disturbance state;

Frequency is One time; habitat loss and mortality will be limited to a discrete occurrence during the Construction Phase;

- Reversibility is Partial, because although the habitat loss is permanent, the benthic invertebrate and periphyton populations will recover; and
- Context is High; benthic invertebrate and periphyton populations have high resilience to a relatively small decrease in available habitat.

17.7.3.1.3 Likelihood

The likelihood of direct mortality of benthic invertebrates from habitat loss is high, as it is unlikely that benthic invertebrate organisms would not be present in the areas that will be infilled to construct the road infrastructure. However, depending on the timing of the work, some watercourses may be dry, which would reduce the likelihood of impacts.

17.7.3.1.4 Significance

Although there will be direct loss of aquatic habitat within Project streams, effects to periphyton and benthic invertebrate abundance from this pathway will be localized and have no far-reaching effects on regional productivity or diversity. Overall, ecological conditions that support populations relative to existing baseline will be maintained. Therefore, the residual effect is considered not significant.

17.7.3.1.5 Confidence and Risk

The level of confidence associated with the predicted residual effect on Aquatic Resources from habitat loss is high. The magnitude of the effect can be quantified (area of habitat loss), and the mechanism through which habitat loss causes direct mortality of benthic invertebrates is well understood. Uncertainty arises because the abundance of benthic invertebrates and periphyton within the areas of habitat will be lost are unknown. However, risk of affecting ecological conditions that support populations relative to existing baseline is low to negligible because the areas lost represent a very small proportion of the available habitat. As such, additional risk analysis is not required.

17.7.3.2 Reduced Abundance and Diversity of Periphyton and Benthic invertebrates from Changes in Surface Water Quality

17.7.3.2.1 Residual Effect Analysis

Residual effects on Aquatic Resources from changes in water quality, are expected, based on the Water and Load Balance Model (Appendix 14-C) which, for the mitigated scenario, predicts that some water quality parameters will exceed guidelines for the protection of aquatic life.

The Water and Load Balance Model (Appendix 14-C) predicted the maximum monthly concentrations of water quality parameters in Goldslide Creek, Bitter Creek, Rio Blanco Creek, and Bear River, for Operations (Years 1 to 6) and Closure/Post-Closure (Years 7 to 21). Water and Load Balance Model predictions are summarized in the Surface Water Quality Effects Assessment (Volume 3, Chapter 13). Potential contaminants of concern (COPCs) for Surface Water Quality were identified as those parameters predicted to exceed water quality guidelines (CCME or BC MOE) in the expected case (P50). The following contaminants of potential concern were identified, which are discussed below in relation to residual effects on Aquatic Resources: antimony, cadmium, copper, selenium, silver, and zinc.

- Goldslide Creek
  - Operations Phase: antimony, cadmium, selenium, and zinc
  - Post-Closure Phase: cadmium, copper, selenium, silver, and zinc

- Rio Blanco
  - Post-Closure Phase: cadmium, silver, and zinc

- Bitter Creek
  - Operations Phase: selenium
  - Post-Closure Phase: cadmium, copper, selenium, silver, and zinc

There are no potential contaminants of concern for Aquatic Resources in Bear River.

Antimony

Antimony exceeds the BC Working WQG (0.009 mg/L) in Goldslide Creek during operations. There is no CCME guideline for antimony, and the BC working WQGs have not yet been fully assessed and formally endorsed by BC MOE. Working guidelines should be used with caution. The working guideline for antimony is based on the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000). The guideline value was derived from a data for a single fish species (*Pimephales promelas;* fathead minnow), with data from two geographic regions in the United States (Puget Sound/Commencement Bay and San Francisco Bay). The guideline is defined in the Australian and New Zealand document as “a freshwater low reliability trigger value”. The document states this value should only be used as an indicative interim working level. Furthermore, a safety factor of 1000 was applied to calculate the guideline value; the minimum acute data point for flathead minnow was 9000 µg/L (9 mg/L). As such, this guideline value does not provide an accurate threshold for adverse effects on Aquatic Resources.

Studies of the impact of antimony on benthic invertebrates are limited, and indicate that different species accumulate metals at different rates, and show varying sensitivity, depending on feeding habits, habitat, and position in the food chain (Culioli *et al.* 2009; Mori *et al.* 1999).

Cadmium

Cadmium exceeds the BC WQG (~2-4 times higher) and CCME WQG (~2-5 times higher) during both operations and post-closure in Goldslide Creek. Exceedances also occur in Rio Blanco Creek (~1-5 times higher than the BC WQG and CCME WQG, respectively) and Bitter Creek (~1-2 times higher than the BC WQG and CCME WQG, respectively) during post-closure only.

These exceedances are in part due to background concentrations, which exceeded guidelines in both the water and sediment. Despite this, Goldslide Creek supports high benthic invertebrate abundance (thousands of individuals in the baseline samples), which suggests that the benthic community is adapted to elevated water and sediment cadmium concentrations. The effect of cadmium on aquatic invertebrates is highly variable among taxonomic groups. Short term toxicity tests have determined crustaceans, hydra and various mussel species to be the most sensitive, whereas mayflies, stoneflies and midges are more tolerant (McCahon and Pascoe, 1988; Shaw *et al*., 2006; Brinkman and Johnston, 2008).

The benthic community in Goldslide Creek is dominated by invertebrate species (i.e. stoneflies) that prefer erosional areas with coarser substrate and flowing water. Baseline sediment samples, targeted depositional areas with fine-grained sediment. Contaminant concentrations in depositional areas would likely be higher than in erosional areas.

There are no baseline data for Aquatic Resources in Rio Blanco Creek, but it can be expected that the sediment chemistry in this creek is similar to Goldslide Creek (i.e. high background sediment cadmium concentrations). As such, like Goldslide Creek, the benthic community are likely adapted to elevated cadmium levels.

Exceedances in Bitter Creek generally occur during the spring / summer months when hardness is lower. Benthic invertebrates in Bitter Creek are dominated by the more cadmium tolerant stoneflies, mayflies and midges (McCahon and Pascoe, 1988; Shaw *et al*., 2006; Brinkman and Johnston, 2008).

Copper

During post-closure, the predicted concentration of copper in Goldslide Creek is 0.00498 mg/L (all months). This is about ~1-2 times the BC and CCME WQGs, respectively. Background concentrations account for between 37% and 76% of the copper in the Post-Closure Phase.

Increased copper concentrations can lead to decreased benthic invertebrate diversity and abundance (Environment Canada, 1998). Decreased abundance of freshwater gastropods have been noted in studies where sediment concentrations of copper are elevated, and it also has been determined to significantly decrease growth of freshwater amphipods and midges (Milani *et al.,* 1996). The BC WQG is only slightly exceeded in Goldslide Creek (1.2 times higher). Therefore, the increases in copper concentrations in the water column are unlikely to affect the benthic community, either indirectly via sediment, or directly via waterborne exposure. Baseline mean sediment copper concentrations in Goldslide Creek exceeded the PEL sediment quality guideline, indicating that the benthic community has adapted to elevated copper concentrations.

Selenium

Selenium exceeds the BC WQG (~2 times higher) and CCME WQG (~4 times higher) during both operations and post-closure in Goldslide Creek. In Bitter Creek, selenium exceeds the BC WQG (1.2-2 times higher) and the CCME WQG (~3-4 times higher) during operations and post-closure. These exceedances are largely due to background concentrations, which exceeded guidelines in both the water and sediment.

CCME and BC water quality guidelines for selenium are based on a lowest observed effect level (LOEL) of 0.01 mg/L introduced by the International Joint Commission (IJC) to protect species in the Great Lakes (IJC 1981). For the CCME guideline, a safety factor of 10 was applied to the LOEL to end up with the guidance of 0.001 mg/L. The BC WQG of 0.002 mg/L incorporates a safety factor of 5 to recognize that selenium is an essential trace element for animal nutrition and that it is the bioaccumulation of selenium through the food chain (chronic effects) that is the major source, not through the water column. Bacteria, algae and invertebrates play a large role in the transformation of selenium and its transfer into the aquatic food web, however these organisms are also subject to selenium toxicity and can be negatively affected (BC MOE, 2014).

During the life of the project, water column selenium concentrations are not more than 2 times the background. In Goldslide Creek this increase from background is predicted in all months, and throughout both phases, and is therefore likely to result in an increase (albeit smaller in magnitude) in sediment selenium concentrations. Baseline sediment selenium concentrations in Goldslide Creek were about 6 times higher than the BC WQG. This indicates that the benthic community is adapted to elevated sediment selenium concentrations, as Goldslide Creek supports high benthic invertebrate abundance (thousands of individuals in the baseline samples).

Selenium concentrations decrease with downstream sites in Bitter Creek. The marginal increases from background and above guidelines are unlikely to affect overall primary and secondary productivity in Bitter Creek, as this is naturally limited by the unstable nature of creek bed.

Silver

Silver exceeds the BC WQG (~2 times higher) but not the CCME WQG in Goldslide Creek. Similarly, in Rio Blanco Creek, silver exceeds the BC WQG (1.2 times higher) but not the CCME WQG. In Bitter Creek, silver does not exceed the BC WQG but does exceed the CCME WQG (~2 times higher). Exceedances in all creeks occur during post-closure only.

Exceedances are attributable to elevated concentrations in the mine contact groundwater that is predicted to report to surface water decades after the underground mine refloods.

There is no CCME or BC sediment guideline for silver, and baseline sediment samples from Goldslide, Rio Blanco and Bitter creeks were not analyzed for silver. As a result, the degree to which changes in water column silver concentrations will affect sediment quality (and therefore benthic organisms) in these creeks cannot be estimated with confidence. However, given that the maximum water concentration is 36 times and 15 times higher than the background in Goldslide and Rio Blanco creeks, respectively, a change in sediment silver concentrations is likely in these creeks. In Bitter Creek, silver concentrations remains below the BC WQG guideline and is higher than background by 4 times. Silver concentrations also decrease with distance downstream, therefore an adverse effect on Aquatic Resources because of this increase is likely to be minor, if not negligible.

Zinc

During operations, zinc does not exceed the BC WQG but marginally exceeds the CCME WQG (1.1 times higher) in Goldslide Creek. However, during post-closure in Goldslide Creek, zinc exceeds both the BC WQG (~3 times higher) and CCME WQG (~2 times higher). In Rio Blanco Creek, zinc exceeds the BC WQG (~2 times higher) but not the CCME WQG during post-closure. This trend continues in Bitter Creek, where zinc exceeds the BC WQG (1.4 times higher) but not the CCME WQG and in post-closure only.

Elevated zinc concentrations can lead to decreased benthic invertebrate diversity and abundance (Environment Canada, 1998). Decreased species richness associated with elevated zinc concentrations have been identified for Ephemeroptera, Plecoptera and Trichoptera (CCME, 1999).

Both CCME and BC guidelines are hardness dependent and so exceedances in Rio Blanco and Bitter creeks occur during the spring / summer months, when hardness levels are lower. The BC long term guideline is for the protection of freshwater aquatic life from chronic effects and so the seasonal exceedances in Rio Blanco and Bitter creeks will unlikely have an adverse effect on the benthic community. During operations, discharge of underground mine water to Goldslide Creek is year-round. However, zinc concentrations are not predicted to be above BC WQG and is only above CCME WQG by 10%. Therefore, adverse effects to Aquatic Resources in Goldslide Creek are also not expected during operations.

17.7.3.2.2 Characterization of Residual Effect

The residual effect from changes in water quality (reduced abundance and diversity of periphyton and benthic invertebrates) is characterized as follows:

- Magnitude is:
  - Moderate for Goldslide Creek; the change in Aquatic Resources is expected to be within 30% of the limits natural variation. The majority of the Surface Water Quality parameters are predicted to be within the limits of natural variability, and only five parameters are predicted to exceed the BC WQG for the protection of aquatic life by more than 30%.

  - Low for Bitter Creek and Rio Blanco Creek; Similar to Goldslide Creek, the change in Aquatic Resources is expected to be within 30% of natural variation. Most of the Surface Water Quality parameters are predicted to be within the limits of natural variability, and only three parameters are predicted to exceed the BC WQG for the protection of aquatic life by more than 30%. Exceedances are lower with distance downstream.

- Geographical extent is Local; effect extends beyond the immediate receiving environment of Goldslide Creek and Bitter Creek near the TMF to the entire Bitter Creek watershed. Effects do not extend into the RSA.

- Duration is Permanent; Surface Water Quality in receiving water bodies will be changed for more than 22 years (beyond Post-Closure);

- Frequency is Sporadic; discharges occur on an as-needed basis, such that potential effects on Aquatic Resources from predicted guideline exceedance may not occur during periods where there are no discharges.

- Reversibility is Partially Reversible; Complete reversibility of Surface Water Quality back to baseline conditions is unlikely or very far into the future. The effect of changes in surface water quality on the abundance and diversity of Aquatic Resources in Goldslide Creek will unlikely be reversible. However, in downstream water bodies, the magnitude of changes in Surface Water Quality is within natural variability and it is expected that any effects to these benthic invertebrate and periphyton populations would be reversible.

- Context is High; benthic invertebrate and periphyton populations appear to be thriving in the receiving water bodies, considering the dynamic, hostile environment of these creeks, many which are naturally elevated in metals. Aquatic Resources therefore has high resilience and adaptability to potential effects from changes in Surface Water Quality.

17.7.3.2.3 Likelihood

The likelihood of effects to Aquatic Resources from Changes in Surface Water Quality is High in Goldslide Creek and Low in Rio Blanco and Bitter Creek. Goldslide Creek is the immediate receiving environment and subject to the highest water quality parameter concentrations. Predicted increases in the contaminants of potential concern decrease with distance downstream in the Bitter Creek watershed.

17.7.3.2.4 Significance

Although there may be a reduction in periphyton and benthic invertebrate abundance and community health within the creeks where exceedances of water quality guidelines are predicted, effects on Aquatic Resources from this pathway, will be localized and have no far-reaching effects on regional productivity or diversity. Based on the model predictions for Surface Water Quality, and inferred effects on Sediment Quality, the capacity of Goldslide, Rio Blanco and Bitter creeks to support a community of benthic organisms will likely be maintained. Therefore, the residual effect is considered not significant. The Assessment Endpoint of maintenance of the ecological conditions that support populations relative to existing baseline may be adversely affected from a residual effect from Changes in Surface Water Quality in Goldslide Creek. An adverse effect is unlikely in Bitter Creek.

17.7.3.2.5 Confidence and Risk

The level of confidence associated with the predicted residual effect on Aquatic Resources from Changes in Water Quality is high. The Changes in Surface Water Quality can be quantified (predicted magnitude of CCME exceedance), and the mechanism through which these changes impact Aquatic Resources are reasonably well understood. The water quality guidelines for the protection of aquatic life, provide a threshold for determining when an effect on Aquatic Resources can be expected, and the severity of the effect can be inferred from the magnitude of guideline exceedances. However, uncertainties are inherent in the water quality modelling, and model predictions are dependent on numerous input sources. This uncertainty may affect the likelihood or significance of the predicted residual effect on Aquatic Resources, as concentrations may be higher than predicted. Where there were uncertainties in the water quality model input assumptions, reasonably conservative assumptions were made to address those uncertainties and thereby reduce risk. Further details on the assumptions, uncertainty, and conservatism in the water quality model are provided in Appendix 14-C.

To address uncertainty in predicting how the changes in Surface Water Quality would affect abundance and diversity of periphyton and benthic invertebrates, the residual effect analysis considered factors such as the resiliency of the benthic community to changes in water quality (based on background concentrations of the potential contaminants of concern), the composition of the community, as well as discharge timing, and magnitude of predicted water concentrations of contaminants. Understanding of how these variables could influence the benthic community during the mine life allowed for a higher level of confidence in predicting the residual effect.

Based on the confidence in the water quality predictions, and the baseline benthic data which covers Goldslide Creek and Bitter Creek, it was determined that additional risk analysis was not required for the residual effect. To reduce uncertainty and maintain the ecological conditions that support populations relative to existing baseline, monitoring and adaptive management strategies will be implemented, as described in the AEMRP (Volume 5, Chapter 29.5) and the Adaptive Management Plan (Volume 5, Chapter 29.2). These management plans have been designed to mitigate the risk related to a residual effect on Aquatic Resources. The objectives of the AEMRP is to minimize the risk of effects to the aquatic environment through Project design, monitoring and adaptive management. The AEMRP includes an AEMP that will provide feedback via the receiving environment on the performance of IDM's management and mitigation during construction, operations, reclamation and closure, and post-closure phases of the Project. The AEMRP also includes management response measures (additional assessment, monitoring and mitigation measures) that would be implemented in response to an unanticipated effect on Aquatic Resources.

17.7.3.3 Reduced Abundance and Diversity of Periphyton and Benthic Invertebrates from Changes in Sediment Quality

17.7.3.3.1 Residual Effect Analysis

A residual effect to Aquatic Resources from changes in Sediment Quality in Goldslide Creek and in Bitter Creek is anticipated based on the predictions of the Water and Load Balance Model. The predictions indicate that concentrations of contaminants of concern in the water column will be above guideline and elevated from background concentrations in Goldslide Creek and Bitter Creek. Based on the magnitude of the predicted increases, changes to sediment quality are also expected in those creeks. This is described in the Sediment Quality effects assessment (Volume 3, Chapter 14).

17.7.3.3.2 Characterization of Residual Effect

Residual effects on Aquatic Resources from Changes in Surface Water Quality and from Changes in Sediment Quality were assessed using model predictions (Appendix 14-C), and so analysis from Section 17.7.3.2.1 applies here as well.

- Magnitude is Low; the change in Aquatic Resources is expected to be within 30% of natural variation. The majority of the Sediment Quality parameters are predicted to be within the limits of natural variability, and the overall predicted change in sediment quality conditions is low.

- Geographical extent is Local; effect extends beyond the immediate receiving environment of Goldslide Creek and Bitter Creek near the TMF to the entire Bitter Creek watershed. Effects do not extend into the RSA.

- Duration is Permanent; Sediment Quality in the receiving water bodies will be changed for more than 22 years (beyond Post-Closure);

- Frequency is Continuous; sediments will integrate and accumulate metals loading from mine discharges and groundwater during the mine life, and therefore Aquatic Resources will be continuously exposed to altered Sediment Quality;

- Reversibility is Reversible; Complete reversibility of Surface Water Quality and Sediment Quality back to baseline conditions is unlikely or very far into the future. However, the magnitude of changes in sediment is within natural variability and it is expected that any effects to these benthic invertebrate and periphyton populations would be reversible.

- Context is High; benthic invertebrate and periphyton populations appear to be thriving in the receiving water bodies, considering the dynamic, hostile environment of these creeks, many which are naturally elevated in metals in the sediment. Aquatic Resources therefore has high resilience and adaptability to potential effects from changes in Sediment Quality.

17.7.3.3.3 Likelihood

The likelihood of effects to Aquatic Resources from Changes in Sediment Quality is High in Goldslide Creek and Low in Rio Blanco and Bitter Creek. Goldslide Creek is the immediate receiving environment and subject to the highest water quality parameter concentrations, which equates to a higher potential for alteration of the sediment chemistry. Predicted increases in the contaminants of potential concern decrease with distance downstream in the Bitter Creek watershed.

17.7.3.3.4 Significance

Although there will be a reduction in periphyton and benthic invertebrate abundance and community health in Goldslide Creek where exceedances of sediment quality guidelines are predicted, effects on Aquatic Resources from changes in sediment quality will be localized and have no far-reaching effects on regional productivity or diversity. Based on the model predictions for Surface Water Quality, and inferred effects on Sediment Quality, the capacity of Goldslide Creek to support a community of benthic organisms will likely be maintained. Therefore, the effect is considered not significant. The Assessment Endpoint of maintenance of the ecological conditions that support populations relative to existing baseline may be altered from a residual effect from changes in Sediment Quality in Goldslide Creek, but not in Bitter Creek.

17.7.3.3.5 Confidence and Risk

The level of confidence associated with the predicted residual effect on Aquatic Resources from changes in Sediment Quality is moderate, because the magnitude of the effect (changes in sediment parameter concentrations) cannot be fully quantified, but only inferred from the water quality predictions. The mechanisms through which physical and chemical changes to sediment quality impact Aquatic Resources are well understood. However, uncertainties are inherent in the water quality modelling, and model predictions are dependent on numerous input sources. Further uncertainty arises from the semi-quantitative method of relating predicted changes in Surface Water Quality to changes in Sediment Quality, and an ultimate effect on Aquatic Resources. This uncertainty may affect the likelihood or significance of the predicted residual effect on Aquatic Resources, as the response in the benthic community to changes in Sediment Quality may differ from what is expected, if water quality deviates from predictions.

Where there were uncertainties in the water quality model input assumptions, reasonably conservative assumptions were made to address those uncertainties and thereby reduce risk. Further details on the assumptions, uncertainty, and conservatism in the water quality model are provided in Appendix 14-C. To address uncertainty in predicting how the changes in Sediment Quality would affect abundance and diversity of periphyton and benthic invertebrates, the residual effect analysis considered factors such as the resiliency of the benthic community to changes in sediment quality (based on background sediment concentrations of the potential contaminants of concern), the habitat preferences of the benthic organisms, as well as discharge timing. Understanding of how these variables could influence the benthic community during the mine life allowed for a higher level of confidence in predicting the residual effect.

Based on the confidence in the Surface Water Quality predictions, and the baseline Aquatic Resources data which covers Goldslide Creek and Bitter Creek, it was determined that additional risk analysis was not required for the residual effect. To reduce uncertainty and maintain the ecological conditions that support populations relative to existing baseline, monitoring and adaptive management strategies will be implemented, as described in the AEMRP (Volume 5, Chapter 29.5) and the Adaptive Management Plan (Volume 5, Chapter 29.2). These management plans have been designed to mitigate the risk related to a residual effect on Aquatic Resources. The objectives of the AEMRP is to minimize the risk of effects to the aquatic environment through Project design, monitoring and adaptive management. The AEMRP includes an AEMP that will provide feedback via the receiving environment on the performance of IDM's management and mitigation during construction, operations, reclamation and closure, and post-closure phases of the Project. The AEMRP also includes management response measures (additional assessment, monitoring and mitigation measures) that would be implemented in response to an unanticipated effect on Aquatic Resources.

17.7.3.4 Reduced Abundance and Diversity of Periphyton and Benthic Invertebrates from Changes in Streamflows

17.7.3.4.1 Residual Effect Analysis

A residual effect to Aquatic Resources from changes in streamflow in Goldslide Creek and in Bitter Creek is anticipated based on the water quantity predictions in Appendix 14-C.

During operations, significant increases in flow will occur in Goldslide Creek and Bitter Creek as result of mine discharge into Goldslide Creek.

- During winter, the predicted flow in Goldslide Creek is approximately 300-400% higher than baseline conditions for those months. When flows are highest in the creek during freshet and summer (May to September) the predicted increase in flow in Goldslide Creek will range from approximately 11% to 24% higher than baseline conditions for those months.

- Since Goldslide Creek flows into Bitter Creek, the increased predicted flow observed in Goldslide Creek from underground dewatering is observed to a lesser extent downstream in Bitter Creek. The maximum predicted increase in flow in winter is approximately 7%, 5%, and 4% of baseline conditions at BC08, BC06, and BC02 respectively. During freshet and summer (May to September) the change in flow is negligible in Bitter Creek.

Further discussion of these flow changes in relation to peak flows and channel geomorphology is provided in Appendix 14-C. In Bear River, changes in predicted flow will be insignificant through all mine phases (±1% or less for all months of the year).

In terms of effects on Aquatic Resources, the flow regime of Goldslide Creek will be considerably altered during operations, with increased flow in every month. This will cause alterations to the physical habitat (stream velocities, water depth, substrate) making it less suitable for supporting the benthic community. The increased flow during operations for the winter is much less than the peak flows during the summer in Goldslide Creek, meaning that the benthic organisms are subject to large fluctuations in flow under natural conditions. However, the life cycle of benthic invertebrates is coupled with the natural hydrograph, including a winter low flow period. Increases above mean peak flow are predicted during May (11% higher than summer high flow). This is expected to pose limits on the productive capacity of benthic organisms, as they will be subjected to higher velocities and flushing flows that would wash substrate (as well as the organisms) downstream, thereby reducing the stability of habitat. Predicted flow changes in Goldslide Creek during the Post-Closure Phase will be minimal, with monthly flows ranging from approximately 1% to 7% over monthly baseline conditions.

In Bitter Creek, the predicted flow changes are less severe and changes greater than 4% occur in the winter months only during operations. During Post-Closure, monthly predicted flows are below 4%. Baseline studies showed that Bitter Creek had low benthic invertebrate abundance (typically less than a hundred individuals per sample), and the benthic samples were also dominated by Plecoptera. Benthic invertebrate colonization in Bitter Creek is limited owing to frequent high-energy, high flow events, which scour the channel and flush substrates downstream. Increases above mean peak flow are predicted during June but are negligible (1-2% increase). Effects on Aquatic Resources in Bitter Creek are therefore not carried forward, because peak flows in summer are what limit the productive capacity of benthic invertebrates and periphyton, and these will not be exceeded. The increases in winter (up to 7%) may a have positive effect, because more water flow will prevent the creek from freezing to bottom in some sections increasing the available flowing water habitat.

17.7.3.4.2 Characterization of Residual Effect

The residual effect from changes in streamflow (reduced abundance and diversity of periphyton and benthic invertebrates) is characterized as follows:

Magnitude is High for Goldslide Creek and Low for Bitter Creek; based on the predictions for increases in flow;

Geographical extent is Discrete for Goldslide Creek and Local for Bitter Creek, as the effect is limited to the immediate receiving environment in Goldslide Creek watershed (mine area) or the immediate freshwater environment in Bitter Creek (TMF and Access Roads);

Duration is Short-term; changes to streamflows from discharge inputs is limited to the operations phase;

- Frequency is Continuous; Aquatic Resources in Goldslide will be subject altered flows in every month;
- Reversibility is Reversible; after operations, the flow regime will return to within baseline levels and therefore the benthic community will recover as well;
- Context is High; Aquatic Resources can recover once flows revert to baseline levels.

17.7.3.4.3 Likelihood

The likelihood of effects to Aquatic Resources from changes in streamflows (increase in flows) is High in Goldslide Creek and Low in Bitter Creek.

17.7.3.4.4 Significance

Although there a reduction in periphyton and benthic invertebrate abundance and community health in Goldslide Creek is predicted, the effect will be localized and have no far-reaching effects on regional productivity or diversity. The effect is also short-term, and reversible. Therefore, the residual effect is considered not significant. The Assessment Endpoint of maintenance of the ecological conditions that support populations relative to existing baseline may be adversely effected from a residual effect from changes in streamflows in Goldslide Creek, but not in Bitter Creek.

17.7.3.4.5 Confidence and Risk

The level of confidence associated with the predicted residual effect on Aquatic Resources from Changes in Streamflows is moderate. The magnitude of the effect can be indirectly quantified (magnitude of flow changes), and the mechanism through which changes in streamflow impact Aquatic Resources is reasonably well understood. However, uncertainties are inherent in the water quantity (flow) modelling, and model predictions are dependent on numerous input sources. Further uncertainty arises from qualitatively predicting how changes in stream flow lead to an ultimate effect on Aquatic Resources. Where there were uncertainties in the model input assumptions for flow predictions, reasonably conservative assumptions were made to address those uncertainties and thereby reduce risk. Further details on the assumptions, uncertainty, and conservatism in the model are provided in Appendix 14-C.

To address uncertainty in predicting how the changes in streamflow would affect abundance and diversity of periphyton and benthic invertebrates, the residual effect analysis considered the magnitude of the flow changes (relative to baseline), and any predicted increases above mean peak flow. Understanding of how these changes in flow would affect the benthic community, both directly (e.g. flushing organisms downstream), and indirectly (by altering their habitat) during the mine life was crucial for increasing the level of confidence in predicting the residual effect. Based on the confidence in the water quantity (streamflow) predictions, and the baseline benthic data which covers Goldslide Creek and Bitter Creek, it was determined that additional risk analysis was not required for the residual effect. To reduce uncertainty and maintain the ecological conditions that support populations relative to existing baseline, monitoring and adaptive management strategies will be implemented, as described in the AEMRP (Volume 5, Chapter 29.5) and the Adaptive Management Plan (Volume 5, Chapter 29.2). These management plans have been designed to mitigate the risk related to a residual effect on Aquatic Resources. The objectives of the AEMRP is to minimize the risk of effects to the aquatic environment through Project design, monitoring and adaptive management. The AEMRP includes an AEMP that will provide feedback via the receiving environment on the performance of IDM's management and mitigation during construction, operations, reclamation and closure, and post-closure phases of the Project. The AEMRP also includes management response measures (additional assessment, monitoring and mitigation measures) that would be implemented in response to an unanticipated effect on Aquatic Resources.

17.7.4 Summary of Residual Effects Assessment

Residual effects and the selected mitigation measures, characterization criteria, likelihood, significance determination, and confidence evaluations are summarized for the four residual effects to Aquatic Resources (Table 17.7-2).

Table 17.7-2: Summary of the Residual Effects Assessment

Residual Effect	Project Phase(s)	Mitigation Measures	Summary of Residual Effects Characterization Criteria *(context, magnitude, geographic extent, duration, frequency, reversibility)*	Likelihood *(High, Moderate, Low)*	Significance *(Significant, Not Significant)*	Confidence *(High, Moderate, Low)*
Direct mortality of benthic invertebrates from habitat loss under the mine footprint	C	Mitigation by Project Design, including minimizing infrastructure footprint disturbance and road crossings	Magnitude: Low Geographic extent: Discrete Duration: Short-term Frequency: One time Reversibility: Partial Context: High	High	Not Significant	High
Reduced abundance and diversity of periphyton and benthic invertebrates from changes in water quality	C, O, D	Surface Water Quality mitigation measures, Project design mitigations (including water treatment, seepage collection and pump back, geomembrane cover), BMPs, Management Plans.	Magnitude: Moderate (Goldslide Creek), Low (Bitter Creek) Geographic extent: Local Duration: Permanent Frequency: Sporadic Reversibility: Partially Reversible Context: High	High (Goldslide Creek) Low (Bitter Creek)	Not Significant	High

Residual Effect	Project Phase(s)	Mitigation Measures	Summary of Residual Effects Characterization Criteria *(context, magnitude, geographic extent, duration, frequency, reversibility)*	Likelihood *(High, Moderate, Low)*	Significance *(Significant, Not Significant)*	Confidence *(High, Moderate, Low)*
Reduced abundance and diversity of periphyton and benthic invertebrates from changes in sediment quality	C, O, D	Surface Water Quality mitigation measures, Project design mitigation, DFO best practices, BMPs, Management Plans.	Magnitude: Low Geographic extent: Local Duration: Permanent Frequency: Continuous Reversibility: Reversible Context: High	Moderate	Not Significant	Moderate
Reduced abundance and diversity of periphyton and benthic invertebrates from changes in stream flow	O	Hydrology mitigation measures, Project design mitigations, BMPs, Management Plans, regulatory requirements.	Magnitude: High (Goldslide Creek), Low (Bitter Creek) Geographic extent: Discrete (Goldslide Creek), Local (Bitter Creek) Duration: Short-term Frequency: Continuous Reversibility: Reversible Context: High	High (Goldslide Creek) Low (Bitter Creek)	Not Significant	Moderate

17.8 Cumulative Effects Assessment

Cumulative effects are the result of Project residual effects on Aquatic Resources interacting with residual effects of other physical activities (i.e., anthropogenic developments, projects, or activities) that have been or will be carried out (Agency 2014a).

Guidance documents specific to the cumulative effects methodology are identified below:

- Reference Guide: Addressing Cumulative Environmental Effects (Agency 1994a);
- Practitioners Glossary for the Environmental Assessment of Designated Projects under the *Canadian Environmental Assessment Act, 2012* (Agency 2013);
- Guidelines for the Selection of Valued Components and Assessment of Potential Effects. British Columbia Environmental Assessment Office: Victoria, BC. (BC EAO. 2013);
- Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*, Operational Policy Statement (Agency 2014a); and
- Draft Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012* (Agency, 2014b).

17.8.1 Review Residual Effects

Residual effects after application of mitigation measures are:

- Reduced abundance and diversity of periphyton and benthic invertebrates from habitat loss;
- Reduced abundance and diversity of periphyton and benthic invertebrates from changes in water quality;
- Reduced abundance and diversity of periphyton and benthic invertebrates from changes in sediment quality; and
- Reduced abundance and diversity of periphyton and benthic invertebrates from changes in streamflows.

17.8.2 Cumulative Effects Assessment Boundaries

Similar to the Project effects assessment, the cumulative effects assessment boundaries are defined as the maximum spatial and temporal scales over which there is a potential for residual Project effects on Aquatic Resources to interact with the residual effects of other past, present, and future projects and activities.

17.8.2.1 Spatial Boundaries

The spatial boundaries for the cumulative effects assessment on the Aquatic Resources VC are restricted to areas that are hydrologically linked to the residual effects of the Project. Given that the residual effects to Aquatic Resources are not predicted to extend beyond the LSA of the Project, it is reasonable to define the cumulative effects assessment boundary as the RSA, which surrounds the LSA, and also includes the Bear River watershed, from American Creek to Stewart and the northern end of the Portland Canal.

17.8.2.2 Temporal Boundaries

The following temporal boundaries are evaluated as part of the cumulative effects assessment:

1. Past: 1988 to 2014;
2. Present: 2014 to 2017, from the start of the Red Mountain Underground Gold Project's detailed baseline studies to the completion of the effects assessment; and
3. Foreseeable Future: the cutoff date for incorporating any new future developments in the cumulative effects assessment in the Application/EIS is 2029. This represents the final anticipated year of the mine life after the Closure and Reclamation Phase is complete.

17.8.3 Identifying Past, Present, or Reasonably Foreseeable Projects and/or Activities

The list of past, present, and reasonably foreseeable projects and/or activities for consideration in the cumulative effects assessment was compiled from a variety of information sources, including municipal, regional, provincial, and federal government agencies and company websites. This list was reviewed to determine which projects and activities that have potential to interact with residual effects on Aquatic Resources. Projects and activities with potential to interact with Aquatic Resources residual effects are in Table 17.8-1.

Table 17.8-1: List of Projects and Activities with Potential to Interact within the Aquatic Resources Residual Effects

Project/Activity	Project Life	Location	Proponent
Bitter Creek Hydro Project	Proposed	15 km northeast of Stewart	Bridge Power
Stewart Bulk Terminal	Currently Operating	Stewart	Stewart Bulk Terminals Ltd.
Mineral exploration	Ongoing	Regional	Various

Project/Activity	Project Life	Location	Proponent
Commercial recreations	Ongoing	Regional	Various
Fishing	Ongoing	Regional	Various
Forestry	Ongoing	Regional	Various
Guide outfitting	Ongoing	Regional	Various
Transportation	Ongoing	Regional	Various
Trapping	Ongoing	Regional	Various

17.8.4 Potential Cumulative Effects and Mitigation Measures

17.8.4.1 Habitat Loss

Direct habitat loss under the footprint could occur from the Bitter Creek Hydroelectric Project. The proposed Bitter Creek Hydroelectric Project includes the following site components:

- An intake and diversion structure on upper Bitter Creek, located close to the Rio Blanco confluence with Bitter Creek;
- Approximately 2 km of penstock through which water will diverted from Bitter Creek; and
- A powerhouse located on the north east side of Bitter Creek, on the opposite side to the Red Mountain TMF.

Loss of habitat from the Bitter Creek Hydroelectric Project would be in addition to the approximately 520 m^2 of aquatic habitat loss under the Project TMF footprint.

17.8.4.2 Changes in Water Quality

The land use activities outlined in Table 17.8-1 have the potential to interact with residual effects on Aquatic Resources because of increased road use: mineral exploration, commercial recreations (e.g. river rafting, guided mountaineering), fishing, guide outfitting, transportation, and trapping. Increased road use represents a pathway to a potential cumulative effect, as there is increased potential for runoff, sediment runoff (TSS), and dust deposition, along the Access Road adjacent to Bitter Creek, and at ford crossings.

Mineral exploration could also result in reduced water quality and disturbances to the aquatic habitat from drilling and trail clearing.

The Hydroelectric project could reduce flows and therefore dilution capacity in Bitter Creek.

17.8.4.3 Changes in Sediment Quality

The Bitter Creek Hydroelectric Project could result in increased rates of sediment transport and deposition, as well as changes in particle size distribution.

Increased road use from the land use activities has potential for increased sediment loads to Bitter Creek, from erosion and sedimentation, along the Access Road adjacent to Bitter Creek, and at ford crossings.

17.8.4.4 Changes in Stream Flows

Operation of the Bitter Creek Hydroelectric Project can lead to reduced flow in the diversion reach, between the point of diversion (intake) and the point of return (tailrace).

17.8.4.5 Additional Mitigation Measures

Proposed Mitigation Measures of the Red Mountain Project are outlined in Section 17.6.

Mitigation measures for cumulative effects may involve taking further action, where possible, to avoid or minimize cumulative effects on the Aquatic Resources VC.

It is assumed that proponents of proposed development projects will adhere to their own developed mitigation plans, including sediment and erosion mitigation around construction activities and access roads. In conjunction with mitigation plans implemented by the Red Mountain Underground Gold Project, areas of spatial and temporal overlap between projects will be monitored and mitigated, as necessary. IDM and other project proponents could also share monitoring data to help in the detection of unanticipated cumulative effects, and adaptively manage, accordingly. No other additional mitigation measures were identified for the Project for mitigating cumulative effects.

The permitting and monitoring of run-of-river hydroelectric projects has additional mitigation built into its regulatory infrastructure. Instream flow requirements and ramping rates during operations are generally designed based on the fish bearing status of the stream. The Bitter Creek Hydroelectric Project is proposed within the non-fish bearing section of Bitter Creek. As such, instream flow and ramping requirements will be less stringent than for a fish bearing stream, although they not be protective of benthic invertebrates. However, given that fish are present downstream of project, controls on the rate of flow change will still be required to protect fish below the Project. Applicable guidelines that cover protection of Aquatic Resources include:

- Long term Aquatic Monitoring Protocols for New and Upgraded Hydroelectric Projects (DFO, 2012; Lewis *et al.*, 2011);
- Flow Ramping Guidelines for Hydroelectric Projects: Developing, Testing, and Compliance Monitoring (Lewis *et al.*, 2013);
- Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia; and

- British Columbia Instream Flow Standards for Fish, Phase II: Development of instream flow thresholds as guidelines for reviewing proposed water uses.

17.8.5 Cumulative Effects Interaction Matrix

Potential cumulative effects on Aquatic Resources are based on the potential for interaction between the Aquatic Resources residual effects with the projects and activities identified in Section 17.8.3. The interaction with effects of reasonably foreseeable future projects and activities are in Table 17.8-2.

Table 17.8-2: Interaction with Effects of Reasonably Foreseeable Future Projects and Activities

Residual Effects of this Project on Aquatic Resources	Current and Ongoing Projects and Activities								Future Projects and Activities
	Mineral Exploration	Commercial Recreation	Fishing	Forestry	Guide Outfitting	Transportation	Trapping	Stewart Bulk Terminal	Bitter Creek Hydro Project
Habitat Loss	N	N	N	N	N	N	N	N	Y
Changes in Surface Water Quality	N	N	N	N	N	N	N	N	Y
Changes in Sediment Quality	N	N	N	N	N	N	N	N	Y
Changes in Streamflows	N	N	N	N	N	N	N	N	Y

Notes:
Y = Yes, interaction exists between the residual effect of the Project and the other past, current, or future project/activity
N = No, interaction does not exist between the residual effect of the Project and the other past, current, or future project/activity

The interaction matrix identified the Bitter Creek Hydroelectric Project as the only project with potential to interact with the residual effects on Aquatic Resources. The others were determined as not having an interaction due to the following reasons:

- The Stewart Bulk Terminal is located in the RSA, where no Aquatic Resources residual effects have been determined.

- While there are mineral exploration claims within the RSA, there are no projects that have entered the approval process and thus it is unknown whether any future projects could potentially add to the proposed Project residual effects, *i.e.*, act cumulatively with the Project.

- The remaining land use activities listed in Table 17.8-2 have the potential to interact with residual effects on Aquatic Resources because of increased road use. Increased road use represents a pathway to a potential cumulative effect, as there is increased potential for sediment runoff into Bitter Creek. Currently use of the Bitter Creek valley for these activities is limited:

    - There is a single commercial recreation licence, for a heli-ski operation, which does not require road use.

    - In the Stewart area, recreational fishing is limited to the upper reaches of Portland Canal and mouth of the Bear River. According to comments received during consultation with NLG, Nisga'a citizens are not known to fish in Bitter Creek (Volume 3, Chapter 19; Economic Effects Assessment).

    - There is single guider outfitter that uses the area, and one trapline.

- Use of the access road will be tightly controlled for safety reasons (including a gate at the entrance), and unauthorized use will not be permitted. IDM will also enforce a no hunting / no fishing policy for the Project workforce. At closure and reclamation project roads will be decommissioned and reclaimed. As such, the potential for these activities to cause an increase in road use that would interact cumulatively with residual effects on Aquatic Resources is considered negligible and is not carried forward in the cumulative effects assessment.

17.8.6 Cumulative Effects Characterization

17.8.6.1 Habitat Loss

During operation of the hydroelectric project, flow will be reduced in the diversion reach, between the point of diversion (intake) and the point of return (tailrace). Flow changes within the diversion reach induced by operational changes typically occur faster compared to natural flow changes. Rapid changes to stream flow can dewater aquatic habitat and strand aquatic organisms, which can lead to mortality through desiccation, freezing, or increased predation. Fish stranding by hydroelectric operations has been studied extensively, however benthic invertebrates, given their sedentary nature, are also subject to this effect. Frequent dewatering and subsequent wetting of aquatic habitat along the channel margins, may render it unusable by aquatic benthic invertebrates, and therefore constitutes as habitat loss.

Hydroelectric projects have the potential to impact channel stability, channel geomorphology, and sediment transport and deposition. These effects may occur both upstream and downstream of the intake, within the headpond and diversion channel, respectively, as well as below the powerhouse. Modifications to stream channel morphology may directly or indirectly alter physical habitats that support by aquatic benthic invertebrates and periphyton. IDM's confidence in this assessment is high therefore no additional risk analysis is required.

17.8.6.2 Changes in Water Quality

Flow reductions in the diversion reach of the Bitter Creek Hydroelectric Project have the potential to exacerbate changes in water quality in Bitter Creek from mine and TMF discharge, because there will be lower dilution through that reach. IDM's confidence in this assessment is high therefore no additional risk analysis is required.

17.8.6.3 Changes in Sediment Quality

The intake structure (e.g., gallery or weir) may backwater the channel upstream as a headpond, which is typically within the high water perimeter for these types of projects. Reduced stream velocities in the headpond will alter substrate composition such that there is a higher proportion of finer sediments. This physical alteration of benthic habitat effects the benthic invertebrate community composition, as the EPT species, which were dominant in the LSA, prefer coarser substrate and flowing water.

Fine sediments are more likely to bind to dissolved metal particles, thus incorporating them into stream sediments (Manahan 1984). Changes in sediment chemistry from mine discharge combined with the increased potential for sediment deposition with the headpond and diversion reach of the hydroelectric project, represents a potential cumulative effect on Aquatic Resources. Due to their sedentary nature and relatively long lifecycles, benthic invertebrates, are sensitive to changes in sediment chemistry, which occur on over longer timescales compared with changes in water quality. IDM's confidence in this assessment is moderate. In consideration of the adaptive management and follow-up programs proposed by IDM (see Section 17.9), no additional risk analysis is required.

17.8.6.4 Changes in Stream Flows

During operation of the hydroelectric project, flow will be reduced in the diversion reach, between the point of diversion (intake), and the point of return (tailrace). The hydroelectric would operate for approximately nine months per year, March through November, stopping work during the winter months (low flow period).

Flow changes in Bitter Creek from the Red Mountain Project occur during the operations phase (changes during construction and post closure are <3% and therefore considered negligible). Predicted flow changes in Bitter Creek from February to October during operations range from 0 to 8%. During freshet and summer (May to September) the change in flow is negligible (<1%).

The maximum predicted increases in flow occur in winter, and range from 8% (November at BC02) to 18% (December at BC08). Accordingly, the only potential temporal overlap between the flow changes occurring as a result the Red Mountain Project (November to January), with those occurring as a result of the operation of the hydroelectric project (March to November) is in November. However, the hydroelectric project reduces flow in the diversion reach, whereas the flow changes from the Red Mountain Project are increases. As such, effects will not be additive, as the increases in flow from the Red Mountain Project, would counteract the decreases in flow in the diversion reach of the hydroelectric project. IMD's confidence in this assessment is high therefore no additional risk analysis is required.

17.8.7 Summary of Cumulative Effects Assessment

Table 17.8-3: Summary of Residual Cumulative Effects Assessment

Project Phase	VC	Residual Cumulative Effect	Characterization Criteria *(context, magnitude, geographic extent, duration, frequency, reversibility)*	Likelihood *(High, Moderate, Low)*	Significance *(Significant, Not Significant)*	Confidence *(High, Moderate, Low)*
C	Aquatic Resources	Habitat Loss	Magnitude: Low Geographic extent: Discrete Duration: Short-term Frequency: One time Reversibility: Partial Context: High	High	Not Significant	High
C, O, CR	Aquatic Resources	Changes in Water Quality	Magnitude: Low Geographic extent: Discrete Duration: Long-term Frequency: Sporadic Reversibility: Partial Context: High	Moderate	Not Significant	High
C, O, CR	Aquatic Resources	Change in Sediment Quality	Magnitude: Low Geographic extent: Discrete Duration: Long-term Frequency: Continuous Reversibility: Partial Context: High	Moderate	Not Significant	Moderate
O	Aquatic Resources	Change in Stream flow	Magnitude: Low Geographic extent: Discrete Duration: Long-term Frequency: Continuous Reversibility: Reversible Context: High	Low	Not Significant	High

17.9 Follow-up Strategy

IDM has identified a follow-up strategy to evaluate the accuracy of effects predictions and effectiveness of proposed mitigation measures in regards to the Aquatic Resources VC. The strategy focuses on implementation of the AEMRP (Volume 5, Chapter 29.5). The purpose of the AEMRP is to minimize the effects of the Project's activities on the aquatic environment, monitor the results of mitigation to ensure effectiveness, and adaptively manage for any unanticipated effects resulting from the Project. The AEMRP also provides guidance to protect and limit disturbances to the aquatic environment from Project activities.

An AEMP with a Before/After/Control/Impact (BACI) study design is proposed as part of the AEMRP. This study design allows comparison of baseline and Project conditions during the Construction, Operations, and Post-Closure Phases, as well as exposure and reference sites. The results of the AEMP will then be compared with the predictions made in the effects assessment, to evaluate their accuracy. For example, water quality monitoring results will be compared with predictions of the Water Quality Model, and the post-project benthic community will be assessed relative to the predicted effects on Aquatic Resources.

Adaptive management will require consideration of AEMP results, management reviews, incident investigations, shared traditional, cultural, or local knowledge, new or improved scientific methods, regulatory changes, or other Project-related changes. Mitigation and monitoring strategies for Aquatic Resources will be updated to maintain consistency with action plans, management plans, and BMPs that may become available during the life of the Project. Key stakeholders, Aboriginal Groups, and government agencies will be involved, as necessary, in developing effective strategies and additional mitigation.

17.10 Conclusion

No significant change in abundance and diversity of periphyton and benthic invertebrates are predicted to occur at a local or regional scale due to the Project. Likewise, cumulative effects are not anticipated. Ecological conditions that support benthic invertebrates and periphyton may be altered in Goldslide Creek, but not to the extent that primary and secondary productivity will be outside of the range of the existing baseline.

All residual effects were considered non-significant due to the discrete to local geographical extent, and low to moderate magnitude of the anticipated effects. The assessment of significance is contingent on the successful implementation of mitigation measures. The results of this assessment have been carried forward to inform the effects assessments for Fish and Fish Habitat (Volume 3, Chapter 18).

The mitigation measures for potential cumulative effects on Aquatic Resources are expected to reduce the potential for a cumulative effect to a low or negligible level, *i.e.,* measures will be fully effective. Residual cumulative effects that would compromise the maintenance of ecological conditions that support Aquatic Resources relative to existing baseline are therefore not anticipated.

17.11 References

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