14. Assessment of Potential Aquatic Resources Effects

14.1 INTRODUCTION

Aquatic resources refer to the biological communities residing within the water column and sedimentary system compartments of the freshwater environment. These communities include primary producers (organisms that photosynthesize to produce their own energy and form the base of the food web) and secondary producers (organisms that feed on primary producers and on each other). Phytoplankton and periphyton are primary producers that live in the water column and on submerged surfaces, respectively, and perform the key biogeochemical process of producing organic matter from inorganic nutrients and carbon by photosynthesis. As primary producers, phytoplankton and periphyton are important food sources for grazers, such as zooplankton and benthic invertebrates (which, in turn, are consumed by fish), and therefore comprise the base of lake and stream food webs, ultimately driving ecosystem bioenergetics.

Phytoplankton and periphyton also affect water chemistry through their interactions with the carbon, nitrogen, and phosphorus biogeochemical cycles and can be significant sinks and sources of organic carbon and nutrients (Wetzel 2001). Because of their short life cycles, phytoplankton and periphyton are among the first organisms to respond to environmental change, and can exhibit taxon-specific responses to stressors, making them good indicators of current environmental conditions. Periphyton community composition is also used as an indicator of biotic integrity and ecosystem health (Hill et al. 2000).

Secondary producers constitute zooplankton and benthic invertebrate communities (benthos) and represent a critical link between primary producer communities and higher trophic levels in aquatic ecosystems. Zooplankton affect phytoplankton community densities, biomass, and composition directly through grazing, but also indirectly through nutrient regeneration (Elser et al. 1987). Benthos have diets that include algae, bacteria, and detritus and are also an important food source for fish. Benthos are also widely used as indicators of environmental conditions and change due to their close contact with benthic substrates, they are abundant and sessile, and have a wide range of environmental tolerances that are often taxon-specific (Hilsenhoff 1988; Poulton et al. 1995).

Changes of water and sediment quality can affect the diversity, abundance and activities of primary and secondary producer communities. Such effects to aquatic resources may cascade to higher trophic levels that depend directly or indirectly on primary and secondary producer communities to survive, including birds, amphibians and fish. Other roles served by aquatic resources include nutrient and organic matter cycling, photosynthesis, the stabilization of substrata and providing habitat for other organisms. Further, due to their limited mobility and life history characteristics (e.g., living on or in sediment) aquatic communities are closely linked to the physical features of their habitat and, as such, are useful for detecting potential shifts or disturbances of sediment quality, water quality, and aquatic habitat in general.

The proposed Brucejack Gold Mine Project (the Project) could affect aquatic resources through the physical and chemical alteration of their habitat (i.e., changes to surface water quantity, surface water quality and sediment quality). These affects could occur during the Construction, Operation, Closure, and Post closure phases. A pre-development aquatic resources baseline was established to allow for the prediction, assessment, mitigation and management of potential Project-related effects and will be incorporated into mine and mine waste management planning. Cumulative baseline study reports are located in Appendices 13-A and 14-A for surface water quality and aquatic resources, respectively.

14.2 REGULATORY AND POLICY FRAMEWORK

This section provides an overview of the relevant provincial and federal statutory framework, guidance documents, and policies related to potential Project-related effects to aquatic resources (summarized in Table 14.2-1).

Table 14.2-1. Summary of Applicable Statutes and Regulations for Potential Aquatic Resources Effects, Brucejack Gold Mine Project

Name	Level of Government	Description
Waste Discharge Regulation (BC Reg. 320/2004) under the *Environmental Management Act* (EMA; 2003)	Provincial (BC MOE)	The EMA provides the authorization framework to protect human health and the quality of water, land, and air in BC. Mine activities requiring authorization or registration under EMA include discharge of effluents to the aquatic receiving environment and the production, storage, treatment and discharge of prescribed quantities of hazardous waste.
Mines Act (1996)	Provincial (BC MEM)	The *BC Mines Act* and its associated Health, Safety and Reclamation Code for Mines in BC require mines to have programs for the environmental protection of land and watercourses throughout mine life, including plans for prediction and prevention of metal leaching and acid rock drainage, and prevention of erosion and sediment release. Watercourses are required to be reclaimed, and the Ministry of Energy and Mines has the authority to require monitoring and/or remediation programs to protect watercourses and water quality.
Metal Mining Effluent Regulations (SOR/2002-222) under the *Fisheries Act* (1985b)	National (DFO)	The MMER regulate the deposition of mine effluent if it is not within a defined pH range, if the concentrations of the MMER deleterious substances in the effluent do not exceed authorized limits, and if the effluent is demonstrated to be non-acutely lethal to rainbow trout (SOR/2002-222). These discharge limits were established to be minimum national standards based on best available technology economically achievable at the time. To assess the adequacy of the effluent regulations for protecting the aquatic environment, the MMER include environmental effects monitoring (EEM) requirements to evaluate the potential effects of effluent on fish, fish habitat, and the use of fisheries resources.
British Columbia Approved and Working Water Quality Guidelines (BC MOE 2014)	Provincial (BC MOE)	Water quality criteria are defined as maximum or minimum physical, chemical or biological characteristics of water, biota or sediment; and are applicable province-wide. The guidelines are intended to prevent detrimental effects on water quality or aquatic life, under specified environmental conditions.
Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2014)	National	Environmental Quality Guidelines (EQGs) are intended to protect, sustain, and enhance the quality of the Canadian environment. Each jurisdiction determines the degree to which it will adopt CCME recommendations and EQGs should not be regarded as blanket values for national environmental quality; users of EQGs consider local conditions and other supporting information (e.g., site-specific background concentrations of naturally occurring substances) during Project implementation. Science-based site-specific criteria, guidelines, objectives, or standards may, therefore, differ from the Canadian EQGs.
Other Guidance Documents	Provincial and Federal	• *Policy for Metal Leaching and Acid Rock Drainage in British Columbia* (BC MEM and BC MOE 1998). • *Guidelines for Metal Leaching and Acid Rock Drainage at Mine sites in British Columbia* (W. A. Price and Errington 1998). • *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials* (W. A. Price 2009). • *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2012).

Additional legislation with indirect influence on aquatic resources includes the *BC Water Act* (1996m) and *Canada Water Act* (1985b). However, these acts have less relevance to direct protection of aquatics resources compared to applicable statues and regulations listed in Table 14.2-1.

14.3 BASELINE CHARACTERIZATION

14.3.1 Regional Overview

The Brucejack Gold Mine Project area (56°28'20" N, 130°11'31" W) is located in the Boundary Ranges of the Coast Mountains in northwest British Columbia, approximately 950 km northwest of Vancouver, 65 km north-northwest of Stewart, and 21 km south-southeast of the closed Eskay Creek Mine. Existing and proposed mine facilities are or will be situated in the Brucejack Creek watershed (11.7 km^2), a small sub-basin of the Sulphurets Creek watershed (299 km^2) that empties into the Unuk River. Off-site Project infrastructure is located within Knipple Lake, Bowser River, and Wildfire Creek/Scott/ Todedada and Salmon River watersheds (Figure 14.3-1).

The Brucejack Lake watershed (mine site area) and downstream watercourses constitute the primary focus of the Project water quality assessment and management strategy as Brucejack Lake will be used as a permanent disposal site for tailings and waste rock and a source of process water (Chapter 13, Assessment of Potential Surface Water Quality Effects). It is a deep glacial lake with an area of 81 ha, a maximum depth greater than 80 m, and a short open-water season between June and September. Brucejack Lake and its outflow, Brucejack Creek, are at high elevation (1,370 m above sea level) in the headwaters of Sulphurets Creek. Brucejack Lake occasionally receives water from East Lake that is approximately 500 m to the east and adjacent to the Knipple Glacier. The outflow of East Lake has been observed to flow westward into Brucejack Lake on some occasions and eastward underneath Knipple Glacier on others. However, the predominant condition is for East Lake to discharge below the Knipple Glacier (Newhawk Gold Mines Ltd. 1989).

The outlet of Brucejack Lake is at the west end of the lake and empties into Brucejack Creek. This creek flows west in a braided channel through alluvial deposits, then pours through a bedrock-confined canyon containing several waterfalls, chutes, and rapids before plunging beneath Sulphurets Glacier (Newhawk Gold Mines Ltd. 1989). The sub-glacial flow subsequently emerges 4 km downstream in upper Sulphurets Creek, then flows sequentially into Sulphurets Lake (drainage area 84 km^2), lower Sulphurets Creek, the Unuk River (drainage area 400 km^2), and eventually discharging into the Pacific Ocean northeast of Ketchikan, Alaska (drainage area 2,577 km^2 at mouth). Along its flow path to its confluence with the Unuk River, Sulphurets Creek receives inputs from several tributaries, the largest being Mitchell Creek, which is a low pH, high metals stream. Photos of lakes and streams in the area can be seen in Section 13.3 of Chapter 13, Assessment of Potential Surface Water Quality Effects.

Project infrastructure beyond the mine site area includes the Knipple Transfer Area, Bowser Aerodrome, Tide Staging Area, and the access and transmission line corridors (Figure 14.3-1). The proposed transmission line will follow the Bowser River southward, crossing over into the Salmon River watershed that flows into the Pacific Ocean at Hyder, Alaska. The proposed Bowser Aerodrome will be north-adjacent to the Bowser River east of Knipple Lake. The mine access road traverses (from east to west) the Wildfire Creek watershed (tributary to Bell-Irving River), Todedada Lake and Todedada Creek (tributary to Treaty Creek, which is a tributary to the Bell-Irving River), Scott Creek (tributary to Bowser River), and the Bowser River (tributary to Bell-Irving River) watersheds (Figure 14.3-1). The approximately 60-km road section from Highway 37 to the toe of the Knipple Glacier is generally in mid-elevation valley bottom locations. The Knipple Glacier, on which about 12 km of the access road is routed, also drains to the Bowser River. West of the Knipple Glacier, the access road enters the Brucejack Lake watershed and extends a final 3 km to the Brucejack mine site at an elevation of about 1,400 m above sea level.

14.3.2 Historical Activities

Several historical and current human activities have occurred or occur within and near the proposed Project area. These include mineral exploration and production, hydroelectric power generation, forestry, as well as road construction and use. Details on historical activities in the Project area are outlined in Section 13.3.2 of Chapter 13, Assessment of Potential Surface Water Quality Effects. The baseline data included in the report, including data describing the environment during some of the historical activities, are detailed in Section 14.3.3.2.

14.3.3 Approach and Methodology

Aquatic resources baseline data were collected from 2008 to 2013. The studies provide sufficient data for general project planning, the Aquatic Effects Monitoring Plan (Section 29.3) and the environmental effects assessment (Sections 14.5 to 14.9).

The objectives of the baseline studies program varied from year to year to reflect updates to the proposed Project design. However, the primary objective was to characterize spatial and temporal variability of various aquatic resource components in lakes, rivers, and streams near the proposed Project. Aquatic components of interest included:

- physical limnology (temperature and light penetration);
- sediment quality (particle size, cyanides, nutrients, organic carbon, and total metal concentrations);
- stream periphyton community (taxon richness, density, relative abundance, diversity, and biomass);
- stream benthic invertebrate community (genus richness, relative abundance, and diversity);
- lake phytoplankton community (taxon richness, density, relative abundance, diversity, and biomass);
- lake benthic invertebrate community (taxon richness, density, relative abundance, and diversity); and
- lake zooplankton community (taxon richness, density, relative abundance, and diversity).

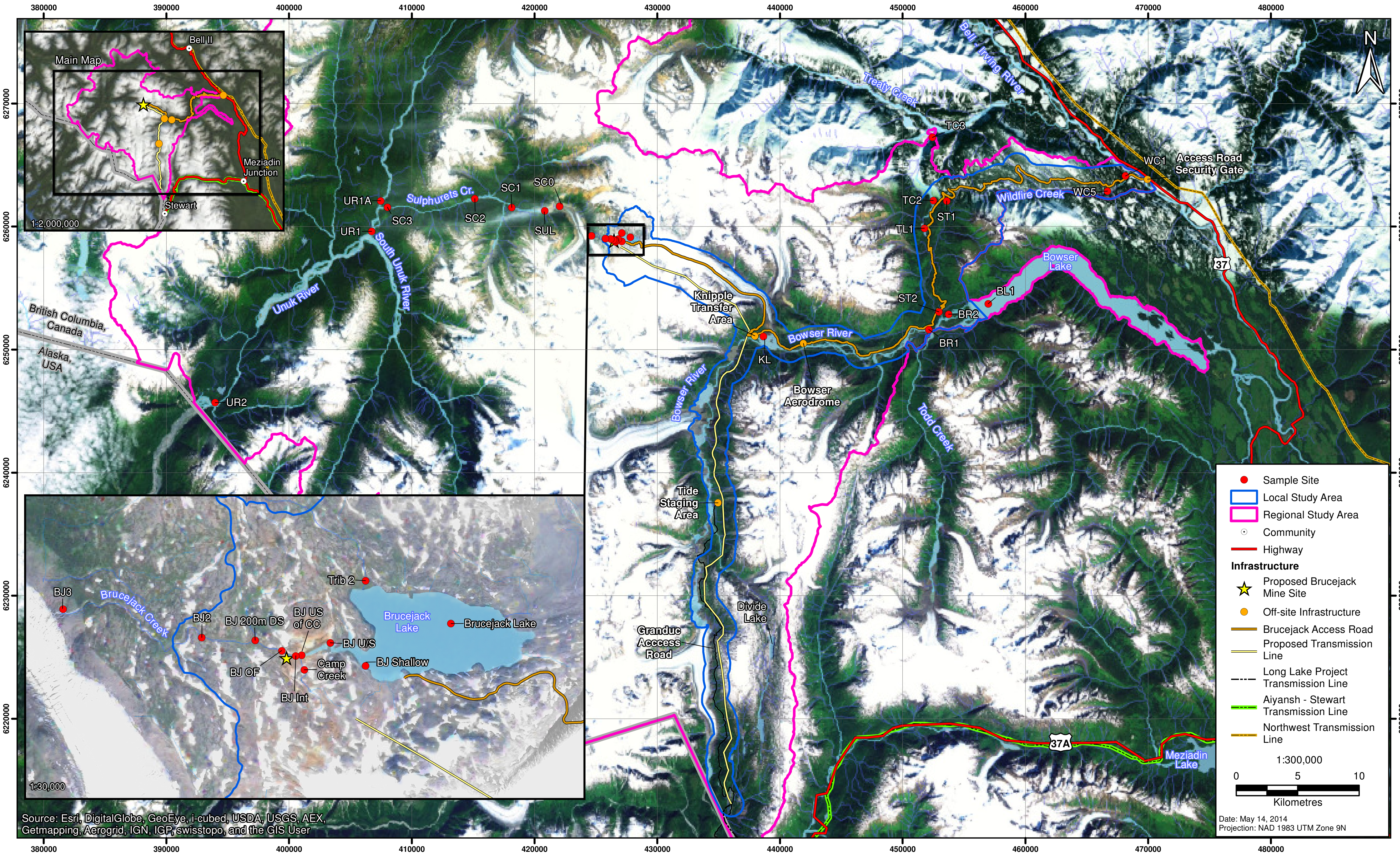
Another key objective was to compare baseline (2008 to 2013) sediment quality to BC and applicable CCME sediment quality guidelines for the protection of freshwater aquatic health.

14.3.3.1 Data Sources

The primary source of aquatic resources data used for the baseline characterization is the Project baseline program (2008 to 2013), which is detailed in Appendix 14-A, Cumulative Aquatic Resources Baseline Report. This information is supplemented with historical data collected by previous property owners Newhawk Gold Mines Ltd., and relevant data from the nearby proposed KSM Project. Studies focused on the downstream pathway flowing west from Brucejack Lake into Brucejack Creek, Sulphurets Creek, and eventually into the Unuk River. Historical aquatic resource data were not available for the Bowser River, Scott Creek, Todedada Creek, and the Wildfire Creek watersheds. Historical data sources include:

- *The Environmental and Socioeconomic Impact Assessment for the Sulphurets Property* (Newhawk Gold Mines Ltd. 1989); and
- the baseline monitoring conducted by Environment Canada and reported in *Baseline Monitoring; Sulphurets Project; August 9, 1988, Regional data report DR90-02* (Godin and Chamberlain 1990).

Figure 14.3-1
Aquatic Resources Setting Study Area, Brucejack Gold Mine Project



Pretium Resources Inc. has a data sharing agreement with Seabridge Gold Inc. for their neighbouring KSM Project; this report includes shared aquatic resource data for sites along Sulphurets Creek and the Unuk River.

Definition of Brucejack Representative Baseline Data Periods

Aquatic resource data were excluded from the baseline characterization if recent Project-related activities affecting water quality (Section 13.3, Baseline Characterization) were considered to have direct or cumulative effects on aquatic resources. Also, pre-disturbance sediment quality data are not available for watercourses in the Brucejack watershed. Sediment quality monitoring was first conducted in 1988 to support a Stage 1 Impact Assessment for the Sulphurets Project proposed by Newhawk Gold Mines Ltd. This occurred after the deposition of roughly 4,000 t of tailings into Goldpan Lake upstream of Brucejack Lake by the Catear Mine between 1982 and 1985 and the underground development that took place at the Brucejack (Sulphurets) site in the autumn of 1986. Subsequent to 1986, Brucejack Creek has been affected by passive drainage from the adit, and various waterbodies within the Brucejack watershed have periodically received drainage from areas disturbed through surface activities, active underground dewatering, and reclamation activities (Newhawk Gold Mines Ltd. 1989; W. Price 2005).

Most available aquatic resource data are included in the aquatic resources environmental settings. Baseline sampling program data were excluded if they were collected outside of the Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS) study area based on the proposed Project infrastructure (Figure 14.3-1). Data were also excluded if they were clearly affected by exploration activities such that their inclusion would result in unrepresentative baseline characterization. The following data were excluded from the settings analysis as they were considered to have likely been influenced by site exploration activities and not appropriate to be considered as baseline conditions:

- 2012: water toxicity and all data from BJ Inter sampling site; and
- 2013: periphyton taxonomy and biomass from BJ U/S, BJ2, and BJ3 sampling sites (Figure 14.3-1).

All aquatic resource data, including data excluded from the environment settings, are available in the cumulative baseline report (Appendix 14-A).

14.3.3.2 Methods

Baseline Study Area

The current aquatic resources study assessed the watercourses that could be potentially affected by Project activities and were further selected to coincide with the locations of the water quantity (Chapter 10) and water quality (Chapter 13) assessments. The spatial boundaries for the fish and fish habitat assessment (Chapter 15) were different as there are no fish or fish habitat present within the Brucejack and upper Sulphurets watersheds (Chapter 15; Appendix 14-A, Brucejack Gold Mine Project: Cumulative Aquatic Resources Baseline Report). The streams and lakes assessed in the aquatic resources characterization program are shown in Figure 14.3-1.

The study area included watercourses within four major watersheds:

1. Brucejack watershed.
2. Sulphurets/Unuk watershed.
3. Bowser River/Knipple Lake watershed.
4. Wildfire Creek/Scott/Todedada watersheds.

For this baseline characterization, the study area was split into three areas based on proposed Project infrastructure and activities:

1. The mine site area in the Brucejack Lake watershed.
2. The mine site area mid- and far-field downstream receiving environment, which comprises the Sulphurets and Unuk watersheds.
3. The off-site Project infrastructure areas, which include the Bowser, Scott, Todedada, and Wildfire watersheds.

The Brucejack Lake watershed (mine site area) and downstream receiving environment (Sulphurets/Unuk watersheds) are the primary focus of the Project aquatic resources assessment and management strategy as Brucejack Lake will be used as a permanent disposal site for tailings and waste rock, and as a source of process water. Aquatic resources sampling was also conducted for the Bowser Aerodrome facility (Bowser River and Knipple Lake), the access corridor (Bowser River and the Wildfire Creek/Scott/Todedada watershed), and far-field monitoring sites on the Unuk River (Figure 14.3-1). No interactions between the freshwater environment of the Salmon River and the transmission line are expected, so the Salmon River is not considered further in the effects assessment for aquatic resources.

Aquatic Resources Sampling Methodology

The 2008 through 2013 aquatic resources sampling program evolved with changes in Project design and to ensure that efforts meet program objectives and environmental assessment and permitting-related information requirements. In general terms, sampling effort was comprehensive and included all study watersheds until 2012, after which the sampling effort became focused on the Brucejack, Sulphurets, and Unuk waterbodies (proposed mine site area and downstream receiving environment).

Overall, baseline sediment and/or biological community data exist for five lake sampling sites and 25 stream sampling sites between 2008 and 2012. A minimum of one year of aquatic resource sampling has been completed for all receiving waterbodies potentially affected by Project infrastructure, and there are three or more years of data for some sites, particularly in the mine site area and the downstream receiving environment.

Sediments were collected from eight streams and four lakes from 2009 to 2013 (Table 14.3-1; Figure 14.3-2). Analysis for pH, particle size, nutrients, and total organic carbon (TOC) was performed by ALS Environmental using the lowest feasible detection limits. Analysis of metals was completed on the less than 63 μm fraction of the sample, as this is more bioavailable to benthic organisms and contains higher concentrations of metals than the coarse sediment fraction (Horowitz 1985; BC MOE 2012). Where applicable, sediment quality parameters were compared to the working BC sediment quality guidelines for freshwater aquatic life (Tables 14.3-2 and 14.3-3; Nagpal, Pommen, and Swain 2006). In absence of an applicable BC MOE guideline, CCME sediment quality guidelines for the protection of aquatic life are used (Tables 14.3-2 and 14.3-3; CCME 2014).

Periphyton samples were collected from rocks *in situ* at 20 stream sites and phytoplankton samples were collected from 1-m depth at five lake sites. Secondary producers were also collected from 20 stream sites and at five lake sites using a Hess net in streams and an Ekman grab sampler in lakes (Figure 14.3-3; Table 14.3-1). Zooplankton samples were collected from the water column in lakes. All biological samples were collected during late summer from 2008 to 2013.

Table 14.3-1. Summary of Aquatic Resource Studies for the Brucejack Gold Mine Project

Location	Watershed	Site Name	Abbreviated Site Name	Physical Limnology	Toxicity	Sediment Quality	Tissue Residues	Primary Producers	Secondary Producers	
								Periphyton / Phytoplankton	Benthos	Zooplankton
Mine Site Area	Brucejack	Tributary 2	Trib 2	-	-	2013	-	-	-	-
		Brucejack Lake	BJ	1987, 1988, 2010, 2012, 2013	-	1988, 2012, 2013	-	2012, 2013	2012, 2013	2012, 2013
		Brucejack Lake (Shallow)	BJ (Shallow)	-	-	2012, 2013	-	2012 (Chl *a* only), 2013	2012, 2013	-
		Brucejack Creek Upstream	BJ U/S	-	2013	2012, 2013	2013	2013	2013*	-
		Brucejack Creek Upstream of Camp Creek	BJ U/S of CC	-	2012	2012	-	2012	2012	-
		Camp Creek	Camp Creek	-	2012, 2013	-	-	-	-	-
		Brucejack Creek Intermediate	BJ Inter	-	-	2012	-	2012	2012	-
		Brucejack Creek Outflow	BJ OF	-	-	1988	-	-	-	-
		Brucejack Creek 200m D/S	BJ 200m D/S	-	-	2012, 2013	-	-	-	-
		Brucejack Creek 2	BJ2	-	2012, 2013	1988, 2011, 2012, 2013	2013	2011, 2012, 2013	2011, 2012, 2013*	-
		Brucejack Creek 3	BJ3	-	-	2013		2013	2013*	-
Mid- and Far-field Downstream Environment	Sulphurets	Sulphurets Creek 0	SC0	-	2013	2013	-	2013	2013*	-
		Sulphurets Lake	SUL	2008, 2009, 2012, 2013	-	2008, 2009, 2013	-	2008, 2009, 2013	2008, 2009, 2013	2008, 2009, 2013
		Sulphurets Creek 1	SC1	-	-	2008, 2009, 2012	2013	2008, 2009	2008, 2009	-
		Sulphurets Creek 2	SC2	-	-	2008, 2009, 2012, 2013	2013	2008, 2009, 2013	2008, 2009, 2013**	-
		Sulphurets Creek 3	SC3	-	-	1988, 2008, 2009, 2012, 2013	2013	2008, 2009, 2013	2008, 2009, 2013**	-
	Unuk	Unuk River 1A	UR1A	-	-	1988, 2008, 2009, 2012, 2013	-	2008, 2009, 2013	2008, 2009, 2013**	-
		Unuk River 1	UR1	-	-	1988, 2008, 2009, 2012, 2013	2013	2008, 2009, 2013	2008, 2009, 2013**	-
		Unuk River 2	UR2	-	-	2009, 2012, 2013	2013	2009, 2013	2009, 2013**	-
Off-site Project Infrastructure	Bowser	Knipple Lake	KL	2010, 2013	-	2013	-	2013	2013	2013
		Bowser River 1	BR1	-	-	2010	-	2010	2010	-
		Bowser River 2	BR2	-	-	2010	-	2010	2010	-
		Bowser Lake	BL1	2010	-	2010	-	2010	-	2010
	Scott, Todedada, and Todd	Scott Creek 1	ST1	-	-	2010	-	2010	2010	-
		Scott Creek 2	ST2	-	-	2010	-	2010	2010	-
		Todedada Lake	TL1	2010	-	2010	-	2009, 2010	2009, 2010	2009, 2010
		Todedada Creek 2	TC2	-	-	2010	-	2010	2010	-
		Todedada Creek 3	TC3	-	-	2010	-	2010	2010	-
	Wildfire and Bell-Irving	Wildfire Creek 5	WC5	-	-	2011	-	2011	2011	-
		Wildfire Creek 1	WC1	-	-	2011	-	2011	2011	-

Notes:

Monitoring sites have varied over the 2008-2013 baseline program to reflect updates to the proposed Project design. Additional sites are outside the current RSA boundary are not reported here; aquatic resource data for these sites are reported within Appendix 14-A.

** 2013: Benthos sampled using both CABIN and Hess methodology*

*** 2013: Benthos sampled using CABIN methodology only*

Figure 14.3-2
Aquatic Sediment Sampling Sites, Brucejack Gold Mine Project, 1988 to 2013

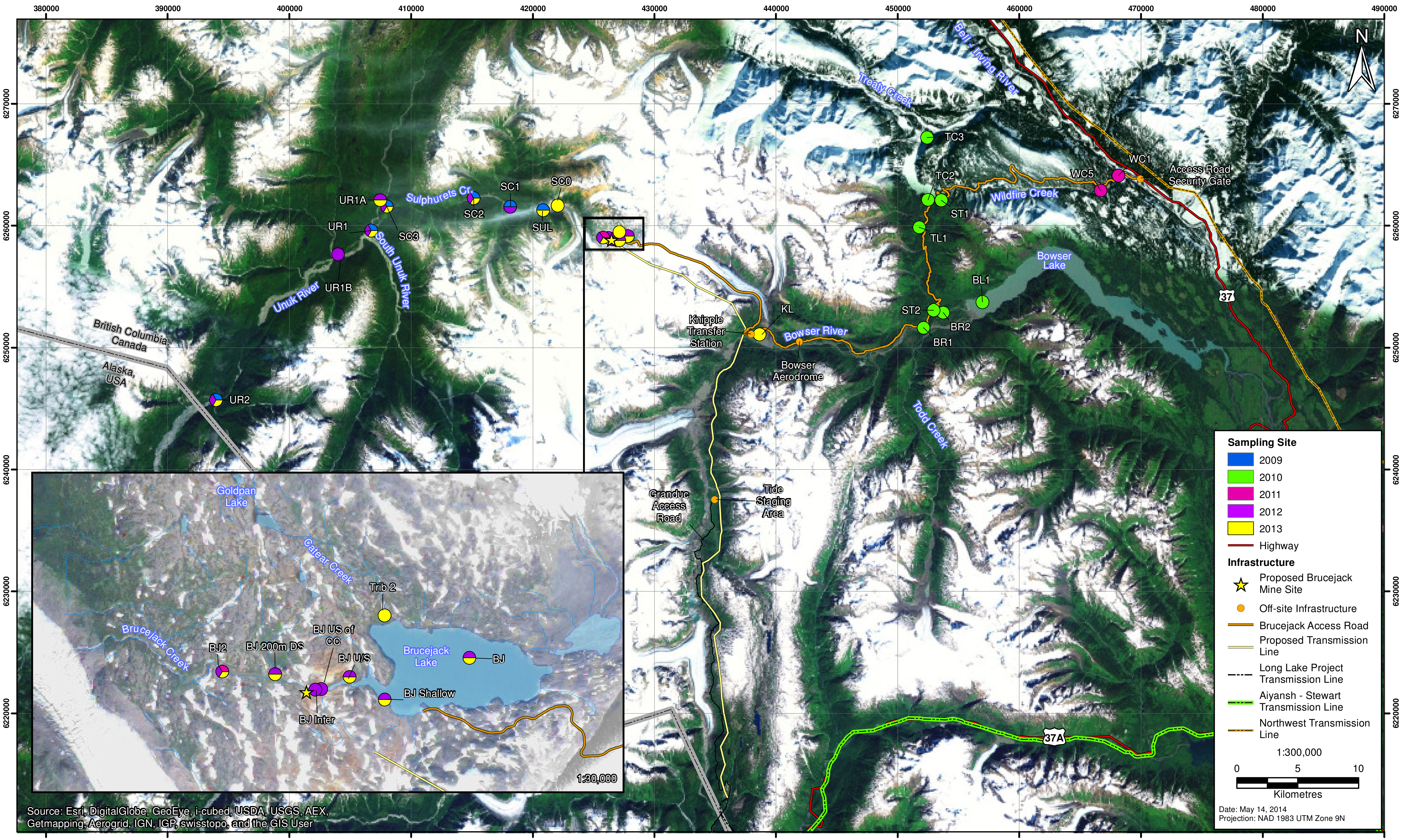


Table 14.3-2. Summary of Aquatic Biology and Sediment Quality Data for Study Streams for the Brucejack Gold Mine Project, 2008 to 2013

		Mine Site Area	Downstream Receiving Environment		Off-site Project Infrastructure			
		Brucejack Creek (7 sites)	**Sulphurets Creek (3 sites)**	**Unuk River (4 sites)**	**Bowser River (2 sites)**	**Scott Creek (2 sites)**	**Todedada Creek (2 sites)**	**Wildfire Creek and Tributaries (2 sites)**
Component	**Indicator**	**BJ U/S, BJ U/S of CC, BJ Inter, BJ 200m D/S, BJ2, BJ3**	**SC0, SC1, SC2, SC3**	**UR1A, UR1, UR2**	**BR1, BR2**	**ST1, ST2**	**TC2, TC3**	**WC1, WC5**
Sediment Quality	Particle composition (avg) %	sand and silt; gravel more common at BJ 200m D/S; clays more common at BJ U/S of CC and BJ2	sand and gravel	sand and gravel; increasing silt relative to Sulphurets Creek sites	sand (63%) and silt (34%)	sand (93%)	sand (90%) and silt (8%)	sand
	Nutrients and organics	very low	very low	very low	very low	very low, moderate TOC at ST1	very low	very low
	Metals exceeding sediment quality guidelines	As, Cd, Cu, Fe, Pb, Mn, Hg, Se, Ag, Zn	As, Cd, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Zn	As, Cd, Cr, Cu, Fe, Mn, Hg, Ni, Se, Ag, Zn	As, Cd, Cu, Fe, Mn, Ni, Zn[†]	As, Cd, Cr, Cu, Fe, Mn, Ni, Zn[†]	As, Cd, Cr, Cu, Fe, Mn, Hg, Ni, Se, Ag, Zn[†]	As, Cr, Cu, Fe, Mn, Ni, Ag, Zn[†]
Periphyon	Biomass (avg) μg chl *a* /cm^2	variable (0.05 to 1.5)	moderate, variable (< 0.1 to 1.0)	moderate, variable (< 0.1 to 0.5)	moderate (0.25)	moderate (0.22)	low (0.01)	moderate to low (0.23)
	Density (avg) cells/cm^2	moderate, but variable	variable (1 to 13,000)	variable (10 to 100,000)	high at BR2 (5,600,000) to very low at BR1 (2,000)	high (3,300,000)	low (48,000)	moderate (450,000)
	Richness (avg number of genera/sample area)*	moderate (10), higher in 2011 at BJ2	moderate at SC1 (7), low at SC2, SC3 (2)	low (3.2)	moderate at BR2 (9) and low at BR1 (4)	moderate (11)	low (5)	high (18)
	Diversity (avg Simpson's Diversity Index)	low (0.42), lowest at BJ inter	moderate (0.67)	moderate (0.59)	moderate at BR1 (0.62) and low at BR2 (0.10)	low (0.28)	low (0.43)	moderate (0.59)
	Dominant Taxa	diatoms, cyanobacteria	diatoms	diatoms	diatoms at BR1, and predominantly cyanobacteria at BR2	cyanobacteria	cyanobacteria and chrysophytes	cyanobacteria and diatoms
Benthic Invertebrates	Density (avg organisms/m^2)	low (50 to 320)	moderate at SC1 (630), very low at SC2 and SC3 (30)	low (200)	moderate at BR2 (790), low at BR1 (110)	high (2,400)	moderate (130)	high (1,600)
	Richness (avg number of genera/sample area)*	low (~4)	moderate at SC1 (9), low at SC2 and SC2 (5)	high (10)	high (14)	high (15)	moderate (9)	high (20)
	Diversity (avg Simpson's Diversity Index)	moderate (~0.48)	moderate (0.61)	high (0.76)	high (0.79)	moderate (0.66)	high (0.79)	high (0.83)
	Dominant Taxa	midges and annelid worms	predominantly midges with small amounts of stoneflies and mayflies	midges, mayflies, and small numbers of stoneflies	midges, mayflies, and stoneflies	midges, mayflies, and stoneflies	midges, mayflies, stoneflies, and craneflies	midges, mayflies, stoneflies, and worms

Notes:

Site sampling program varies with each component. Refer to Table 14.3-1 for site-specific sampling history.

Guidelines are BC MOE and CCME sediment quality guidelines and metals were listed if the mean concentration in sediment samples collected between 2008 and 2013 for the site was greater than the relevant guideline limits.

[†]Metal concentrations at these sites are unaffected by activities in Brucejack watershed.
** Sample area was typically 0.096 m^2, but varied. See Appendix 14-A for details.*

Table 14.3-3. **Summary of Aquatic Biology and Sediment Quality Data for Study Lakes for the Brucejack Gold Mine Project, 2008 to 2013**

Component	Indicator	Mine Site Area	Downstream Receiving Environment	Off-site Project Infrastructure	
		Brucejack Lake BJ (2 sites)	Sulphurets Lake SUL	Bowser Lake BL	Todedada Lake TDL
Sediment Quality	Particle composition (avg) %	silt and clays; more sand and gravel in shallows	silt and clays, more sand and gravel in shallows	sand (33%) and silt (38%)	silt (85%) and clays (14%)
	Nutrients and organics	very low	very low	very low	high phosphate and TOC, low nitrogen
	Metals exceeding sediment quality guidelines	As, Cd, Cu, Fe, Pb, Mn, Hg, Ag, Zn	As, Cd, Cu, Fe, Pb, Mn, Hg, Ni, Se, Zn	As, Cd, Cr, Cu, Fe, Mn, Ni, Zn[†]	As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se, Ag, Zn[†]
Phytoplankton	Biomass (avg) µg chl *a* /L	very low (0.08)	very low (0.09)	very low (0.04)	moderate (0.88)
	Density (avg) cells/L	low (60 to 650)	very low (1)	very low (29)	high (1872)
	Richness (avg number of genera/sample area)*	moderate (7)	very low (<1)	very low (<1)	high (14)
	Diversity (avg Simpson's Diversity Index)	low to moderate (0.45 to 0.68)	moderate (0.5, 2009); could not be calculated in 2008	unknown, could not be calculated	moderate (0.60)
	Dominant Taxa	diatoms	chrysophytes (2008) and diatoms (2009)	unknown, could not be identified	cyanobacteria and chlorophytes
Benthic Invertebrates	Density (avg organisms/m^2)	low to moderate (170 to 1,100); higher in shallows	low (235); higher in shallows	nc	very low (20)
	Richness (avg number of genera/sample area)*	low (6); higher in shallows	very low (<1)	nc	very low (<1)
	Diversity (avg Simpson's Diversity Index)	low (0.24)	low (0.24)	nc	unknown, could not be calculated
	Dominant Taxa	midges	midges	nc	worms and midges
Zooplankton	Density (avg organisms/m^2)	low (60 to 120)	low (160)	low (60)	high (25,000)
	Richness (avg number of genera/sample area)*	unknown, could not be calculated	very low (2)	moderate (7)	moderate (6)
	Diversity (avg Simpson's Diversity Index)	unknown, could not be calculated	low (0.34)	moderate (0.6)	moderate (0.66)
	Dominant Taxa	immature calanoid copepods	rotifers	cyclopoid copepods, rotifers and some cladocerans	rotifers, daphnia, cyclopoid copepods

Notes:

Site sampling program varies with each component. Refer to Table 14.3-1 for site-specific sampling history.

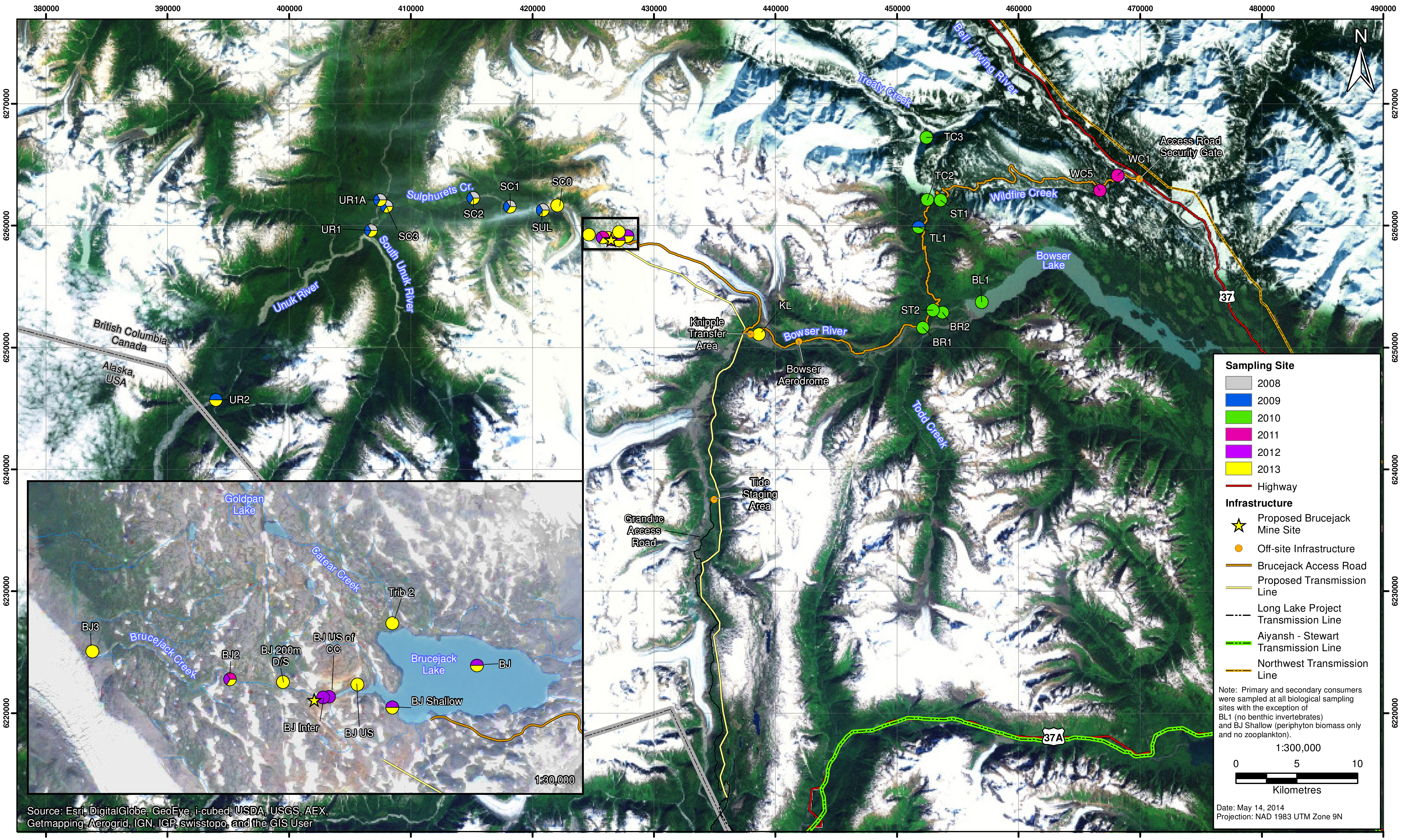
Guidelines are BC MOE and CCME sediment quality guidelines and metals were listed if the mean concentration in sediment samples collected between 2008 and 2013 for the site was greater than the relevant guideline limits.

[†]Metal concentrations at these sites are unaffected by activities in Brucejack watershed.

** Sample area was typically 0.025 m^2, but varied. See Appendix 14-A for details.*

Figure 14.3-3

Aquatic Biology Sampling Sites, Brucejack Gold Mine Project, 2008 to 2013



Primary and secondary consumer samples were analyzed for density, richness and diversity, and algal biomass was estimated by measuring chlorophyll *a*. Sampling methodology is detailed in the cumulative baseline report (Appendix 14-A) and is consistent with the British Columbia Field Sampling Manual (Clark 2003) and the Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring (Clark 2003; Environment Canada 2012).

14.3.4 Characterization of Aquatic Resources

The characterization of aquatic resources in the mine site area and off-site Project infrastructure areas is based on Appendix 14-A, Cumulative Aquatic Resources Baseline Report. Presented is a summary of the observations of the aquatic environment collected in the baseline characterization program; please refer to the cumulative baseline report for details (Appendix 14-A).

14.3.4.1 Mine Site Area: Brucejack Lake Watershed

Physical Limnology

Brucejack Lake is the only lake in the mine site area. Brucejack Lake is a deep well-oxygenated lake that is ice-covered most of the year (usually November to June), and usually experiences local late spring and fall mixing periods (dimictic). The water column is thermally stratified from July through September, with the thermocline reaching depths of 17 to 45 m. Dissolved oxygen concentrations during open-water sampling periods were highly variable, and were occasionally below the CCME guideline range of 6.5 to 9.5 mg/L for the protection of freshwater aquatic life (at depth in August 2011 and August 2013).

The lake is clear, with a mean euphotic zone depth of 11.5 m in summer indicating that primary production can occur deep into the water column.

Detailed results of the baseline physical limnology for the mine site area are included in Section 5.1.1 of Appendix 13-A, Cumulative Surface Water Quality Baseline Report.

Sediment Quality

Brucejack Lake sediment samples were characteristic of a depositional environment and were dominated by silt and clay particles with little inter-annual variability in the baseline sampling program. The sediments in Brucejack Creek downstream of Brucejack Lake showed greater inter-annual variation and larger particles dominated (sand and gravel, over 63 µm), which is typical of streams with periods of high flows. Sediment nutrients (total nitrogen, available phosphate, and TOC) were low in lake and stream sediments in the Brucejack watershed.

Sediments in Brucejack Lake had elevated concentrations of metals in the baseline sampling program, which was likely due to the erosion of highly mineralized outcropping mineral deposits. Elevated concentrations of aluminum, arsenic, cadmium, iron, lead, manganese, mercury, selenium, silver, and zinc were observed in Brucejack Lake sediments. The concentrations of aluminum, arsenic, chromium, copper, iron, and manganese were generally similar between the 1988, 2012, and 2013 sediment samples. Sediment concentrations of lead and zinc were variable between the 1988, 2012, and 2013 samples; however, these differences may have been due to differences in analytical technology and may not represent actual variation in the baseline sediment quality conditions.

Sediment metal concentrations in Brucejack Creek tended to be similar in magnitude to those in Brucejack Lake, and were greater than analytical detection limits. The concentrations of arsenic, cadmium, copper, and zinc tended to be greater at sites further downstream from the Brucejack Lake outflow (BJ 200 m D/S, BJ2, and BJ3), which may have been due to the erosion of outcropping mineral deposits in the watershed including the Valley of the Kings (VOK) Creek and other unnamed tributaries of Brucejack Creek.

Concentrations of arsenic, iron, manganese, mercury and silver in lake and stream sediments were always greater than BC sediment quality guidelines in baseline samples from Brucejack Lake and Brucejack Creek. In addition, the sediment concentrations of cadmium, copper, lead, selenium, and zinc were frequently greater than the BC sediment quality guidelines (Table 14.3-3; Nagpal, Pommen, and Swain 2006).

Detailed results of the baseline sediment quality for the mine site area are included in Section 6.1.2 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Toxicology

Toxicology testing in 2013 was performed on the invertebrates *Daphnia magna* and *Ceriodaphnia dubia* exposed to waters collected from BJ U/S, Camp Creek, Adit and BJ2. Tests included an acute (48 hour) and chronic (6 day) survival assay and a chronic reproductive assay. Survival was greater than 80% across all test sites for both species, except Camp Creek which had lower survival at high concentrations of site water. Reproduction was not affected in test waters collected from BJ2, although waters collected from upstream sites (BJ U/S, Camp Creek and Adit) affected the reproductive capabilities of *C. dubia*.

Detailed results of the baseline toxicology for the mine site area are included in Section 6.1.1 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Primary Producers

The density of primary producers in streams and lakes in the Brucejack watershed was often low in the baseline sampling program, which would suggest that *in situ* primary production was likely very low in these environments. Inter-annual variation was observed in the density and biomass of phytoplankton in Brucejack Lake. The density of phytoplankton varied between 660 cells/mL in 2012 to 66 cells/mL in 2013, whereas the biomass was 0.08 µg chl *a*/L in 2012 and 0.07 µg chl *a*/L in 2013. Brucejack Lake had low water nutrient levels and was classified as ultra-oligotrophic in the baseline sampling program (based on the low concentrations of total phosphorous, less than 0.004 mg/L), with concentrations of several nutrients being below detection limits (see Section 13.3 of Chapter 13, Assessment of Potential Surface Water Quality Effects).

The composition of the phytoplankton community also varied between years as diatoms (primarily genus *Synedra*) comprised 77% of the community in 2012, while the 2013 community was comprised equally of diatoms (43%, primarily genus *Synedra*) and heterotrophic dinoflagellates (43%, genus *Gymnodinium*). The taxonomic richness in Brucejack Lake was generally around seven taxa per sample. Phytoplankton assemblages were moderately diverse. Little spatial variability was observed in the density, community composition, and diversity of the phytoplankton community in Brucejack Lake (both deep and shallow sites).

The Brucejack Creek site BJ U/S of CC had low periphyton densities (370 cells/mL) and biomass (0.02 µg chl *a*/cm^2). As with Brucejack Lake, the upper reach of Brucejack Creek had low water nitrogen and phosphorus concentrations (Section 5.1.2 of Appendix 13-A, Cumulative Surface Water Quality Baseline Report). Substantial inter-annual variation is often a natural feature of the periphyton community because of variation in flow regimes, nutrient supplies, and dynamic cycles in grazing. Periphyton density and biomass varied 2,000-fold and 4-fold, respectively, between 2011 and 2012 at site BJ2 on Brucejack Creek. The inter-annual variation coincided with a change in community composition from filamentous cyanobacteria in 2011 (97% of cells, primarily genus *Schizothrix*) to the larger, but less abundant diatoms (55% of cells, genera *Hannaea* and *Synedra*) in 2012. Interestingly, the largest number of periphyton taxa in the baseline sampling program was observed at BJ2 when the site was dominated by cyanobacteria in 2011.

Details of the baseline primary producers for the mine site area are included in Section 6.1.4 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Secondary Producers

Benthic invertebrates were variable temporally and spatially in lakes and streams in the Brucejack watershed. Benthic invertebrate densities were higher at the shallow Brucejack Lake (10-m depth) site (mean range: 170 to 1,100 organisms/m^2) compared to the deep Brucejack Lake (78-m depth) site (mean range: 50 to 320 organisms/m^2). Benthic invertebrate densities in Brucejack Lake were six times higher in 2012 compared to 2013. Brucejack Creek mean benthic invertebrate densities varied between sites and ranged from 50 organisms/m^2 at BJ U/S of CC (2012) to 380 organisms/m^2 at BJ U/S (2013).

Brucejack Lake benthic invertebrate communities were dominated by non-biting midges (Diptera - Chironomidae), which comprised 80 to 96% of lake benthic invertebrate communities. This is typical of the low-productivity, high-altitude lakes in the area (Appendix 14-A, Cumulative Aquatic Resources Baseline Report). Brucejack Creek benthic invertebrate communities were primarily composed of Chironomidae and Annelida. Arachnida, Bathynellacea (crustacean), other Diptera families, and Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies; EPTs) were also present in Brucejack Creek communities in low proportions.

Brucejack Lake had low benthic invertebrate richness (annual mean: less than 4 families/sample) that was generally consistent between years. Brucejack Creek also had low benthic invertebrate richness, which ranged from a mean of 2.6 families/sample near the terminus of Brucejack Creek (site BJ3; 2013) by Hess sampler to 6 families/sample near the outflow of Brucejack Lake by CABIN kick-net sampler (site BJ U/S; 2013). Like taxonomic richness, benthic invertebrate diversity was highest in upper Brucejack Creek near the outflow of Brucejack Lake (site BJ O/F), and lowest at the end of Brucejack Creek (site BJ3).

Brucejack Lake had low mean zooplankton densities of 120 organisms/m^3 in 2012 and 60 organisms/m^3 in 2013. Only immature Copepoda specimens were found in 2012. Brucejack Lake zooplankton communities in 2013 were almost entirely composed of Calanoida copepods from the genus *Hesperodiaptomus* (96% of the community). Lake zooplankton richness (mean: 3 genera/sample) and genus diversity (Simpson's index 0.40) was low and the majority of individuals in all zooplankton samples were immature nauplii and copepodites.

Details of the baseline secondary producers for the mine site area are included in Section 6.1.5 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Aquatic Invertebrates — Tissue Metal Concentrations

Benthic invertebrate tissues were analyzed for metal concentrations from Brucejack Lake watershed sites BJ U/S and BJ2 in 2013. Substantial variability was observed in the tissue concentrations of most metals among surveyed sites. Benthic invertebrates collected at BJ2 in Brucejack Creek had higher overall tissue metal concentrations than organisms collected from sites upstream and downstream. However, all tissue concentrations observed were less than CCME guidelines for the protection of wildlife consumers of aquatic biota and BC MOE guidelines (BC MOE 2014; CCME 2014).

Tissue mercury concentrations were correlated with sediment mercury concentrations, with the highest tissue mercury concentration observed in benthic invertebrate tissue from site BJ U/S on (i.e., upstream of adit drainage and Camp Creek influences) Brucejack Creek (R^2 = 0.84, p = 0.01, n = 6). In contrast to mercury, tissue selenium concentrations were not well-correlated to sediment selenium concentrations.

Details of the baseline tissue metal analyses for the mine site area are included in Section 6.1.3 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

14.3.4.2 Mid- and Far-field Downstream Receiving Environment: Sulphurets/Unuk Watersheds

Physical Limnology

Sulphurets Lake is similar to a typical sub-polar lake; water temperatures are generally between 0.4˚C and 2.0˚C and do not exceed 4°C. The lake does not stratify and experiences frequent mixing throughout the entire open-water period. This temperature regime is likely due to the significant glacier influences in the watershed, which contribute cold water and substantial suspended material to the lake. Dissolved oxygen tends to be homogenous throughout the water column and across open-water and winter sampling periods. During winter months dissolved oxygen within Sulphurets Lake can be very low, falling below guidelines (CCME: 6.5 to 9.5 mg/L) throughout the water column (under ice, March 2013).

Light penetration was extremely limited in Sulphurets Lake, with a Secchi depth near 0.1 m; thus, overall lake productivity is likely limited by light availability throughout the water column (Section 5.1.1 of Appendix 13-A, Cumulative Surface Water Quality Baseline Report). The reduced water clarity in Sulphurets Lake (glacial-headed lake) would be due to the high total suspended solids and turbidity loads fed by glacial run-off.

Details of the baseline physical limnology for the downstream receiving environment are included in Section 5.1.1 of Appendix 13-A, Cumulative Surface Water Quality Baseline Report.

Sediment Quality

Immediately downstream of the Sulphurets Glacier (SC0), sediments in upper Sulphurets Creek were dominated by sand-sized particles. Sulphurets Lake sediments were generally composed of smaller silt- and clay-sized particles, although some inter-annual variation was observed. Sulphurets Creek below Sulphurets Lake (SC1, SC2, and SC3) and the Unuk River (UR1A, UR1, and UR2) sites had typical stream sediments composed of ≥ 50% sand-sized particles, with generally small proportions of silt- and clay-sized particles. Sediment total nitrogen and TOC concentrations in lake and stream sites in the Sulphurets and Unuk watersheds were low and similar to those in the Brucejack watershed.

Sediment metal concentrations in Sulphurets Lake, Sulphurets Creek, and the Unuk River were naturally high. Samples from all sites in the Sulphurets and Unuk watersheds had sediment arsenic, cadmium, copper, iron, manganese, mercury, nickel, and selenium concentrations greater than the BC sediment quality guidelines (Table 14.3-3; Nagpal, Pommen, and Swain 2006).

Sediment arsenic concentrations were always greater than the BC working sediment quality guidelines for freshwater aquatic life, but were greater than provincial guidelines to a lesser degree with distance from the highly mineralized Brucejack and Sulphurets watersheds (Nagpal, Pommen, and Swain 2006). The concentrations of cadmium, iron, manganese, mercury and nickel were naturally higher than BC sediment quality guidelines throughout the downstream receiving environment with no observed spatial trends. Selenium levels in the Sulphurets/Unuk watershed sites were above the BC guideline of 2 mg/kg by a greater factor (mean range: 1.4 to 3.8) than Brucejack watershed sites (mean range: 1.0 to 1.9).

Silver concentrations in sediments in the Sulphurets/Unuk watershed sites were all greater than the BC LEL (lowest effect level) guideline of 0.5 mg/kg, with exceedances on average an order of magnitude lower than observed in the Brucejack watershed sites (mean range: 1.3 to 4.9 compared to 9.6 to 80.4 at Brucejack watershed sites). Sediment zinc concentrations were generally greater than the BC LEL guidelines in the Sulphurets and Unuk watersheds, except for the far-field downstream UR2 site on the Unuk River. Chromium concentrations in sediments were observed to be naturally greater than the BC LEL guideline (37.3 mg/kg) in Sulphurets Creek (site SC1) and the Unuk River (sites UR1A, UR1, and UR2).

Detailed results of the baseline sediment quality analyses for the downstream receiving environment are included in Section 6.1.2 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Toxicology

Toxicology testing in 2013 was performed on the invertebrates *Daphnia magna* and *Ceriodaphnia dubia* exposed to waters collected from SC0. Tests included an acute (48 hour) and chronic (6 day) survival assay in addition to a chronic reproductive assay. Survival of test organisms was high (above 90%) for both species, although the upper Sulphurets Creek site (SC0) impaired *C. dubia* reproduction to a greater degree compared to Brucejack Creek and adit waters.

Details of the baseline toxicology for the downstream receiving environment are included in Section 6.1.1 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Primary Producers

The Sulphurets Creek site, SC0, downstream from the Sulphurets Glacier, and Sulphurets Lake were both characterized by naturally low primary producer density and biomass that was lower than upstream sites in the Brucejack watershed (e.g., less than 0.01 µg chl a/cm^2; Table 14.3-2). The only primary producers observed at SC0 were diatoms and chrysophytes.

Downstream of Sulphurets Lake, sites SC2 and SC3 had relatively higher periphyton cell densities and biomass, but inter-annual variability was observed. For example, periphyton densities ranged from 13,000 cells/cm^2 in 2008 to ~1 cell/cm^2 in 2013 (site SC2). The periphyton community in Sulphurets Creek was generally dominated by diatoms (≥ 80% of cells, *Cymbella* and *Gomphonema* genera), but chrysophytes were a noteworthy component of the community during periods of low periphyton density in 2013.

Sites in the Unuk River, both upstream (site UR1A) and downstream (sites UR1 and UR2) of the confluence with Sulphurets Creek, had periphyton communities generally similar in density, biomass, and community composition to the lower stretch of Sulphurets Creek. Inter-annual variation was observed in density, biomass, and community composition. For example, the density and biomass of periphyton cells at UR1 varied 10-fold and 140-fold, respectively, between 2009 and the years 2008 and 2013. The richness of the Unuk River sites was generally low (less than 6 taxa per sample), and the community varied from diatoms to cyanobacteria (site UR1) or diatoms to chrysophytes (site UR2).

Details of the baseline primary producers for the Downstream Receiving Environment are included in Section 6.1.4 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Secondary Producers

Very low benthic invertebrate densities were observed in upper Sulphurets Creek (SC0) near the toe of Sulphurets Glacier, with only one Nemouridae (Plecoptera) individual found from five replicate Hess samples (Section 6.1-5 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report). Benthic invertebrate densities were also low just downstream in Sulphurets Lake, which had a maximum yearly mean of 35 organisms/m^2 in 2009. Downstream from Sulphurets Lake, SC1 had high benthic invertebrate densities in 2009 (1,030 organisms/m^2). Benthic invertebrate densities were an order of magnitude greater at SC1 compared to further downstream in Sulphurets Creek at SC2 and SC3, where densities were less than 70 organisms/m^2. Benthic invertebrates densities were comparable along the Unuk upstream (UR1A) and downstream (UR1 and UR2) of the confluence with Sulphurets Creek.

Benthic invertebrate densities were very low in Sulphurets Lake in 2008 and 2013, and were dominated by Chironomidae, which comprised 33 to 100% of lake benthic invertebrate communities (Section 6.1.5 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report). In 2008, only one individual organism was found in the Sulphurets Lake sample, which belonged to the Chironomidae genus *Pseudodiamesa*. Chironomidae (12 to 93% of the community), Ephemeroptera (1 to 48%), and Plecoptera (3 to 42%) dominated the Sulphurets Creek and the Unuk River benthic invertebrate communities, and *Baetis* (Ephemeroptera), *Rhithrogena* (Ephemeroptera) and *Taenionema* (Plecoptera) were the dominant genera. As with Brucejack Creek, *Diamesa* and *Cricotopus/Orthocladius* were common chironomids. Sulphurets Creek and the Unuk River also had small proportions of Annelida, Coleoptera (beetles), Trichoptera and other dipteran families. Benthic invertebrate communities were comparable among years and between sampling methodologies (Hess and CABIN kick-net sampling).

Sulphurets Lake had particularly low benthic invertebrate family richness, and the yearly means were all below one family/sample. Generally, only Chironomidae were collected from the Sulphurets Lake benthic communities. Benthic invertebrate family richness at Sulphurets Creek (mean range: 0 to 5.8 families/ sample) were lower than those observed in the Unuk River (mean range: 4.8 to 10 families/sample). As observed for family richness, Sulphurets Creek had slightly lower family diversity (mean range: 0.10 to 0.53 Simpson's index) than the Unuk River (mean range: 0.44 to 0.78 Simpson's index). Sulphurets Creek and Unuk River family diversity in the CABIN kick-net samples ranged from 0.51 at SC2 to 0.74 at UR1 and were slightly higher than Brucejack Creek diversities (less than 0.4 Simpson's index).

Sulphurets Lake had variable zooplankton densities, with a minimum of 16 organisms/m^3 in 2013 and a maximum of 210 organisms/m^3 in 2009. The zooplankton abundances were similar between Sulphurets and Brucejack lakes, but the Sulphurets Lake community was dominated by Rotifera (97% to 100% of the community), with *Kellicottia* and *Notholca* being most abundant. Lake zooplankton genus richness and diversity at Sulphurets Lake were low, with means all below 3 genera/sample and a Simpson's diversity index of less than 0.3.

Aquatic Invertebrates — Tissue Metal Concentrations

Benthic invertebrate tissues were analyzed for metal concentrations from sites SC2, SC3, UR1, and UR2 in the downstream receiving environment in 2013. Substantial variability was observed in the tissue concentrations of most metals among surveyed sites. All tissue concentrations were less than the CCME guidelines for the protection of wildlife consumers of aquatic biota and BC MOE guidelines.

Details of the baseline secondary producers for the downstream receiving environment are included in Section 6.1.5 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

14.3.4.3 Off-site Project Infrastructure Areas: Bowser River and Scott/Todedada/Todd Creek Watersheds

Physical Limnology

Knipple Lake is a glacier-fed lake, with temperatures ranging from 2.5°C in surface waters to 1.8°C at depth. This result suggests that, similar to glacier-fed Sulphurets Lake, Knipple Lake is likely unstratified throughout the year.

In contrast to Knipple Lake, Todedada and Bowser Lakes turn over early and late in open-water season (dimictic) and are stratified in summer. In these lakes, temperature and dissolved oxygen were greater at the surface and decreased toward the sediments, a pattern that likely reflected surface warming and photosynthetic activity in the upper layer. Stratification occurred at 8 m in Todedada Lake and between 1 and 2 m in Bowser Lake. Todedada Lake was poorly oxygenated relative to Knipple, Bowser, Brucejack, and Sulphurets lakes, likely a result of the comparatively shallow depth and higher organic concentrations of Todedada Lake. Dissolved oxygen concentrations were less than the CCME guideline for early life stages (9.5 mg/L) throughout the entire water column in Todedada Lake, and generally less than 6 mg/L at depths greater than 6 m.

Water clarity was greatest at Todedada Lake, with the greatest mean euphotic zone depth (17.6 m). In contrast, and similar to Sulphurets Lake, Secchi depths were extremely shallow for both Knipple (also glacial-headed lake; D_s = 5.0 cm) and Bowser Lakes (D_s = 0.2 m), resulting in poor light penetration and a very shallow euphotic zone. Primary producers, which are dependent on solar radiation for growth, would have very low productivity in these low light conditions.

Details of the baseline physical limnology for the off-site Project infrastructure areas are included in Section 5.2.1 of Appendix 13-A, Cumulative Surface Water Quality Baseline Report.

Sediment Quality

Sediment samples from Knipple Lake and Todedada Lake were composed primarily of silt- and clay-sized particles (90 and 70%, respectively), and were similar to the sediment compositions observed in Brucejack and Sulphurets lakes. The west end of Bowser Lake, which is downstream of Knipple Lake, and the Bowser River and Scott Creek, had coarser sediments that were 50% sand- and gravel-sized particles.

Streams in the off-site Project infrastructure areas tended to have coarser sediments, which were characteristic of streams with dynamic flow regimes like many of the streams in the Brucejack and Sulphurets watersheds. However, two sites (BR2 on the Bowser River and ST1 on Scott Creek) had sediments composed of 50% silt-sized particles, which suggests these sites were lower flowing and more depositional.

Sediment nutrient concentrations varied among streams and lakes in the off-site Project infrastructure areas, ranging from near or below detection limits in streams to higher concentrations in Todedada Lake (for example TOC concentrations of 18% in 2010 sediment samples). Higher catchment and in-lake productivity were likely causes of the nutrient concentrations in the Todedada Lake sediments.

Metals were generally abundant in lake and stream sediments in the off-site Project infrastructure areas, which was consistent with the mineralogy of the region. The concentrations of arsenic, cadmium, copper, iron, manganese, mercury, nickel, selenium, and zinc were frequently greater than BC LEL and CCME sediment quality guidelines (Nagpal, Pommen, and Swain 2006; CCME 2014). The largest factor of exceedances relative to BC LEL guidelines were observed for arsenic (9.8 in Todedada Creek site TC3), nickel (7.5 in Wildfire Creek site WC5), and zinc (4.2 in Todedada Creek site TC2). Sediment metal concentrations greater than the BC SEL guidelines were also observed in the majority of sites for arsenic (91% of sites), iron (64% of sites), manganese (82% of sites), and nickel (64% of sites).

Details of the baseline sediment quality for the off-site Project infrastructure area are included in Section 6.2.1 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Primary Producers

Primary producer density and biomass in the off-site Project infrastructure areas were variable and ranged from very low in low-order streams (e.g., TC2), Bowser Lake, and Knipple Lake to high in high-order streams (e.g., WC1) and Todedada Lake. The sparse populations observed in Knipple Lake were likely due to the heavy sediment loading from the Knipple Glacier and the similarly low productivity in western Bowser Lake can be contributed to high sediment contributions from the Bowser River that is predominantly glacial-fed. Cyanobacteria were generally the dominant taxa, although diatoms (Bacillariophyceae) and chrysophytes (golden algae) were usually observed. The abundance and taxonomic composition of the benthic invertebrate community varied among streams and lakes in off-site Project infrastructure areas. The productive, wetland-headed Todedada Lake had the highest density of primary producers and aquatic invertebrates.

Sites on Todedada Creek (TC2 and TC3), and Wildfire Creek (WC5) were all broadly similar in terms of their periphyton communities. Biomass was very low with an average of 0.01 µg chl *a*/cm^2 and cell densities ranged from 33,000 cells/cm^2 (TC3) to 62,000 cells/cm^2 (TC2). Cyanobacteria were the dominant taxa in these streams, and composed between 25% (TC2) and 80% of the cells (WC5). The dominant cyanobacteria were the filamentous genera *Homoeothrix* and *Chamesiphon*. Taxonomic richness and diversity were variable between these streams, with no notable spatial patterns or associations with periphyton biomass or cell density.

Todedada Lake had relatively large densities and biomass of phytoplankton cells, although substantial inter-annual variability was observed. Cyanobacteria were the dominant taxa in Todedada Lake (genera *Chroococcus* and *Anacystis*), but the community was relatively rich (about 14 taxa per sample).

The highest periphyton cell densities and biomass were observed on the Bowser River (site BR2), Scott Creek (site ST2), and Wildfire Creek (site WC1). These sites were from higher-order streams sites: ST2 is located just before the confluence of Scott Creek and the Bowser River; BR2 is located on the Bowser River downstream from the confluence of Todedada Creek and Todd Creek; and WC1 is the most downstream site on Wildfire Creek before the Bell-Irving River. Periphyton cell densities, for example, ranged from 650,000 cells/cm^2 (WC1) to 6,300,000 cells/cm^2 (ST2). Both the Bowser River BR2 and Scott Creek ST2 sites were dominated by the cyanobacteria genus *Homoeothrix;* the filamentous *Homoeothrix* made up 45% of the cells at the Wildfire Creek WC1 site. The periphyton communities at sites WC5 and ST1 were generally rich (~16 genera/sample) and moderately diverse (Simpson's diversity index 0.4 to 0.6); however taxonomic richness (10 genera/sample) and diversity (0.10) were lower at the Bowser River site BR1 due to the dominance of cyanobacteria at that site.

Details of the baseline primary producers for the off-site Project infrastructure area are included in Section 6.2.2 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

Secondary Producers

Stream benthic invertebrate densities varied in the off-site Project infrastructure areas, and means ranged from 110 organisms/m^2 at BR1 to 4,100 organisms/m^2 at ST1. Lakes in the off-site Project infrastructure areas also had variable benthic invertebrate densities spatially and temporally. For example, Todedada Lake mean benthic invertebrate density in 2009 was 1,700 organisms/m^2 and in 2010 was 20 organisms/m^2. Like the mine site area, Chironomidae were the most common benthic invertebrate taxa, along with Ephemeroptera and Plecoptera. However, the more-productive Todedada Lake also had abundant Amphipoda, Annelida, and Bivalvia taxa.

Zooplankton densities in the off-site Project infrastructure areas were highly variable. Knipple Lake sampled in 2013 had very low zooplankton densities of 1.1 organisms/m^3, whereas Todedada Lake had very high zooplankton densities that were three times higher in 2009 (mean: 94,000 organisms/m^3) than in 2010 (mean: 25,000 organisms/m^3). The zooplankton community in off-site Project infrastructure area lakes were generally composed of rotifers. Lake zooplankton genus richness was higher at Todedada Lake (mean range: 6.0 to 6.5 genera/sample) compared to Bowser Lake (mean: 3.7 genera/sample). Lake zooplankton communities in the off-site lakes also had low genus diversity, and reached a maximum mean of 0.54 Simpson's Index at BL1 (2010).

Details of the baseline secondary producers for the mine site area are included in Section 6.2.3 of Appendix 14-A, Cumulative Aquatic Resources Baseline Report.

14.4 ESTABLISHING THE SCOPE OF THE EFFECTS ASSESSMENT

This section of the assessment of aquatic resources includes a description of the scoping process used to identify potentially affected Valued Components (VCs), select assessment boundaries, and identify the potential effects of the Project that are likely to arise from the Project's interaction with a VC. Scoping is fundamental to focusing the Application/EIS on those issues where there is the greatest potential to cause significant adverse effects. The scoping process for the assessment of aquatic resources consisted of the following four steps:

- *Step 1:* scoping process to select aquatic resources VCs and indicators based on a consideration of the Project's potential to interact with a VC;
- *Step 2:* consideration of feedback on the results of the scoping process;
- *Step 3:* defining assessment boundaries for aquatic resources VCs and indicators; and
- *Step 4:* identification of key potential effects on aquatic resources VCs and/or indicators.

These steps are described in detail below.

14.4.1 Selecting Valued Components and Indicators

Aquatic resources were screened for inclusion as a Receptor Valued Component as result of the scoping process as described in Section 6.4.1, Selecting Candidate Components. As described in Section 6.4.1.1, Scoping Potential Interactions between the Project and Candidate Components, a scoping exercise was conducted during the development of the draft Application Information Requirements (AIR) to explore potential Project interactions with candidate receptor VCs, and to identify the key potential adverse effects associated with that interaction. The results of the scoping exercise were circulated for review and approval by the Environmental Assessment (EA) Working Group, and feedback from that process was integrated into the Application/EIS.

Aquatic resources were identified as a receptor VC because of the potential for effects on aquatic organisms by changes in the baseline condition of other environmental components thereby acting as receptors of that change. Aquatic resources were defined, through a review of relevant regulations, guidelines, scientific literature, and the application of professional experience and judgment, as the biological communities residing in the pelagic (water column) and benthic habitats of waterbodies. These biological communities comprise the following components:

- primary producers, which are the photosynthetic plants and algae that form the base of the aquatic food web;
- secondary producers, which are aquatic invertebrates that are the crucial link in the food web between primary production and higher trophic levels; and

- higher trophic levels, which are fish and other vertebrates living in the higher levels of the food web. The higher trophic levels are considered in other VCs and not considered further in this assessment.

These organisms are fundamental components for aquatic ecosystem functioning, processing available nutrients and providing the biomass to support higher trophic levels. Benthic community assemblages also stabilize substrata and serve as a habitat for many other organisms. Further, due to their limited mobility and life history characteristics (e.g., living on or in sediment), aquatic communities are closely linked to the physical features of their habitat and, as such, are useful for detecting potential shifts or disturbances of sediment quality, water quality, and aquatic habitat.

Effects to aquatic organisms may occur through changes in water quality, sediment quality, and the physical limnology of the aquatic environment. Sediment quality describes the physical and chemical characteristics of the benthic sediment environment, and has a complex, long-term interaction with water quality through the fluxes of particulate matter and dissolved compounds between the water and sediment phases. Sediments represent a compartment in the aquatic ecosystem that may accumulate substantial quantities of metals and organic compounds due to the high surface area of sediment particles, favourable redox conditions, and low oxygen concentrations. Aquatic organisms in lakes and streams live, for at least a portion of their life cycles, in close contact with the sediments, and thus can be affected by changes in sediment quality.

The aquatic resources VC will consider the potential effects from Project activities and infrastructure on primary producers, secondary producers, and sediment quality. The proposed Project has the potential to affect sediment quality, primary producers and secondary producers during the Construction, Operation, Closure, and Post-closure phases.

Close biophysical connections exist between aquatic resources and other VCs, in particular the following:

- hydrogeology (ground water quality and quantity; Chapter 9);
- hydrology (surface water quantity; Chapter 10);
- surface water quality; Chapter 13); and
- air quality (via dust deposition; Chapter 7).

The assessment of potential Project effects on aquatic resources is supported by the analyses and conclusions from these other VCs. Specific references to other VCs are made throughout this assessment of potential effects on aquatic resources to the relevant sections of the other VC assessments, including the predictive modelling results for groundwater, surface water quality, surface water quantity, and air quality.

14.4.1.1 Potential Interactions between the Project and Valued Components and Indicators

Project components and activities with possible or likely interactions with aquatic resources are identified in an impact scoping matrix (Table 14.4-1). A full impact scoping matrix for all intermediate and receptor VCs is described in Table 6.4-1 of Chapter 6, Assessment Methodology. Interactions between the Project and aquatic resources are classified based on the probability of interactions using professional experience, relevant guidance documents, and consultation, and assigned a colour code as follows:

- not expected (white);
- possible (grey); and
- likely (black).

Table 14.4-1. Interaction of Project Components and Physical Activities with Aquatic Resources

Project Components and Physical Activities by Phase	Aquatic Resources
Construction Phase	
Activities at existing adit	
Air transport of personnel and goods	
Avalanche control	
Chemical and hazardous material storage, management and handling	
Construction of back-up diesel power plant	
Construction of Bowser Aerodrome	
Construction of detonator storage area	
Construction of electrical tie-in to BC Hydro grid	
Construction of electrical substation at mine site	
Construction of equipment laydown areas	
Construction of helicopter pad	
Construction of incinerators	
Construction of Knipple Transfer Area	
Construction of local site roads	
Construction of Mill Building (electrical induction furnace, backfill paste plant, warehouse, mill/concentrator)	
Construction of mine portal and ventilation shafts	
Construction of Brucejack Operations Camp	
Construction of ore conveyer	
Construction of tailings pipeline	
Construction and decommissioning of Tide Staging Area construction camp	
Construction of truck shop	
Construction and use of sewage treatment plant and discharge	
Construction and use of surface water diversions	
Construction of water treatment plant	
Development of underground portal and facilities	
Employment and Labour	
Equipment maintenance/machinery and vehicle refuelling/fuel storage and handling	
Explosives storage and handling	
Grading of the mine site area	
Helicopter use	
Installation and use of Project lighting	
Installation of surface and underground crushers	
Installation of transmission line and associated towers	
Machinery and vehicle emissions	
Potable water treatment and use	
Pre-production ore stockpile construction	
Procurement of goods and services	
Quarry Construction	

(continued)

Table 14.4-1. Interaction of Project Components and Physical Activities with Aquatic Resources (continued)

Project Components and Physical Activities by Phase	Aquatic Resources
Construction Phase (cont'd)	
Solid waste management	
Transportation of workers and materials	
Underground water management	
Upgrade and use of exploration access road	
Use of Granduc access road	
Operation Phase	
Air transport of personnel and goods and use of aerodrome	
Avalanche control	
Backfill paste plant	
Back-up diesel power plant	
Bowser Aerodrome	
Brucejack Access Road use and maintenance	
Brucejack Operations Camp	
Chemical and hazardous material storage, management, and handling	
Concentrate storage and handling	
Contact water management	
Detonator storage	
Discharge from Brucejack Lake	
Electrical induction furnace	
Electrical substation	
Employment and Labour	
Equipment laydown areas	
Equipment maintenance/machine and vehicle refueling/fuel storage and handling	
Explosives storage and handling	
Helicopter pad(s)	
Helicopter use	
Knipple Transfer Area	
Machine and vehicle emissions	
Mill building/concentrators	
Non-contact water management	
Ore conveyer	
Potable water treatment and use	
Pre-production ore storage	
Procurement of goods and services	
Project lighting	
Quarry operation	
Sewage treatment and discharge	
Solid waste management/incinerators	

(continued)

Table 14.4-1. Interaction of Project Components and Physical Activities with Aquatic Resources (continued)

Project Components and Physical Activities by Phase	Aquatic Resources
Operation Phase (cont'd)	
Subaqueous tailings disposal	
Subaqueous waste rock disposal	
Surface crushers	
Tailings pipeline	
Truck shop	
Transmission line operation and maintenance	
Underground backfill tailing storage	
Underground backfill waste rock storage	
Underground crushers	
Underground: drilling, blasting, excavation	
Underground explosives storage	
Underground mine ventilation	
Underground water management	
Use of mine site haul roads	
Use of portals	
Ventilation shafts	
Warehouse	
Waste rock transfer pad	
Water treatment plant	
Closure Phase	
Air transport of personnel and goods	
Avalanche control	
Chemical and hazardous material storage, management, and handling	
Closure of mine portals	
Closure of quarry	
Closure of subaqueous tailing and waste rock storage (Brucejack Lake)	
Decommissioning of Bowser Aerodrome	
Decommissioning of back-up diesel power plant	
Decommissioning of Brucejack Access Road	
Decommissioning of camps	
Decommissioning of diversion channels	
Decommissioning of equipment laydown	
Decommissioning of fuel storage tanks	
Decommissioning of helicopter pad(s)	
Decommissioning of incinerators	
Decommissioning of local site roads	
Decommissioning of Mill Building	
Decommissioning of ore conveyer	

(continued)

Table 14.4-1. Interaction of Project Components and Physical Activities with Aquatic Resources (completed)

Project Components and Physical Activities by Phase	Aquatic Resources
Closure (cont'd)	
Decommissioning of Project lighting	
Decommissioning of sewage treatment plant and discharge	
Decommissioning of surface crushers	
Decommissioning of surface explosives storage	
Decommissioning of tailings pipeline	
Decommissioning of transmission line and ancillary structures	
Decommissioning of underground crushers	
Decommissioning of waste rock transfer pad	
Decommissioning of water treatment plant	
Employment and Labour	
Helicopter use	
Machine and vehicle emissions	
Procurement of goods and services	
Removal or treatment of contaminated soils	
Solid waste management	
Transportation of workers and materials (mine site and access roads)	
Post-closure Phase	
Discharge from Brucejack Lake	
Employment and Labour	
Environmental monitoring	
Procurement of goods and services	
Subaqueous tailing and waste rock storage	
Underground mine	

Notes:
Black = likely interaction between Project components/physical activities and an environmental, social, economic, heritage, or health candidate component.
Grey = possible interaction between Project components/physical activities and an environmental, social, economic, heritage, or health candidate component.
White = unlikely interaction between Project components/physical activities and an environmental, social, economic, heritage, or health candidate component.

Interactions coded as not expected (white) are considered to have no potential for adverse effects on a receptor VC, and are not considered further.

<u>Spills and Hazardous Materials</u>

Spills of petroleum products, process chemicals, reagents, or concentrate have the potential to occur during the Construction, Operation, Closure, and Post-closure phases of the Project due to various Project activities. The main risks associated with spills are related to occurrences of low likelihood outside of normal operating conditions and are addressed in Chapter 31, Accidents and Malfunctions, and Section 29.14, Spill Prevention and Response Plan, and will not be considered further.

Hazardous waste materials, such a spoiled reagents and used batteries, will also be generated throughout the life of the Project, from Construction to Post-closure. These materials will be anticipated in advance; they will be segregated, inventoried, and tracked in accordance with federal and provincial legislation and regulations such as the federal *Transportation of Dangerous Goods Act* (1992). A separate secure storage area will be established with appropriate controls to manage spillages. Hazardous waste will be labeled and stored in appropriate containers for shipment to approved off-site disposal facilities. The main risks for hazardous waste effects are related to occurrences of low likelihood outside of normal operating conditions and are addressed in Chapter 31, Accidents and Malfunctions, and in the Spill Prevention and Response Plan (Section 29.14), Waste Management Plan (Section 29.17), and Hazardous Materials Management Plan (Section 29.7), and will not be considered further.

14.4.1.2 Consultation Feedback on Valued Components

Potential interactions between the Project and aquatic resources, identified in the scoping process, were further refined through consultation with government, aboriginal, and stakeholder groups. The consultations included the following groups:

- federal government agencies including the Canadian Environmental Assessment Agency, Environment Canada, Fisheries and Oceans Canada, Natural Resources Canada, Transport Canada, and Health Canada;
- BC provincial government agencies including the Ministry of Energy and Mines, Ministry of Environment, and the BC Environmental Assessment Office;
- American government agencies including the Alaska Department of Natural Resources, Department of the Interior, and the National Marine Fisheries Service;
- aboriginal groups including First Nations, Nisga'a, and the Métis; and
- the general public and other stakeholders, including the Regional District of Kitimat-Stikine.

The consultation process, described in Section 6.4.1.2 of Chapter 6, Assessment Methodology, comprised the distribution of a preliminary list of components for comment and feedback in May 2013. The scoping feedback was incorporated in the definition of VCs, in the aquatic resources VC.

14.4.1.3 Summary of Valued Components Included/Excluded in the Application/EIS

As a result of the consultation process, the aquatic resources VC is defined as the primary and secondary producers living in the freshwater environment in the Project area (Table 14.4-2). Aboriginal groups and government agencies identified aquatic resources as important components of the biophysical environment because of their key position in aquatic foodwebs and their potential as indicators of ecosystem health. Furthermore, the impact scoping process indicated the potential for interactions between Project activities and aquatic resources.

Table 14.4-2. Aquatic Resources Receptor Valued Components Included in the Application/EIS

	Identified by*				
Sub-components	**AG**	**G**	**P/S**	**IM**	**Rationale for Inclusion**
Primary producers	X	X		X	Aquatic resources (primary and secondary producers) are important indicators of ecological health and are a component of fish habitat.
Secondary producers	X	X		X	

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; IM = Impact Matrix*

Sediment quality, which describes the physical and chemical characteristics of the benthic environment, is considered a pathway component for the aquatic resources effects assessment (Table 14.4-3). The biophysical receptors for potential Project effects on aquatic resources are the aquatic organisms (e.g., phytoplankton, zooplankton, and benthic invertebrates), whereas sediment quality serves as a valuable indicator of the quality of the environment. Therefore, the effects assessment considers changes to sediment quality as a potential significant pathway of interaction between the Project and aquatic resources (see Section 14.5.1.4 for a description of potential interactions).

Table 14.4-3. Aquatic Resources Receptor Valued Components Excluded from the Application/EIS

Sub-components	Identified by*				Rationale for Exclusion
	AG	G	P/S	IM	
Sediment quality	X	X			Sediment quality is considered to be a pathway through which potential effects to aquatic resources may occur, similar to groundwater quality/quantity and water quality/quantity. Changes in sediment quality have the potential to affect the biomass and diversity of aquatic resources (i.e., primary and secondary producers). Sediment quality will therefore be considered as a pathway component, rather than as a sub-component of the aquatic resources VC.

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; IM = Impact Matrix*

14.4.2 Assessment Boundaries for Aquatic Resources

Assessment boundaries define the spatial and temporal limits of the effects assessment. They describe the extent of the potential interactions between the Project and the aquatic resources VC, and serve to focus the analysis of the most significant and relevant potential effects. The assessment boundaries are designed to include possible direct, indirect, and induced effects of Project activities and infrastructure. The boundaries for the assessment of effects on aquatic resources are, by necessity, informed by the boundaries for the assessment of other VCs because of the significant biophysical connections between aquatic resources and other VCs. These connections are identified where relevant in Sections 14.4.2.1 and 14.4.2.2.

14.4.2.1 Spatial Boundaries

Spatial boundaries reflect the Project components and, in the case of aquatic resources, boundaries are shared with surface water quality, surface water quantity as well as fish and fish habitat VCs (Sections 10.4.2.1, 13.4.1.5, 15.4.2.1). The spatial boundaries include the Environmental Setting study area watershed boundaries (Section 14.3) and have considered watersheds over a range of spatial scales from local (i.e., immediately downstream of Brucejack Lake) to regional (i.e., Unuk River at the international border). The fish and fish habitat VCs have different spatial boundaries because of the absence of fish at the mine site area (Brucejack watershed) and the downstream receiving environment (the majority of the Sulphurets watershed). Only the potential changes to aquatic resources (primary and secondary producers) within watersheds identified below have been addressed in this assessment. Effects related to historic activities are addressed in the Aquatic Resources Setting (Section 14.3) as well as the Cumulative Aquatics Baseline Report (Appendix 14-A).

Two spatial boundaries are defined for the aquatic resources effects assessment: a Local Study Area (LSA) and a Regional Study Area (RSA). The LSA is defined as the area with the potential for direct effects from Project activities on aquatic resources, including intermediate receptors and pathways. The RSA, which includes the LSA, encompasses the region with the potential for indirect effects, and includes the far-field receiving environment downstream of Project activities in the Brucejack watershed.

Local Study Area

The LSA constitutes the Project footprint (all physical structures and activities that comprise the Project) and all aquatic environments that could be potentially indirectly or directly affected by mine development and operation (Figure 14.4-1). These include lakes and streams within and downstream of Brucejack Lake, sewage treatment plant (STP), mine water treatment plant (WTP), pre-production ore and waste rock transfer storage areas, and the quarry (mine site area, Brucejack watershed), as well as off-site infrastructure outside of the mine site area, including the proposed transmission line, access corridor, Knipple Transfer Area and the Bowser Aerodrome facility.

The LSA is depicted in Figure 14.4-1 and consists of three main areas:

1. Brucejack watershed (mine site area).
2. Knipple Lake/Bowser River watershed (off-site Project infrastructure, access corridor).
3. Wildfire Creek watershed (access corridor).

Within the Brucejack watershed (mine site area), the LSA follows the boundary of Brucejack Lake watershed at hydrometric station BJL-H1 (corresponds to water quality monitoring station BJ2). Along the proposed discharge flow path (Brucejack Creek), spatial boundaries of the LSA were confined to areas upstream of where the creek passes under Sulphurets Glacier, between sampling sites BJ2 and BJ3 (Figure 14.3-1). This boundary is defined in the quantitative water quality effects assessment as the downstream limit of the predictive water quality modelling (Section 13.6.1, Predictive Water Quality Modelling).

The spatial boundaries of the LSA along the eastern extent of the Project (Bowser River and Wildfire Creek watersheds) were identified as buffer zones around the access corridor and transmission line. At the eastern terminus of the access road corridor, the LSA is bounded by the Bell-Irving River, which is considered to be the furthest extent of potential direct Project effects on aquatic resources. Beyond this boundary, Project-related activities in these areas are not expected to directly affect biophysical receptors and pathways (e.g., streamflows or surface water quality; Chapters 10 and 13). Therefore, the off-site Project infrastructure LSA does not include the entire watershed boundaries of streams within them.

Regional Study Area

The Regional Study Area (RSA), shown in Figure 14.4-1, extends beyond the LSA and includes the portion of the watersheds downstream of the Project with a potential for both direct and indirect effects on aquatic resources. The boundaries of the RSA include watersheds upstream of those with a potential for direct effects.

The RSA includes the following watersheds:

- Unuk River: far-field receiving environment along the proposed discharge pathway; there is a potential for change to streamflows, surface water quality and sediment quality due to the Project activities in the headwaters of the Sulphurets/Unuk watersheds; potential effects on the Unuk River would has international transboundary implications;
- Lower Bowser River (downstream of Knipple Lake), Scott Creek, Todedada Creek, and Wildfire Creek: the access road passes through these watersheds; and
- Salmon River and Upper Bowser River (upstream of Knipple Lake): These watersheds may potentially be affected by the transmission line. Similar to the Unuk River watershed, potential effects on Salmon River would have international implications because it crosses the international border.

At this stage, Project-related activities in these areas are not expected to directly interact with surface water quality and quantity; quantitative predictive studies were not performed in such areas. Rather, qualitative assessments were performed in these areas.

14.4.2.2 Temporal Boundaries

Temporal boundaries for the effects assessment are defined by the characteristics of the proposed Project and the VCs being assessed. Temporal boundaries for aquatic resources begin at the initiation of project construction, and continue through all periods with the potential for interactions between the Project and the aquatic resources VC. The aquatic resources effects assessment considered the four following Project phases:

- **Construction:** 2 years;
- **Operation:** 22-year run-of-mine-life;
- **Closure:** 2 years (includes Project decommissioning and reclamation activities); and
- **Post-closure:** minimum of 3 years (includes ongoing reclamation activities and post-closure monitoring).

14.4.3 Identifying Potential Effects on Aquatic Resources

Potential effects to aquatic resources originating from Project activities are identified in this section. The impact scoping process (Section 14.4.1) identified Project components with potential for interactions with aquatic resources.

14.4.3.1 Categories of Potential Effects on Aquatic Resources

These potential effects to aquatic resources have the potential to occur through various pathways during the life of the Project, many of which overlap in terms of definition and scope. For the purposes of the aquatic resources effect assessment, potential effects were classified into five categories:

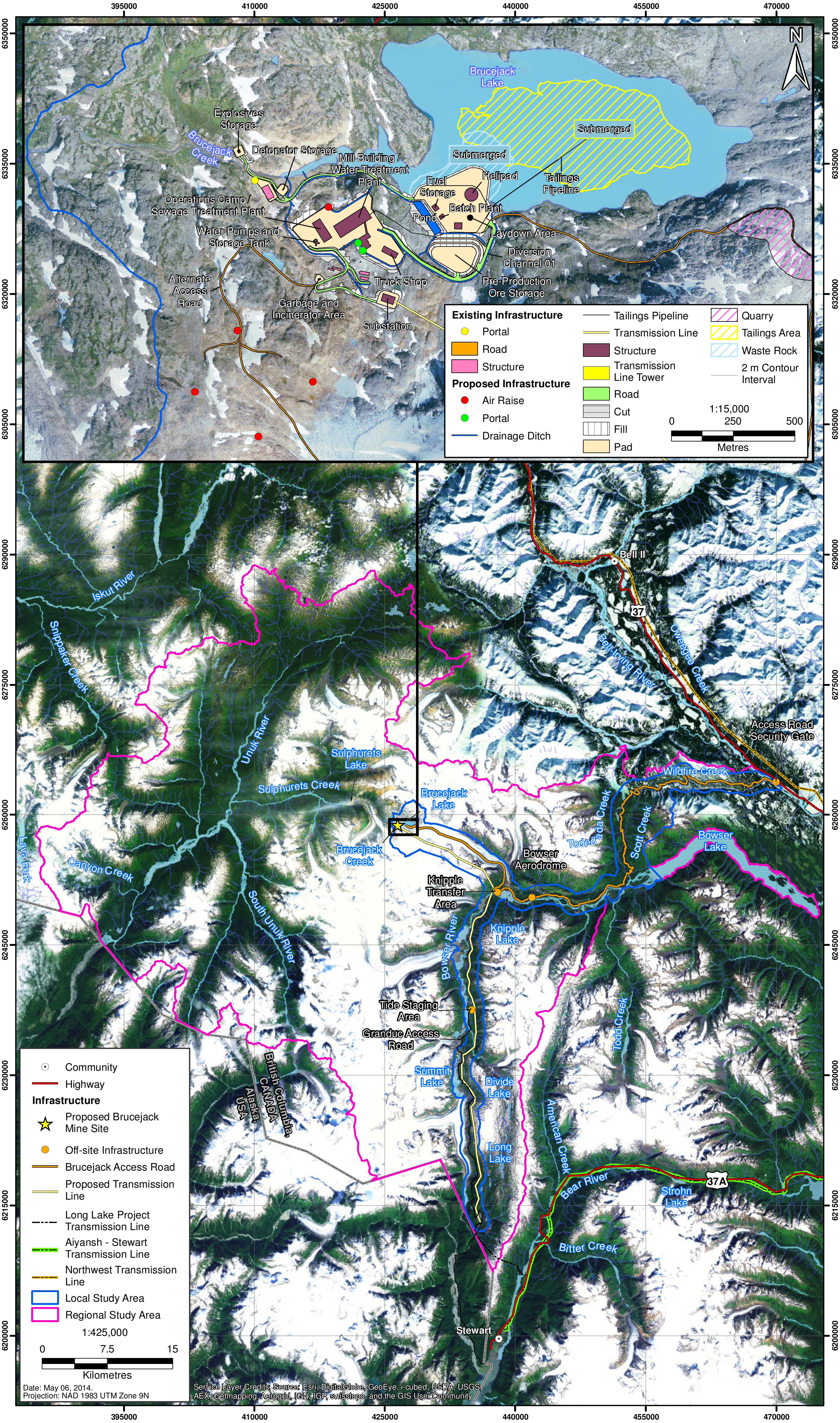
1. Erosion and Sedimentation.
2. Changes in Surface Water Quantity.
3. Changes in Surface Water Quality.
4. Changes in Sediment Quality.
5. Habitat Loss.

These categories represent groups of potential Project effects that share biophysical pathways, specific mitigation and management measures, regulatory and management criteria, and/or are identified as separate VCs in the Application/EIS. For example, the erosion and sedimentation category is intended to encompass all Project activities that may introduce sediments into the aquatic environment, including site contact water or discharge from Brucejack Lake. By grouping these activities together in this shared category, the effects assessment considers the contributions of all potential Project effects, defines specific indicators of effects, identifies the specific and relevant mitigation and management measures, and presents an effective analysis of the residual effects. Furthermore, these categories draw on predictive analyses conducted for other VCs, such as surface water quality in the mine site area, to provide quantitative predictions of potential effects on aquatic resources. Below are presented short descriptions of the categories of Project interactions with aquatic resources.

Figure 14.4-1

Regional and Local Study Areas, Aquatic Resources Effects Assessment, Brucejack Gold Mine Project

ERM



Erosion and Sedimentation

Physical disturbance of the terrain during all Project phases have the potential to increase erosion and sedimentation, affecting primary and secondary producers though both the physical and chemical alteration of their habitat. Project-related increases in sedimentation and erosion interact with sediment quality, surface water hydrology (Chapter 10), surface water quality (Chapter 13), and contribute to potential habitat loss in aquatic receiving environments within the LSA and RSA.

Surface Water Quantity

Surface water quantity is a key component of the physical and biological environment and was screened for inclusion as an Intermediate VC as a result of the scoping process, as described in Section 6.4.1 Selecting Candidate Components. Changes in the condition of the surface water hydrology have the potential to effect aquatic resources through alteration of stream flows and channel morphology; Chapter 10, Surface Water Hydrology Predictive Study, presents the detailed predictive study and effects assessment for surface water quantity.

Surface Water Quality

Surface water quality was screened for inclusion as a Receptor VC as a result of the scoping process as described in Section 6.4.1, Selecting Candidate Components, and includes the physical and chemical constituents of water. Potential pathways to changes in surface water quality include effluent discharges, ML/ARD, nutrient loading from blasting residues and sewage, groundwater interactions/seepage, and atmospheric deposition. Chapter 13 presents the detailed predictive study and effects assessment for surface water quality. The effects of increased surface runoff and erosion on surface water quality are addressed separately under sedimentation and erosion. Changes in surface water quality can have both direct and indirect effects on primary and secondary producers, including direct toxicity, increases/ decreases in productivity, and alteration of community structure.

Sediment Quality

Sediment quality includes the physical and chemical properties of sediments which, in turn, are important determinants of the quantity and identity of benthic organisms present in that habitat. Further, sediment quality is strongly linked to surface water quality as the chemical compositions of water and sediment will co-vary, with factors such as pH and temperature driving a dynamic and reversible exchange of elements and molecules between the water column and underlying sedimentary materials. As in surface quality, pathways to changes in sediment quality include effluent discharge, ML/ARD, nutrient loading from blasting residues, groundwater interactions/seepage, spills/hazardous waste, and atmospheric deposition. The effects of increased surface runoff and erosion on sediment quality are addressed separately under sedimentation and erosion. Changes in sediment quality can have both direct and indirect effects on primary and secondary producers, including direct toxicity, increases/ decreases in productivity, and alteration of community structure.

Habitat Loss

Habitat loss refers to the removal or physical alteration of the environment as a result of Project activities, resulting in adverse conditions for aquatic organisms. Loss of aquatic habitat has both direct and indirect effects on primary and secondary producers, including mortality and elimination of suitable area in which aquatic life can survive, as well as the reduction or elimination of the transfer or nutrients, organic matter, and organisms lost from upstream habitat to downstream habitat. Habitat loss and alteration related to physical changes, such as increased siltation resulting in morphological changes to side channels, or to altered flow patterns changing water levels in a habitat, are considered separately in the sedimentation and erosion and surface water quantity categories.

The Project activities with potential interactions with aquatic resources, identified in Section 14.4.1, are classified spatially and temporally, and then assigned to categories for the effects assessment. The primary interactions between the Project and the freshwater environment will be occurring within the mine site area in the Brucejack watershed. As a result, the effect assessment explicitly considers two separate spatial domains in the LSA: the mine site area, and the off-site Project infrastructure areas.

14.4.3.2 Mine Site Area

Potential Project effects on aquatic resources in the mine site area may occur through all phases of the Project. The extent and magnitude of the interactions, along with proposed mitigation and management measures, may vary between Project phases. For the purposes of the aquatic resources effects assessment, consideration of the far-field receiving environment in the Sulphurets and Unuk watersheds is included in the assessment of effects in the mine site area.

<u>Construction</u>

Construction activities for the Project are focused at the Brucejack mine site area and along the transmission line. Effects on aquatic resources have the potential to occur through various pathways. These pathways are outlined below.

- **Erosion and sedimentation:** potential effects on aquatic resources through the erosion of surface disturbances leading to sedimentation; this includes potential disturbance of the terrain during the establishment and/ or upgrade of the Brucejack Access Road, equipment and material storage yards, laydown areas, surface water diversions and soil storage areas. Deposition of waste rock into Brucejack Lake during the Construction phase may also increase the concentration of suspended material and potential siltation of downstream receiving waters.
- **Changes in surface water quantity:** potential effects on streamflow during the construction and use of surface water diversions, underground water management; upgrades to existing roads and placement of transmission line towers could potentially result in effects on channel morphology.
- **Changes in surface water and sediment quality:** potential changes of receiving and downstream water quality through the directed discharge of effluent into Brucejack Lake, upper Brucejack Creek, and Camp Creek; ML/ARD effects from surface disturbances and subsequent weathering of newly exposed rock, nutrient loading from blasting residues, atmospheric deposition (fugitive dust emissions, fuel combustion, exhaust from equipment tailpipe), groundwater interactions and seepage. The transportation and storage of chemicals and petroleum products could also result in a spill into the freshwater environment.
- **Habitat loss:** aquatic habitat loss within the Brucejack watershed through construction and use of surface water diversions, tailings pipelines in Brucejack Lake, and other mine site area infrastructure.

<u>Operation</u>

During the Operation phase, the majority of Project-activities are focused at the mine site area (Brucejack watershed); effects on aquatic resources have the potential to occur through various pathways.

- **Erosion and sedimentation:** potential effects on aquatic resources through the surface runoff and erosion of surfaces leading to sedimentation (e.g., access and local site roads, equipment and material storage yards, laydown areas, surface water diversions and soil storage areas); deposition of waste rock and tailings into Brucejack Lake (discharge from lake outlet).

- **Changes in surface water quantity:** changes in streamflows due to diversion of contact and non-contact water within the mine site area, management of discharge from Brucejack Lake.
- **Changes in surface water and sediment quality:** ML/ARD as a result of subaqueous deposition of waste rock and tailings into Brucejack Lake as well as continued weathering of rock from surface disturbances; erosion of surface disturbances (e.g., pad and laydown areas) leading to sedimentation, discharge from Brucejack Lake/TMF, groundwater interactions and seepage, and atmospheric deposition (fugitive dust, fuel combustion, exhaust from equipment tailpipe). The transportation of chemicals and petroleum products could also result in a spill into the freshwater environment.
- **Habitat loss:** aquatic habitat loss within the Brucejack watershed through use of surface water diversions, tailings pipelines in Brucejack Lake, and other mine site area infrastructure.

<u>Closure</u>

During the Closure phase, Project infrastructure will be decommissioned and disturbances reclaimed; decommissioning of Project infrastructure within the Brucejack watershed is part of the current closure and reclamation plan (Chapter 30).

- **Erosion and sedimentation:** potential effects on aquatic resources through surface runoff and erosion (e.g., access roads, equipment and material storage yards) leading to sedimentation; surface disturbance and subsequent erosion due to decommissioning/reclamation activities.
- **Changes in surface water quantity:** decommissioning of surface water diversions may affect streamflows within the Brucejack watershed.
- **Changes in surface water and sediment quality:** ML/ARD as a result of waste rock and tailings deposited in Brucejack Lake during construction and operations as well as continued weathering of rock from surface disturbances; discharge from Brucejack Lake/TMF, groundwater interactions and seepage, and atmospheric deposition. The transportation of chemicals and petroleum products could also result in a spill into the freshwater environment.
- **Habitat loss:** aquatic habitat loss in Brucejack watershed from mine tailings and waste rock deposited in Brucejack Lake during construction and operations.

<u>Post-closure</u>

- **Surface runoff, sedimentation, and erosion:** potential effects on aquatic resources from monitoring activities and discharge from Brucejack Lake.
- **Changes in surface water quantity:** Potential changes of instantaneous flows (i.e., peak flows) in the Brucejack Lake watershed may occur if geometry of the lake outlet is altered.
- **Changes in surface water and sediment quality:** ML/ARD as a result of subaqueous deposition of waste rock and tailings into Brucejack Lake (discharge from lake outlet); groundwater interactions and seepage; potential degradation of water quality through spills of chemicals and fuel during monitoring activities.

14.4.3.3 Off-site Project Infrastructure

Potential Project effects on aquatic resources in the off-site Project infrastructure areas may occur through all phases of the Project. As was discussed for the mine site area, the extent and magnitude of the interactions, along with proposed mitigation and management measures, may vary between Project phases.

Construction

Construction activities for the Project in the off-site Project infrastructure areas consist of activities along the transmission line and transportation corridors. Potential effects categories are outlined below.

- **Erosion and sedimentation:** potential effects on aquatic resources through the erosion of surface disturbances leading to sedimentation; this includes potential disturbance of the terrain during the rehabilitation and expansion of the Brucejack Access Road, construction of the Bowser Aerodrome facility, construction of the transmission line, equipment and material storage yards, laydown areas, surface water diversions and soil storage areas.
- **Changes in surface water quantity:** upgrades to existing roads and placement of transmission line towers could results in effects on channel morphology.
- **Changes in surface water and sediment quality:** ML/ARD effects from surface disturbances and subsequent weathering of newly exposed rock, nutrient loading from blasting residues, atmospheric deposition (fugitive dust, fuel combustion, exhaust from equipment), groundwater interactions and seepage (camp septic fields). The transportation of chemicals and petroleum products could also result in a spill into streams and waterbodies along the access roads.
- **Habitat loss:** potential habitat loss associated with construction of off-site Project infrastructure including the Brucejack Access Road, Brucejack Transmission Line, Bowser Aerodrome, and the Knipple Transfer Area.

Operation

During the Operation phase, the majority of Project-activities will be focused at the mine site area (Brucejack watershed); effects on aquatic resources in the off-site Project infrastructure area are associated with activities in the transportation corridor.

- **Erosion and sedimentation:** potential effects on aquatic resources through surface runoff and erosion of surface disturbances leading to sedimentation (e.g., access and local site roads, Bowser Aerodrome facility, transmission line, equipment and material storage yards, laydown areas, surface water diversions and soil storage areas).
- **Changes in surface water quantity:** changes in streamflows due to use and maintenance of Brucejack access road altering the sediment feed into the channels, and by changing the channel hydraulics at the stream crossings (potential effects on channel morphology).
- **Changes in surface water and sediment quality:** ML/ARD from the weathering of rock from surface disturbances; transport of material from surface disturbances (e.g., access roads, equipment and material storage yards), groundwater interactions and seepage, and atmospheric deposition. The transportation of chemicals and petroleum products could also result in a spill into the freshwater environment along the access roads.
- **Habitat loss:** potential Project-specific habitat loss associated with off-site project infrastructure including the Brucejack Access Road, Brucejack Transmission Line, Bowser Aerodrome and the Knipple Transfer Area.

Closure

During the Closure phase, Project infrastructure will be decommissioned and disturbances reclaimed; decommissioning of Project infrastructure within the Knipple Lake, Bowser and Wildfire Creek watersheds are part of the current closure and reclamation plan (Chapter 30).

- **Erosion and sedimentation:** potential effects on aquatic resources through surface runoff and erosion of surface disturbances (e.g., access roads, equipment and material storage yards) leading to sedimentation; disturbances generated through decommissioning/reclamation activities.
- **Changes in surface water quantity:** decommissioning of the Brucejack Access Road, the Bowser Aerodrome, and the Knipple Transfer Area could affect channel morphology if stream banks were affected by decommissioning activities.
- **Changes in surface water and sediment quality:** ML/ARD as a result of weathering of rock from surface disturbances; groundwater interactions and seepage, and atmospheric deposition (fugitive dust emissions, fuel combustion, exhaust from equipment tailpipe). The transportation of chemicals and petroleum products could also result in a spill into streams and waterbodies along the access roads.
- **Habitat loss:** potential Project-specific habitat loss associated with off-site Project infrastructure including the Brucejack Access Road, Brucejack Transmission Line, Bowser Aerodrome, and the Knipple Transfer Area.

<u>Post-closure</u>

- **Erosion and sedimentation:** potential effects on aquatic resources from monitoring activities.
- **Changes in surface water and sediment quality:** potential degradation of water quality through spills and accidents during monitoring activities.

14.5 EFFECTS ASSESSMENT AND MITIGATION FOR AQUATIC RESOURCES

The potential significance of the effects of Project activities and infrastructure on aquatic resources is considered for each of the effect categories identified in Section 14.4.3.1. The Project activities identified in Section 14.4.3 are considered for every Project phase and the potential significance of effects is ranked. The ranking process identifies the key potential interactions between the Project and aquatic resources, focuses the discussion of planned mitigation and management measures, and will help describe the significant residual effects. The ranking scheme is based on the expected significance of the potential effects and shown in detail in Table 14.5-1. The ranks are:

- **Red:** key interaction resulting in potential significant major adverse effect or significant concern, further consideration is required;
- **Yellow:** potential moderate adverse effect requiring unique active management/monitoring/ mitigation, further consideration is required;
- **Green:** negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required, no further consideration is required; and
- **No colour:** effects are expected to be negligible.

Project components and physical activities that could potentially cause key effects on aquatic resources during different phases of the Project (Table 14.5-1) are described in the following sections. The effects assessment for aquatic resources is necessarily dependent on the analyses for other biophysical components of the environment. The effects assessments for the following VCs are used extensively in the aquatic resources effects assessment to describe mitigation and management measures, describe the extent and magnitude of residual effects, and establish the significance of residual effects.

Table 14.5-1. Ranking Potential Project Effects on Aquatic Resources

Project Components and Physical Activities by Phase	Potential Effects on Aquatic Resources				
	Erosion and Sedimentation	Changes in Surface Water Quantity	Changes in Surface Water Quality	Changes in Sediment Quality	Habitat Loss
Construction					
Activities at existing adit	● (yellow)	● (yellow)	● (red)	● (red)	○
Air transport of personnel and goods	○	○	○	○	○
Avalanche control	○	○	○	○	○
Chemical and hazardous material storage, management and handling	○	○	● (red)	● (red)	○
Construction and use of sewage treatment plant and discharge	● (red)	● (red)	● (red)	● (red)	● (green)
Construction and use of surface water diversions	● (red)	● (red)	● (red)	● (red)	● (green)
Construction of detonator storage area	● (yellow)	● (green)	● (green)	● (green)	○
Construction of electrical substation at mine site	● (yellow)	● (green)	● (green)	● (green)	○
Construction of equipment laydown areas	● (yellow)	● (yellow)	● (yellow)	● (yellow)	○
Construction of helicopter pad	● (green)	● (green)	● (green)	● (green)	○
Construction of incinerator	● (green)	● (green)	● (green)	● (green)	○
Construction of local site roads	● (red)	● (red)	● (yellow)	● (yellow)	● (green)
Construction of mine portal and ventilation shafts	● (green)	● (green)	● (green)	● (green)	○
Construction of ore conveyer	● (yellow)	● (yellow)	○	○	○
Construction of tailings pipeline	● (red)	● (red)	● (yellow)	● (yellow)	● (yellow)
Construction of transfer station	● (red)	● (red)	● (yellow)	● (yellow)	○
Construction of water treatment plant	● (yellow)	● (green)	● (green)	● (green)	○
Construction/installation of back-up power plant	● (yellow)	● (green)	● (green)	● (green)	○
Construction/installation of electrical induction furnace, backfill paste plant, warehouse, mill/concentrator building, and truck shop	● (yellow)	● (yellow)	● (yellow)	● (yellow)	○
Development of the underground portal and facilities	● (yellow)	● (green)	● (yellow)	● (yellow)	○
Employment and labour	○	○	○	○	○
Equipment maintenance/machinery and vehicle refuelling/fuel storage and handling	○	○	○	○	○
Expansion of current exploration camps	● (yellow)	● (yellow)	● (yellow)	● (yellow)	○
Explosives storage and handling	○	○	● (yellow)	● (yellow)	○
Grading of the mine site area	● (red)	● (red)	● (red)	● (red)	○
Helicopter use	○	○	○	○	○
Installation and use of Project lighting	○	○	○	○	○

(continued)

Table 14.5-1. Ranking Potential Project Effects on Aquatic Resources (continued)

Project Components and Physical Activities by Phase	Potential Effects on Aquatic Resources				
	Erosion and Sedimentation	Changes in Surface Water Quantity	Changes in Surface Water Quality	Changes in Sediment Quality	Habitat Loss
Construction (cont'd)					
Installation of surface and underground crushers	● (yellow)	○	● (yellow)	● (yellow)	○
Installation of the transmission line and associated towers	● (yellow)	● (yellow)	● (yellow)	● (yellow)	● (yellow)
Solid waste management	● (yellow)	● (yellow)	● (yellow)	● (yellow)	○
Machinery and vehicle emissions	○	○	● (green)	● (green)	○
Maintenance and use of exploration access road	● (red)	● (red)	● (yellow)	● (yellow)	○
Potable water treatment and use	○	● (yellow)	○	○	○
Pre-production ore stockpile construction	● (yellow)	○	● (yellow)	● (yellow)	○
Procurement of goods and services	○	○	○	○	○
Quarry construction	● (red)	● (yellow)	● (yellow)	● (yellow)	○
Rehabilitation of aerodrome	● (red)	● (yellow)	● (yellow)	● (yellow)	○
Transportation of workers and materials	○	○	○	○	○
Underground water management	● (yellow)	● (red)	● (yellow)	● (yellow)	○
Use of Granduc Access Road	● (yellow)	○	● (green)	● (green)	○
Operation					
Aerodrome	● (green)	● (yellow)	● (green)	● (green)	○
Air transport of personnel and goods and use of aerodrome	○	○	○	○	○
Avalanche control	○	○	○	○	○
Backfill paste plant	○	● (yellow)	○	○	○
Back-up power plant	○	○	○	○	○
Brucejack Access Road use and maintenance	● (yellow)	● (green)	● (yellow)	● (yellow)	○
Brucejack camp	● (green)	● (green)	● (green)	● (green)	○
Chemical and hazardous material storage, management, and handling	○	○	● (red)	● (red)	○
Concentrate storage and handling	○	○	○	○	○
Contact water management	● (red)	● (red)	● (red)	● (red)	● (green)
Detonator storage	○	○	○	○	○
Discharge from Brucejack Lake	● (red)	● (red)	● (red)	● (red)	● (yellow)
Electrical induction furnace	○	○	○	○	○
Electrical substation	○	○	○	○	○
Equipment laydown areas	● (green)	● (yellow)	● (green)	● (green)	○
Equipment maintenance/machine and vehicle refueling/fuel storage and handling	○	● (yellow)	● (yellow)	○	○
Explosives storage and handling	○	○	● (yellow)	● (yellow)	○
Helicopter pad(s)	○	○	○	○	○

(continued)

Table 14.5-1. Ranking Potential Project Effects on Aquatic Resources (continued)

Project Components and Physical Activities by Phase	Potential Effects on Aquatic Resources				
	Erosion and Sedimentation	Changes in Surface Water Quantity	Changes in Surface Water Quality	Changes in Sediment Quality	Habitat Loss
Operation (cont'd)					
Helicopter use	○	○	○	○	○
Machine and vehicle emissions	○	○	Green	Green	○
Mill building/concentrators	○	Yellow	○	○	○
Non-contact water management	Red	Red	Red	Red	Green
Ore conveyer	○	Yellow	○	○	○
Potable water treatment and use	○	Red	○	○	○
Pre-production ore storage	Yellow	○	Yellow	Yellow	○
Project lighting	○	○	○	○	○
Quarry operation	Yellow	Green	Yellow	Yellow	○
Sewage treatment and discharge	Yellow	Red	Yellow	Yellow	○
Solid waste management/incinerator	○	Yellow	Green	Green	○
Subaqueous tailings disposal	Red	Red	Red	Red	Red
Subaqueous waste rock disposal	Red	Red	Red	Red	Red
Surface crushers	○	○	Green	Green	○
Tailings pipeline	Yellow	Red	Yellow	Yellow	○
Transfer station	Yellow	Yellow	Yellow	Yellow	○
Transmission line operation and maintenance	Green	Yellow	Green	Green	○
Truck shop	○	○	○	○	○
Underground backfill tailing storage	○	Yellow	Green	Green	○
Underground backfill waste rock storage	○	Yellow	Green	Green	○
Underground explosives storage	○	○	Green	Green	○
Underground mine ventilation	○	○	Green	Green	○
Underground water management	○	Red	Green	Green	○
Underground: drilling, blasting, excavation	○	Yellow	Green	Green	○
Use of mine site haul roads	Yellow	Yellow	Green	Green	○
Use of portals	○	○	○	○	○
Ventilation shafts	○	○	○	○	○
Waste rock transfer pad	Yellow	Yellow	Yellow	Yellow	○
Employment and labour	○	○	○	○	○
Procurement of goods and services	○	○	○	○	○
Underground crushers	○	○	○	○	○
Warehouse	○	○	○	○	○
Water treatment plant	Yellow	Red	Yellow	Yellow	○
Closure					
Air transport of personnel and goods	○	○	○	○	○
Avalanche control	○	○	○	○	○
Chemical and hazardous material storage, management, and handling	○	○	Red	Red	○

(continued)

Table 14.5-1. Ranking Potential Project Effects on Aquatic Resources (continued)

Project Components and Physical Activities by Phase	Potential Effects on Aquatic Resources				
	Erosion and Sedimentation	Changes in Surface Water Quantity	Changes in Surface Water Quality	Changes in Sediment Quality	Habitat Loss
Closure (cont'd)					
Closure of mine portals	○	● green	○	○	○
Closure of quarry	● yellow	● green	○	○	○
Closure of subaqueous tailing and waste rock storage (Brucejack Lake)	● red	● red	● red	● red	● red
Decommissioning of aerodrome	● yellow	● yellow	● yellow	● yellow	○
Decommissioning of back-up power plant	● yellow	● green	○	○	○
Decommissioning of Brucejack Access Road	● yellow	● yellow	● yellow	● yellow	● green
Decommissioning of camps	● yellow	● yellow	● yellow	● yellow	○
Decommissioning of diversion channels	● red	● red	● yellow	● yellow	● green
Decommissioning of equipment laydown	● yellow	● yellow	○	○	○
Decommissioning of fuel storage tanks	● yellow	○	● yellow	○	○
Decommissioning of helicopter pad(s)	● yellow	○	○	○	○
Decommissioning of incinerator	● yellow	○	○	○	○
Decommissioning of local site roads	● yellow	● green	○	○	○
Decommissioning of mill building	● yellow	○	● yellow	● yellow	○
Decommissioning of mill/concentrators	● yellow	● yellow	○	○	○
Decommissioning of surface crushers	● yellow	● green	○	○	○
Decommissioning of underground crushers	○	○	○	○	○
Decommissioning of ore conveyer	● yellow	● yellow	○	○	○
Decommissioning of Project lighting	○	○	○	○	○
Decommissioning of sewage treatment plant and discharge	● yellow	● red	○	○	○
Decommissioning of solid waste incineration	● yellow	○	○	○	○
Decommissioning of surface explosives storage	● yellow	○	● yellow	● yellow	○
Decommissioning of transmission line and ancillary structures	● yellow	○	○	○	○
Decommissioning of waste rock transfer pad	● yellow	○	● yellow	● yellow	○
Decommissioning of water diversion channels	○	● red	○	○	● yellow
Decommissioning of water treatment plant	● yellow	● red	○	○	○
Decommissioning of tailings pipeline	● yellow	● yellow	● yellow	● yellow	○
Employment and labour	○	○	○	○	○
Helicopter use	○	○	○	○	○
Machine and vehicle emissions	○	○	● green	● green	○
Procurement of goods and services	○	○	○	○	○
Removal or treatment of contaminated soils	● yellow	● green	♍ (yellow)	♍ (yellow)	○
Solid waste management	○	● yellow	○	○	○
Transportation of workers and materials (mine site and access roads)	● yellow	○	● green	● green	○

(continued)

Table 14.5-1. Ranking Potential Project Effects on Aquatic Resources (completed)

Project Components and Physical Activities by Phase	Potential Effects on Aquatic Resources				
	Erosion and Sedimentation	Changes in Surface Water Quantity	Changes in Surface Water Quality	Changes in Sediment Quality	Habitat Loss
Post-closure					
Underground mine	○	● (yellow)	○	○	○
Discharge from Brucejack Lake	● (red)	● (red)	● (red)	● (red)	● (yellow)
Subaqueous tailing and waste rock storage	● (red)	● (red)	● (red)	● (red)	○
Environmental monitoring	● (green)	● (green)	● (green)	● (green)	○
Employment and labour	○	○	○	○	○
Procurement of goods and services	○	○	○	○	○

Notes:
○ = No detectable interaction anticipated.
● (green) = Negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required, no further consideration warranted.
● (yellow) = Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.
● (red) = Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.

Key VC effects assessments for the aquatic resources VC include:

- air quality (via dust deposition; Chapter 7);
- hydrogeology (groundwater quality and quantity; Chapter 9);
- hydrology (surface water quantity; Chapter 10);
- surface water quality (Chapter 13); and
- fish and fish habitat (Chapter 15).

14.5.1 Identifying Key Effects: Mine Site Area

The key potential effects from Project activities and infrastructure in the mine site area on aquatic resources are described for each of the categories of potential effects in Sections 14.5.1.1 through 14.5.1.5. The key effects are summaries based on the descriptions of the proposed Project in the Project Description (Chapter 5) combined with regulatory and permitting requirements and professional judgment and experience. The potential effects on both the primary producer and secondary producer communities are discussed together because of the close association of these two components of the aquatic foodweb. For example, many of the established criteria and guidelines for the protection of aquatic life incorporate the potential effects of chemical on both components of the aquatic foodweb. Once identified, the mitigation and management measures proposed to eliminate, mitigate, reduce, or otherwise manage the potential effects will be discussed (Section 14.5.3).

14.5.1.1 Erosion and Sedimentation

Physical disturbance of the terrain during all Project phases has the potential to increase surface runoff and erosion, resulting in increased turbidity, total suspended solids (TSS), particle-associated nutrients and metals, and sedimentation in receiving waters. The potential for erosion and sedimentation is greatest during periods of disturbance of natural surface cover and vegetation, such as during construction and site decommissioning.

Potential Project-specific sources of erosion and sedimentation include:

- upgrades to the exploration access road to accommodate mine traffic, routine maintenance and grading, and the decommissioning of roads;
- construction and use of surface water diversions for contact and non-contact water;
- subaqueous tailings and waste rock disposal, including construction and decommissioning of tailings and waste rock management infrastructure;
- operation and decommissioning of the quarry; and
- construction, maintenance, and decommissioning of pads and laydown areas.

These Project components and activities have the potential to cause temporary increases in TSS and turbidity of receiving waters. High concentrations of suspended material can occur from erosion events during construction and decommissioning (e.g., materials accidently pushed into streams or the loosening of materials along stream banks) and runoff of disturbed surfaces during spring snowmelt and summer rains. Similarly, during Construction and Operation, the erosion of roadways in this mountainous area as well as soil compaction by heavy vehicles could provide other sources of silt to contact waters within the mine site area. Other sources of TSS include particulates from construction equipment activity, blasting activities, and dust deposition. Further, subaqueous tailings and waste rock disposal in Brucejack Lake have the potential to result in periodic releases of waters with elevated TSS at the lake outlet.

These Project-related increases in the quantity of suspended material in the freshwater environment could affect primary producers and secondary producers through both physical and chemical alteration of their habitat. The resulting decrease in water clarity and enhanced suspended particle loads could reduce primary producer biomass and activity by altering the light penetration and intensity required to support photosynthetic metabolism, as well as through scouring of the host substrates in the stream environment. Further, responses to changes in light intensity are species-specific and could thus affect species richness and diversity of primary producers within that habitat (Wetzel 2001). Sediments may also accumulate in some streams that are shallow with low discharge rates, resulting in burial of organisms and habitat, abrasion, as well as the potential changing watercourse flow and side channel morphology such that the wetted width availability for primary producer colonization would be altered.

The effects of increased surface runoff and erosion to secondary producers will be similar to those described for primary producers. Increases in the concentration of suspended material may cause mortality or reduced growth through respiratory inhibition via smothering at various life stages, diminishing feeding efficiency, and increased exposure to elevated metal concentrations. The decreases in feeding efficiency could lead to the alteration of community structure through selection against certain feeding guilds (e.g., filter feeders) and visual predators. Silt deposited from erosion events could also affect invertebrate production as gravel interstices are filled by silt and algae are buried or abraded (Beschta et al. 1995). In these instances, community diversity can become reduced, with the remaining assemblages being typically made up of a few tolerant, colonizing species (Newbold, Erman, and Roby 1980; Murphy, Hawkins, and Anderson 1981; Hawkins, Murphy, and Anderson 1982). This loss of substrate complexity, including large woody debris, is associated with decreases in the diversity of aquatic invertebrates.

Secondary producer biomass also tends to be positively correlated to phytoplankton biomass (e.g., Hanson and Peters 1984; Manca et al. 2007); reductions in primary production due to reduced water clarity and particle scouring may have cascading effects up the foodweb. For example, under food limiting conditions, the body size and mass of zooplankton decreases, the number of instars or preproductive stages increases, the duration of development is prolonged, and fecundity is reduced (Wetzel 2001). This could affect the diversity and abundance of aquatic invertebrates (effects to fish assessed are in Chapter 15, Assessment of Potential Fish and Fish Habitat Effects).

14.5.1.2 Changes in Surface Water Quantity

Project-related changes to surface water hydrology have the potential to affect aquatic resources through alteration of stream flows and channel morphology. Surface water hydrology is discussed in detail in the corresponding assessment chapter, including details of the predictive studies on water quantity (Chapter 10). Potential sources of changes to water quantity in the mine site area across all Project phases include:

- construction, operation, and decommissioning of surface water management structures, including the diversion of contact and non-contact water;
- construction, operation, and decommissioning of the tailings pipeline;
- site roads;
- underground water management, including the operation of the water treatment plant;
- operation of the sewage treatment plant; and
- changes to morphology/geometry of Brucejack Lake outlet.

Changes to surface water quantity within the mine site area can affect primary producers primarily by physical alteration of habitat. Water management, including diversion channels for non-contact water, affects discharge rates and stream flows and therefore may alter the wetted width availability for aquatic life colonization at different times of the year. For example, decreased water flow in summer would decrease aquatic habitat available for periphyton, while in the winter, decreased flow rates could lead to increased ice formation, which could build up and block flows in diversion channels or low-flow streams. In the other extreme, increase in water flow can cause scouring and bank erosion, which may also decreased primary producer biomass and productivity as potential aquatic habitats are altered and suspended material concentrations are increased. In such cases, the *in situ* retention of nutrients would be substantially reduced, as would nutrient spiralling lengths potentially leading to effects at higher trophic levels (Newbold et al. 1983).

Water management within the mine site area may affect secondary producers through a similar pathway involving the physical alteration in habitat. Water management may affect discharge rates and stream flows and therefore may alter the wetted width availability for aquatic life colonization at different times of the year. Higher stream discharge rates may increase scour and reduce the availability of suitable low-flow refuges and habitat.

14.5.1.3 Changes in Surface Water Quality

Project-related changes in surface water quality can affect aquatic resources through the chemical alteration of their habitat. The major identified pathways resulting in potential changes of surface water quality condition during the life of the Project are detailed in Chapter 13, Assessment of Potential Surface Water Quality Effects, and are discussed below in the context of effects to aquatic resources. Sedimentation and erosion effects related to changes in the quantity of suspended material are discussed in Section 14.5.1.1, but the transport of chemicals by surface runoff and suspended material is considered within the discussion on changes to surface water quality.

Metal Leaching / Acid Rock Drainage

Acid rock drainage (ARD) occurs when sulphide minerals are exposed to oxygen and water and naturally oxidize without the presence of sufficient quantities of neutralizing minerals. Mining can accelerate the rate of this process by crushing, processing, and redistributing large quantities of rock. In the event that acid rock drainage is formed, the lower pH can accelerate the rate of metal leaching (ML). However, metal leaching can also occur at sites of neutral and alkaline drainage. Metals also occur naturally in watercourses within the LSA and RSA of the Project (Section 13.3, Baseline Characterization) due to the presence of mineral-rich deposits, sometimes at concentrations above provincial and/or federal guideline limits (e.g., Al, Cu, Zn, Ag; Tables 13.3-3 to 13.3-4).

Within the LSA, ML/ARD has the potential to occur as a result of surface disturbances during the Construction phase and subsequent weathering of newly exposed rock. Project-specific sources of potential ML/ARD effects include:

- upgrades to the existing exploration access road to accommodate mine traffic, and the operation and decommissioning of site roads. Surface disturbances resulting in ML/ARD have the potential to occur during re-alignments of the sharper curves, reduction of the steeper gradients, and additional surfacing of some road sections;
- surface runoff from pad areas, infrastructure, ore storage areas, and mine surface infrastructure; and
- waste rock and tailings deposition.

The generation of ML/ARD can affect primary producers through the alteration of pH due to the introduction of acidifying compounds, potentially leading to both lethal and sublethal effects. Acidification of receiving waters can also result in changed metal and metalloid speciation such that metal mobility and bioavailability in the aquatic environment is increased. This would alter the toxicological implications of exposure and further, these effects will be both element- as well as species-specific. In general, acids and metals leaching into aquatic environments can result in decreased biomass, densities, and diversities of primary producer communities (Kimmel 1983; McKnight and Feder 1984; Niyogi, Lewis, and McKnight 2002). Further, the toxicology of mixtures of metals and other chemicals in the aquatic environment is poorly understood, although it is known that antagonistic, additive, synergistic, or potentiating effects are possible outcomes.

The effects of ML/ARD to secondary producers are similar to those described for primary producers. Exposure of secondary producers to extremes in pH or metals can lead to both lethal and sublethal effects. At high enough concentrations, metals can result in direct toxicity and mortality in exposed organisms. For example, aquatic insects are affected by low pH, with lethal and sublethal effects (Bell 1971; Carbone, Keller, and Griffiths 1998).

At lower concentrations, sublethal effects may occur and although these effects do not cause immediate mortality, they can lead to reduced productive capacity that affects population dynamics or stability in the long term. For example, there are a number of potential sublethal effects that ultimately lead to reduced growth or reproduction (e.g., fecundity and egg survival), altered physiology, (e.g., metabolism, energy storage, and oxygen consumption), or altered behaviour (e.g., feeding rates, drift, and predator avoidance).

Nutrient Loading

Project activities involving nitrogen-based explosives, the directed discharge of effluent, and groundwater interactions could contribute inputs of nitrogenous and phosphorus compounds into the aquatic environment. The directed discharge of STP and mine WTP effluent into Brucejack Creek (Construction phase) and Brucejack Lake (Operation, Closure phases) has the potential to contribute to nutrient loading within the mine site area and the downstream receiving environment. Similarly, residues from blasting will contain nitrogen compounds that may leach from the surface of newly exposed rock, waste rock, tailings and pad areas. The accumulation of these residues (nitrate, nitrite, ammonia) on disturbed rock material and the corresponding nitrogen load to the aquatic environment will depend on the volume of explosives used and the retention and weathering rates from surfaces.

Most nitrogen loading from these sources will occur from runoff, although a minor source may be from dust/atmospheric loading (Chapter 7, Air Quality Predictive Study). The surface runoff and nutrient loading is expected to exhibit substantial intra-seasonal variation, and be the greatest during spring freshet and rain events.

Any changes in nutrient concentrations and supply can contribute to alterations in productive capacity and increase the potential eutrophication of the receiving environment. Primary producer community composition and diversity can also be affected by changes in nutrient concentrations such that one group of organisms may be selected over another. For example, freshwater primary producers exhibit marked differences in phosphorous growth requirements as well as tolerances to elevated phosphorus concentrations (Wetzel 2001). Similarly, bacterioplankton have substantially higher phosphorus requirements than phytoplankton, but can out-compete algae for phosphorus at elevated supply rates (Wetzel 2001). Further, changes in nutrient supply would not only influence the absolute concentration of nutrients, but also the ratio of nutrients available. The ratio of nitrogen to phosphorus is a commonly cited example driving primary producer abundance and overall community structure. For example, cyanobacteria are generally thought to have an advantage in periphyton communities when nitrogen to phosphorus ratios are low, due to their ability to use atmospheric nitrogen (N_2) for growth (e.g., Havens et al. 2003; Nõges et al. 2008).

Secondary producer abundance and diversity can also be affected by any changes in the structure and abundance of the primary producer community due to nutrient loading (i.e., “bottom-up” effects). Invertebrate grazers tend to exhibit prey size and species selectivity (Wetzel 2001). If nutrient loading induces any changes in the community composition of the primary producer community, then the abundance and diversity of the invertebrate community may change as a result of these feeding preferences. Any community shifts of secondary producer community composition may have a cascading effect, leading to changes in the structure of several successive trophic levels due to the dietary preferences of higher trophic levels and so influence trophic energy transfers.

The inorganic nitrogen compounds nitrate, nitrite, and ammonia, which are the most common forms of nitrogen usable as nutrients for primary producers, are also potentially toxic to aquatic organisms. Lethal and sublethal effects to growth and reproduction of primary producers and secondary producers may occur from exposure to relatively high concentrations of these inorganic nitrogen compounds (Camargo and Alonso 2006).

Atmospheric Deposition

Air quality is a pathway VC to surface water quality and, by extension, aquatic resources. The aerial deposition of Project-generated dust will be the primary pathway of interaction. Dust deposition from blasting and other mining activities has the potential to effect aquatic resources during the Construction, Operation, Closure, and Post-closure phases. Fugitive dust will also occur via vehicle traffic along local site roads. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. Predictive modelling and detailed effects assessment of air quality and dustfall are presented in Chapter 7. Atmospheric deposition is considered separately because of the specific mitigation and management measures.

Dust deposition into the freshwater environment could affect aquatic resources by introducing suspended material and associated metals and nutrients into receiving waters. The deposited material can therefore have effects similar to mobilized sediments (Section 14.5.1.1) or may transport metals with subsequent effects to the growth, reproduction, and longevity of primary producers and secondary producers (metal leaching, see Section 14.5.1.3).

14.5.1.4 Changes in Sediment Quality

Sediment quality describes the physical and chemical properties of sediments, and is a valuable description of the quality of habitat for aquatic organisms. As discussed in Section 14.4.1.3, sediment quality is considered a pathway component for this effects assessment. Sediment quality is strongly linked to surface water quality as the chemical compositions of water and sediment will co-vary, with factors such as pH, temperature, and hydrologic regime driving a dynamic and reversible exchange of elements and molecules between the water column and underlying sedimentary materials.

Potential Project-related changes to sediment quality in the mine site area are similar to the interactions described for surface water quality (Section 14.5.1.3). Generally, Project activities that introduce dissolved or particulate material in the freshwater environment have the potential to change sediment quality. These activities include:

- construction, operation, and decommissioning of site roads, laydown areas, pads, and other infrastructure;
- construction, operation, and decommissioning of the WTP and the STP;
- construction, operation, and decommissioning of water management structures, including the diversion of non-contact water; and
- deposition of tailings and waste rock into Brucejack Lake, with subsequent discharge.

Changes in sediment quality can have both direct and indirect effects on aquatic organisms, including direct toxicity, changes in productivity, and alteration of community structure. Alteration of aquatic pH from *in situ* ARD can have direct toxic effects on aquatic organisms. Changes in sediment pH and redox conditions can result in the dissolution of common metal-bearing mineral phases (e.g., iron (oxy)hydroxides) or the de-sorption and liberation of previously sediment-bound metal elements that can have lethal and sublethal effects on aquatic organisms (McKnight and Feder 1984; Niyogi, Lewis, and McKnight 2002).

The physical and chemical compositions of sediments are also interrelated, with strong associations between grain sizes and elemental concentrations. For example, once introduced into an environment many potentially toxic metals sorb onto fine-grained sediments (e.g., clay). For this reason, higher concentrations of metals tend to be found in depositional areas, including the deepest area of lakes and areas of slow-moving water and back-eddies in streams. The physical and chemical compositions of sediments are important determinants of the abundance and diversity of the benthic invertebrate community. Changes in sediment size or chemistry can have significant effects on benthic communities, with subsequent consequences for trophic dynamics and biodiversity.

14.5.1.5 Habitat Loss

Loss of habitat for aquatic resources could occur in certain areas due to Project development. In the mine site area, the primary loss of aquatic habitat will be due to the deposition of waste rock and tailings in Brucejack Lake. The potential for habitat losses from water management activities within the mine site area are addressed as changes to surface water quantity (Section 14.5.1.2). Direct mortality and the loss of habitat are the primary effects to aquatic organisms. Indirect effects can include the loss of significant reproductive or feeding habitat and changes to nutrient and organic material cycling.

14.5.2 Identifying Key Effects: Off-site Project Infrastructure

The key potential effects from Project activities and infrastructure in the off-site Project infrastructure areas on aquatic resources are described for each of the categories of potential effects in Sections 14.5.2.1 through 14.5.2.5. As in the mine site area key effects section, the key effects are summaries based on the descriptions of the proposed Project in the Project Description (Chapter 5) combined with regulatory and permitting requirements and professional judgment and experience. The potential effects on both the primary producer and secondary producer communities are discussed together because of the close association of these two components of the aquatic foodweb. Once identified, the mitigation and management measures proposed to eliminate, mitigate, reduce, or otherwise manage the potential effects will be discussed (Section 14.5.3).

14.5.2.1 Erosion and Sedimentation

Physical disturbance of the terrain during all Project phases has the potential to increase surface runoff and erosion, resulting in increased turbidity, increases suspended material and sedimentation in receiving waters. The potential for erosion and sedimentation is greatest during periods of disturbance of natural surface cover and vegetation, such as during construction and site decommissioning. Potential Project-specific sources of erosion and sedimentation relevant to the off-site infrastructure area include:

- construction and decommissioning of the transmission line: construction and installation of towers may require surface clearings and grubbing of the surface and result in the loss of vegetation and increases in erosion and sedimentation within the Bowser River and Knipple Lake watersheds, although tower foundations will be small and widely-spaced, and the clearing of the corridor will not require grubbing;
- Bowser Aerodrome facility: rehabilitation of the Bowser Aerodrome facility, including the elongation and widening of the original Newhawk airstrip;
- construction of the Knipple Transfer Area near the base of the Knipple Glacier, adjacent Knipple Lake;
- Brucejack access corridor: upgrading, maintenance, and decommissioning of the existing exploration access road to accommodate mine traffic; and
- construction, use, and decommissioning of surface water management structures for contact and non-contact water.

These Project components and activities have the potential to cause temporary increases in suspended material concentrations and turbidity of receiving waters that can affect aquatic organisms though both the physical and chemical alteration of their habitat. As discussed in erosion and sedimentation in the mine site area key effects analysis (Section 14.5.1.1), the movement of suspended material from the landscape into the aquatic environment can have lethal and sublethal effects on primary producers and secondary producers (see Section 14.5.1.1 for a detailed discussion).

14.5.2.2 Changes in Surface Water Quantity

Changes in surface water hydrology have the potential to affect primary producers through alteration of stream flows and channel morphology; changes in surface water hydrology due to Project-activities are discussed in detail within the corresponding assessment and predictive study (Chapter 10). Potential Project-related changes to water quantity in the off-site Project infrastructure areas are associated with the following activities:

- construction and operation of the Knipple Transfer Area and Bowser Aerodrome facility; and
- expansion, use, and maintenance of Brucejack Access Road.

These activities may result in changes in stream flow or alter channel morphology. Changes to surface water quantity in the off-site Project infrastructure areas can affect aquatic resources primarily by physical alteration of habitat, as discussed in Section 14.5.1.2. Water management, including diversion channels for non-contact water, affects discharge rates and stream flows and therefore may alter the wetted width availability for aquatic life colonization at different times of the year. Higher stream discharge rates may increase scour and reduce the availability of suitable low-flow refuges and habitat.

14.5.2.3 Changes in Surface Water Quality

Changes in surface water quality can affect aquatic resources through the chemical alteration of their habitat, as discussed in Section 14.5.1.3. The major identified pathways resulting in potential changes of surface water quality condition during the life of the Project are detailed in Chapter 13 and are discussed below in the context of effects to primary producers. Sedimentation and erosion effects to surface water quality and aquatic resources are discussed in a separate section because of the specific mitigation and management measures associated with sediment and erosion (Sections 14.5.1.1 and 14.5.1.2).

<u>Metal Leaching/Acid Rock Drainage</u>

Acid rock drainage occurs when sulphide minerals are exposed to oxygen and water and naturally oxidize without the presence of sufficient quantities of neutralizing minerals. Mining can accelerate the rate of this process by crushing, processing and redistributing large quantities of rock. In the event that acid drainage is formed, the lower pH can accelerate the rate of metal leaching. However, metal leaching can also occur at sites of neutral and alkaline drainage.

Within the LSA, ML/ARD has the potential to occur as a result of surface disturbances and subsequent weathering of newly exposed rock. Sources of potential ML/ARD in the off-site Project infrastructure areas include:

- upgrades to the existing 75-km exploration access road to accommodate mine traffic. Surface disturbances resulting in ML/ARD have the potential to occur during re-alignments of the sharper curves, reduction of the steeper gradients, and additional surfacing of some road sections; it is not anticipated that any upgrades to stream crossing will be required (Section 5.7.4, Construction of On-site and Off-site Surface Facilities);
- the continued weathering of exposed rock cuts and fills from historical and current road construction and use; and
- rehabilitation of the Bowser Aerodrome facility, including the elongation and widening of the original Newhawk airstrip; ML/ARD has the potential to occur during the levelling of high ground to provide safe approach and take off angles for air traffic.

Construction of the transmission line is not anticipated to be associated with any significant effects to water quality; no blasting is anticipated and BMPs will be implemented to minimize land disturbance and preserve stream bank integrity (see Section 14.5.3). Thus, the potential for ML/ARD effects along the transmission line is considered negligible during all Project phases and potential effects will not be considered further.

A site characterization program was conducted to assess the ML/ARD characteristics of surface materials near the proposed aerodrome as well as along the Brucejack Access Road. Samples taken from the high ground to be removed west of the aerodrome are characterized as non-PAG and thus the potential for ML/ARD effects is considered very low with negligible effects and will not be considered further (Table 13.5-2; Section 13.5.3.2, Chapter 13). For complete details of the ML/ARD baseline study, see Appendix 5-B, Brucejack Environmental Assessment ML/ARD Baseline Report.

The majority of access road samples have negligible acid generation potential, although approximately half of the samples of shale material had low carbonate content, and thus lower neutralizing potential in the event of acid generation (Table 13.5-2, Section 13.5.3.2, Chapter 13). However, minimal quantities of new rock are anticipated to be exposed during the development of off-site infrastructure, which will minimize the potential for ML/ARD (Chapter 5, Project Description). The generation of ML/ARD can have lethal and sublethal effects on aquatic organism by altering pH due to the introduction of acid. Acidification of receiving waters can also result in changed metal and metalloid speciation such that metal mobility and bioavailability in the aquatic environment is increased. In general, acids and metals leaching into aquatic environments can result in decreased biomass, densities, and diversities of primary producer and secondary communities.

Nutrient Loading

Project activities may increase the loading of nutrients in the freshwater environment. Project-related activities in the off-site Project infrastructure areas that may increase nutrient concentrations include:

- blasting with nitrogen-containing explosives, which can lead to the runoff or atmospheric deposition of explosive residues; and
- groundwater interactions and seepages with camp septic fields.

Residues from blasting will contain nitrogen compounds that will remain on the surface of newly exposed rock; waste rock, tailings and laydown areas may all have surface residues of nitrogen compounds from blasting. These nitrogen compounds (nitrate, nitrite, and ammonia) are derived from the ammonium nitrate explosives and residues can be transported in the freshwater environment through runoff or atmospheric deposition. Project-related sources of nitrogen loading from blasting residues in the off-site Project infrastructure areas may include:

- construction of the Bowser Aerodrome in the Bowser River Valley; blasting will occur during the levelling of high ground to provide safe approach and take off angles for air traffic; and
- Brucejack Access Road upgrades.

Most nitrogen loading from these sources will occur from runoff, although a minor source may be from dust/atmospheric loading (Chapter 7, Air Quality Predictive Study). For this reason, the potential for this effect would exhibit substantial intra-seasonal variation, and be the greatest during spring freshet and rain events.

Seepage from septic fields at the Knipple Transfer Area camp could potentially be introduced into the receiving environment during the Construction, Operation, and Closure phases of the Project.

The seepage may contain phosphorus and nitrogen compounds that may subsequently be used as nutrients by aquatic primary producers.

As discussed in Section 14.5.1.3, the loading of nitrogen and phosphorus nutrients 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 foodweb. Furthermore, some nitrogen compounds (nitrate, nitrite, and ammonia) can have sublethal and lethal effects on aquatic organisms.

Atmospheric Deposition

Dust deposition from blasting and other Project activities has the potential to effect aquatic resources during the Construction, Operation, Closure, and Post-closure phases. Fugitive dust emission will also occur from vehicle traffic along local site roads. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. Atmospheric deposition is considered separately because of the specific mitigation and management measures.

Dust deposition into the freshwater environment could affect the surface water and sediment quality and, by extension, aquatic resources, by introducing suspended material. The deposited material can therefore have effects similar to mobilized sediments (Section 14.5.2.1).

14.5.2.4 Changes in Sediment Quality

Sediment quality describes the physical and chemical properties of sediments, and is a valuable description of the quality of habitat for aquatic organisms. As discussed in Section 14.4.1.4, sediment quality is considered a pathway component for this effects assessment. Sediment quality is strongly linked to surface water quality as the chemical compositions of water and sediment will co-vary, with factors such as pH, temperature, and hydrologic regime driving a dynamic and reversible exchange of elements and molecules between the water column and underlying sedimentary materials.

Potential Project-related changes to sediment quality in the off-site Project infrastructure areas are similar to the interactions described for surface water quality (Section 14.5.2.3). Generally, Project activities that introduce dissolved or particulate material in the freshwater environment have the potential for changing sediment quality. These activities include:

- construction, operation, and decommissioning of site roads, laydown areas, pads, and other infrastructure; and
- construction, operation, and decommissioning of water management structures, including the diversion of non-contact water.

Changes in sediment quality can have both direct and indirect effects on aquatic organisms, including direct toxicity, changes in productivity, and alternation of community structure. Alteration of aquatic pH from *in situ* ARD can have direct toxic effects on aquatic organisms. Changes in sediment pH and redox conditions can result in the dissolution of common metal-bearing mineral phases or de-sorption and liberation of previously sediment-bound metal elements, which can have lethal and sublethal effects on aquatic organisms.

The physical and chemical compositions of sediments are also interrelated, with strong associations between grain sizes and elemental concentrations. For example, once introduced into an environment many potentially toxic metals sorb onto fine-grained sediments (e.g., clay). For this reason, higher concentrations of metals tend to be found in depositional areas, including the deepest area of lakes and areas of slow-moving water and back-eddies in streams. The physical and chemical compositions of sediments are important determinants of the abundance and diversity of the benthic invertebrate community. Changes in sediment size or chemistry can have significant effects on benthic communities, with subsequent consequences for trophic dynamics and biodiversity.

14.5.2.5 Habitat Loss

Loss of habitat for aquatic resources will occur in certain areas due to Project development. In the off-site Project infrastructure areas, the primary loss of aquatic habitat will be due to the construction of off-site project infrastructure including the Brucejack Access Road, Brucejack Transmission Line, Bowser Aerodrome, and the Knipple Transfer Area. Direct mortality and the loss of habitat are the primary effects to aquatic organisms. Indirect effects can include the loss of significant reproductive or feeding habitat and changes to nutrient and organic material cycling.

14.5.3 Mitigation Measures for Aquatic Resources

The Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3), Soil Environment Management Plan (Section 29.13), and ML/ARD Management Plan (Section 29.10) detail a range of mitigation measures and monitoring schedules to reduce and eliminate Project effects, as well as to detect potential residual effects of the Project on primary and secondary producers. Monitoring programs will include triggers for risk assessment of potential effects that will allow detection of measureable alterations in productive capacity, allow for identification of potential causes, and include the provision of additional mitigation or adaptive management strategies. A summary of these mitigation and management measures for potential Project-related effects on aquatic resources, identified in Sections 14.5.1 and 14.5.2, are presented in the following sections. The mitigation and management measures are presented for each of the potential effect categories described in Section 14.4.3.1.

Successful implementation of management and monitoring plans will require adaptation to updates in Project design as well as site conditions. Adaptive management is a process for continually improving management practices by learning from the outcomes of operational approaches. Adaptive management applies prompt responses to field observations of changing environmental conditions and limitations or deficiencies in existing water treatment and management structures. Management and mitigation of potential surface water quality effects is therefore a cyclical ongoing process of monitoring, maintenance, and reassessment. Adaptive management procedures and Best Management Practices (BMPs) related to surface water quality, including surface water hydrology, aquatic resources, and fish and fish habitat, are also described in corresponding management plans detailed in Chapter 29, Environmental Management and Monitoring Plans.

14.5.3.1 Erosion and Sedimentation

Erosion and sediment control BMPs will be implemented to minimize the potential for surface runoff, erosion and sedimentation and are outlined in detail within the Water Management Plan (Section 29.19), Soil Management Plan (Section 29.13), and Aquatic Effects Monitoring Plan (Section 29.3). These include isolation of work areas from surface waters and proper use of structural practices such as sediment traps, geotextile cloth, sediment fences, gravel berms, and straw bales to mitigate and control erosion and sediment. Water management and erosion and sediment control measures will be implemented beginning at the start of the Construction phase.

Further, as outlined in the Surface Water Hydrology Predictive Study (Chapter 10), baseline data on surface water quantity and soils and terrain will be used along with visual surveys of construction activities to identify potential sites that require focused attention for water management for erosion and sedimentation effects. Routine surveillance and monitoring, combined with the available baseline information, will help identify vulnerable sites, such as potential ditch failures or culvert blockages, and risks in these areas will be addressed by site-specific contingency plans (Chapter 10).

Specific mitigation and management measures for erosion and sedimentation control include:

- minimizing the extent of ground cover disturbance during the construction of infrastructure, including the transmission line site preparation and tower installation, as well as upgrades to the exploration access road for use during Construction, Operation, and Closure;
- establishing perimeter water diversion and sediment collection as a first step to work activities. In addition to perimeter diversion ditches, small-scale runoff collection and treatment measures may be used locally (e.g., temporary sediment fences around the perimeter of stockpiles, sediment pools at culvert inlets);
- Ensuring clearing activities are coordinated with other management plans including, but not limited to, the Wetlands Monitoring Plan (Section 29.20), the Air Quality Management Plan (Section 29.2), the Soil Management Plan (Section 29.13), the Aquatic Effects Monitoring Plan (Section 29.3), the Wildlife Management and Monitoring Plan (Section 29.21), and the Water Management Plan (Section 29.19);
- regular inspection and maintenance of all water management and sediment control structures. Maintenance procedures will include prompt attention to potential erosion sites, ditch or culvert failure, ditch or culvert blockage, or outside seepage, because such problems could lead to structural failure and sediment transport. Maintenance will also include routine removal of accumulated sediment from ditches and retention structures. The sediment removed will be used as fill or placed in spoil areas for potential reclamation (Chapter 30, Closure and Reclamation); and
- re-establishing vegetation cover during site restoration and reclamation, as detailed in Chapter 16 (Assessment of Potential Terrestrial Ecology Effects) and Chapter 30 (Closure and Reclamation).

As identified in Sections 14.5.1.1 and 14.5.2.1, the expansion, use, and maintenance of the Brucejack access road could be a potential source of erosion and sedimentation into the aquatic environment. The existing 73 km exploration access road crosses steep slopes and areas of erodible soils. Road upgrades have the potential to cause erosion and sedimentation due to soil disturbing activities. Roads will be constructed according to the *Forest Road Engineering Guidebook* and maintained to ensure low landslide risk and continuous, efficient, controlled water drainage (BC MOF 2002). Additional erosion and sediment control BMPs that may be implemented during road upgrades include:

- cross-drain culverts that will not discharge directly into streams. Unless they are in use as part of a stream crossing, culverts should discharge onto rock or another stable energy dissipater and then diffuse flow should be directed away from site;
- catch basins excavated around the inlet of culverts to trap the coarse material that is transported in drainage ditches; and
- following ground cover disturbance, re-vegetate exposed slopes as soon as feasibly possible, within the growing season. Temporary cover may be used if re-vegetation is not imminently possible.

The access road will be decommissioned upon site closure. A deactivation plan will be prepared and submitted to the authorities for approval prior to the start of deactivation activities. The culverts will be removed and natural drainage will be restored. Cross ditches, water bars and drains will be constructed where necessary. The road surface will be ripped to increase water infiltration, reduce the potential for surface runoff, and to prepare for re-vegetation. Soils will be spread on the surface where soil is available to further establish surface cover.

The proposed transmission line alignment follows bedrock-dominated terrain. Stream crossing are not planned as construction will generally use helicopters. Should there prove to be the need for the construction and maintenance of stream crossings along the transmission line alignment, they will be consistent with Fisheries and Oceans Canada's *Pacific Region Operational Statement for Overhead Line Construction* (DFO 2007d) and *Operational Statement for Maintenance of Riparian Vegetation in Existing Rights-of-Way* (DFO 2007c). Watercourse crossings will also be assessed against the Minor Works and Water Order, under the *Navigation Protection Act* (1985c).

As identified in Section 14.5.1.1, increases in suspended material from the outflow of Brucejack Lake due to tailings and waste rock deposition during the life of the Project have potential to affect aquatic resources in downstream receiving waters. The tailings deposition system has been developed to minimize the concentration of fine suspended solids in the outflow of Brucejack Lake to Brucejack Creek as to comply with discharge standards outlined in the MMER (Maximum TSS of 15 mg/L) (TetraTech 2013). The solids concentration of the tailings will be adjusted using thickeners and dilution to meet the performance requirements of the paste backfill plan and the tailings discharge system. The tailings discharge pipeline will extend along the lakebed to the point of maximum depth (85 m) on the east side of the lake (TetraTech 2013). A deposit of solids will be intentionally allowed to form over the end of the tailings outfall. Discharged, tailings will accumulate over the discharge outfall through the operation of the tailings deposition system, which will further cover the outfall and act as a filter to intercept and immobilize fine tailings particles in a manner similar to a sand filter. Furthermore, the deposition of tailings at the east end of Brucejack Lake will maximize the depth of deposition as well as the distance from the lake outlet, further minimizing the potential for suspended solids discharge to the downstream receiving environment.

Waste rock will be deposited subaqueously in the southwest corner of Brucejack Lake during the Construction phase and to a lesser degree during the Project's Operation phase. After the Construction phase most waste rock will be deposited underground once voids are available for backfilling (TetraTech 2013). To minimize potential for increased suspended sediments due to waste rock deposition and from tailings, turbidity curtains will be deployed at the outlet of Brucejack Lake and around the perimeter of the waste rock disposal area.

The mitigation and management measures, combined with the small extent and short duration of surface disturbances by Project activities, are predicted to control and mitigate potential erosion and sedimentation effects in the off-site Project infrastructure areas. With adherence of BMPs and routine monitoring, any runoff of sediment is expected to be undetectable against the natural sediment loads (Section 13.5.4.3, Chapter 13). The residual effect on aquatic resources is assessed in Section 14.6.2.1.

The potential for residual effects on aquatic resources from suspended material is predicted to exist within the mine site area because of the deposition of tailings and waste rock in Brucejack Lake and subsequent flow to Brucejack Creek, and because of the transportation of sediment material associated with the disturbance of surface cover. Therefore, this residual effect on aquatic resources is assessed in Section 14.6.1.1.

14.5.3.2 Changes in Surface Water Quantity

Management and mitigation measures for changes in surface water quantity are outlined in detail within the Water Management Plan (Section 29.19), including the integration of water management activities with other management and monitoring programs. Throughout the life of the Project, the use of freshwater will be minimized as water requirements for the process plant, including fresh water, will be met with treated underground seepage water and reclaim water from Brucejack Lake. Environmental protection measures in the Operation phase will focus primarily on monitoring and maintenance of established water management structures and facilities. If necessary repairs and/or improvements to these systems are identified, these will be undertaken on a timely basis. Key water management systems for the Operation phase include diversion and collection ditches, road drainage features (e.g., roadside ditches, cross-drain culverts, stream crossings), the WTP and a lined contact water pond. The major water usage requirements will be the process plant and the camp.

The mitigation and management measures are expected to completely mitigate potential effects from changes in surface water quantity in the off-site Project infrastructure areas because of the relatively small surface areas affected by Project activities. As a result, no residual effects from changes in surface water quantity in the off-site Project infrastructure areas are predicted and will not be discussed further.

The potential for residual effects on aquatic resources from changes in surface water quantity is predicted to exist within the mine site area because of the discharges from the WTP and STP, the management of underground water, and the modifications to existing surface flows. Therefore, this residual effect on aquatic resources is assessed in Section 14.6.1.2.

14.5.3.3 Changes in Surface Water Quality

Metal Leaching/Acid Rock Drainage

The ML/ARD Management Plan (Section 29.10) details the actions to avoid, control, and mitigate ML/ARD effects on surface water quality in the Construction, Operation, Closure, and Post-closure phase of the Project. ML/ARD will be monitored, mitigated, and adaptively managed to avoid adverse effects on surface water quality. All potentially acid-generating (PAG) geological materials will be used as backfill in underground workings or disposed subaqueously in Brucejack Lake (see Section 13.5.4 in Chapter 13, Assessment of Potential Surface Water Quality Effects). Material used for construction will be sampled and analyzed at an on-site lab to ensure that only non-potentially acid-generating (NPAG) material is used where drainage may reach the receiving environment; PAG will be appropriately stored for eventual disposal. ML/ARD mitigation associated with the access road will also include the use of non-PAG material (quarry, overburden) to cover road sections of exposed PAG material (shale) and compact heavily to limit water infiltration. Mitigation and management measures for ML/ARD will include the re-establishment of vegetation cover during site restoration and reclamation, as detailed in Chapter 16, Assessment of Potential Terrestrial Ecology Effects, and Chapter 30, Closure and Reclamation. Further details on the mitigation and management of ML/ARD are described in Sections 13.5.2.2 and 13.5.4.2.

Potential effects from ML/ARD are predicted to exist after the application of the mitigation and management measures, based on the predictive water quality modelling (Section 13.6.1) and professional judgment (Section 13.6.4). The potential residual effects on aquatic resources from ML/ARD are assessed for the mine site area in Section 14.6.1.3 and for the off-site Project infrastructure areas in Section 14.6.2.2.

Nutrient Loading

Project activities involving nitrogen-based explosives, the directed discharge of effluent as well as groundwater interactions and seepage from camp septic fields could result in loading of nitrogenous and phosphorus compounds into the aquatic environment.

Project activities requiring the use of explosives in or near water bodies will adhere to the *Guidelines for Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky 1998) to mitigate effects of blasting on surface water quality, and, by extension, on aquatic resources. Leaching of blasting residues will be mitigated by minimizing use during the Construction phase and using the minimal quantity of explosives necessary for the desired task throughout the Construction and Operation phases.

Explosives transportation, storage, and use will be consistent with the requirements of the federal *Explosives Act* (1985a), *Transportation of Dangerous Goods Act* (1992), and the provincial *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008). The Hazardous Materials Management Plan (Section 29.7), to be developed prior to Construction, will guide the safe transportation, storage, use, and disposal of explosives at the site throughout the life of the Project. The Spill Prevention and Emergency Response Plan (Section 29.14) will implement documented operational procedures to avoid spills during explosives handling that will minimize nitrogen loadings. Further, within the mine site area, effects of leaching of blasting residues and effluent discharges will be mitigated through water treatment during the Construction, Operation, and Closure phases. Effects to water quality and aquatic resources from nutrients will be monitored and adaptively managed as outlined in the Aquatic Effects Monitoring Plan (Section 29.3).

To minimize the effects on aquatic resources relating to nutrient loading from sewage effluent, several mitigation measures relating to sewage effluent will be required. The mine site will have a STP, with subsequent disposal of the effluent in a manner that is acceptable to regulatory agencies. Effluent quality standards of the Municipal Wastewater Regulation (BC Reg. 87/2012) or the Sewerage System Regulation (BC Reg. 326/2004) will be met, and monitoring programs will be implemented as required by the applicable regulation and permit conditions. BMPs will be followed during the construction, operation, maintenance, and closure of the STP to ensure the protection of aquatic environments.

The Knipple Transfer Area and the Tide Staging Area facilities will use septic ground disposal systems that meet the requirements for setback from waterbodies to prevent any effects to surface waters. Sewage effluent from the Brucejack Mine Site STP will receive secondary treatment prior to discharge to Brucejack Lake.

The mitigation and management measures are expected to control and mitigate potential effects from changes in nutrient loading in the off-site Project infrastructure areas because of the adherence of the blasting and sewage activities to the applicable guidelines and regulations. The residual effect on aquatic resources from nutrient loading in the off-site infrastructure areas is assessed in Section 14.6.2.2.

The potential for residual effects on aquatic resources from changes in nutrient loading is predicted to exist within the mine site area because of the discharges of the WTP and STP, and the management of underground water. Therefore, this residual effect on aquatic resources is assessed in Section 14.6.1.3.

Atmospheric Deposition

The goal of mitigating emissions and dustfall effects on aquatic receiving environments begins with avoiding the emission sources followed by controlling the sources. Mitigation measures have already been incorporated into the Project during the design stage. The specific mitigation measures are discussed in the following sections and more detail can be found in the Air Quality Management Plan (Section 29.2).

Dust will be controlled by using water sprays as required. Wet suppression will increase the moisture content that conglomerates particles and reduces the likelihood of becoming re-suspended when vehicles pass over the surface. Chemical stabilization or chemical suppressants are more effective than watering, but also introduce other environmental issues by introducing chemicals into the soil and eventually the freshwater environment by runoff. Use of alternative dust suppressants will consider potential environmental effects, including attracting wildlife and degrading fish habitat, and will follow established guidelines and BMPs. If required, various contingency mitigation measures can be further applied to reduce unpaved road dust such as changing the road surface material or applying surface treatments.

Within the mine site area, blasting and part of the material handling and ore processing will occur underground, limiting the effect on ambient air quality. Due to the large particle sizes, fugitive dust sources do not typically travel upward toward the air raises to be eventually transported to the ambient air. Primary crushing of ore will also take place underground to control fugitive dust emissions to the environment. The crushed ore will be transported to the mill through the conveyor decline where ore will be further processed. To reduce fugitive dust emissions dust pickup points will capture dust and pipe it to baghouses that will be installed both underground and in the process building.

The application of these mitigation and management measures are expected to control and mitigate potential effects on aquatic resources from atmospheric deposition in the mine site area and the off-site Project infrastructure areas. As a result, no residual effects from atmospheric deposition are anticipated and will not be discussed further.

14.5.3.4 Changes in Sediment Quality

Mitigation of sediment quality effects on aquatic resources will be as described for surface water quality (Section 14.5.3.3) and sedimentation and erosion (Section 14.5.3.1). The mitigation and management measures for sediment and erosion will minimize the inputs of material in runoff, and thus minimize potential changes in sediment quality from the deposition of material and the transport of adsorbed metals and compounds. The mitigation and management measures for water quality (Section 14.5.3.3) have direct application for changes in sediment quality because of the interactions and known processes of transfer of suspended material, metals, and compounds between the water and sediment phases.

The mitigation and management measures are expected to control and mitigate potential effects from changes in sediment quality in the off-site Project infrastructure areas from changes in surface water quality (Section 14.5.3.3). As a result, no residual effects on sediment quality are anticipated for the off-site Project infrastructure areas, and will not be discussed further in this assessment.

The potential for residual effects on aquatic resources from changes in sediment quality is predicted to exist within the mine site area because of the potential for effects from erosion and sedimentation and the predicted changes in surface water quality. Therefore, this residual effect on aquatic resources is assessed in Section 14.6.1.4.

14.5.3.5 Habitat Loss

As part of the design for the Project, consideration has been given in the selection of access road and transmission line routes that avoid or minimize the number and potential effects on stream crossings (including those of fish-bearing watercourses, discussed in Chapter 15, Assessment of Potential Fish and Fish Habitat Effects). These efforts may or have included:

- selecting alignments that, where practical, minimize the number of watercourse crossings required;
- avoiding parallel road and transmission line alignment directly adjacent to watercourses where practical;
- selecting structure placements and designs that minimize loss or disturbance to riparian vegetation (e.g., higher structures allow for wider span lengths);

- avoiding, when possible, development of structures or access roads on meander bends, braided streams, alluvial fans, active floodplains, unstable slopes, or any other areas that are inherently unstable and may result in erosion and scouring of the stream bed;
- wherever feasible, towers will have sufficient setback from watercourses to avoid adverse effects on riparian areas; and
- during transmission line construction, clearing with no removal (trees bucked and left in place along the corridor) where permissible. In riparian areas tree cutting will be limited to topping of taller trees that may interfere with the conductors, with other vegetation being left in place.

Within fish-bearing waters of the off-site Project infrastructure areas, aquatic habitat loss will be mitigated and managed following DFO's operational statements for bridges and culverts (DFO 2007b, 2007a) and DFO's *Land Development Guidelines for the Protection of Aquatic Habitat* (1992). To protect aquatic habitat near Project infrastructure, such as the Bowser Aerodrome and Knipple Transfer Area, appropriate riparian zones will be applied according to the *Forest and Range Practices Act* (2002b). Riparian reserve zones will be applied to fish-bearing streams near the Bowser Aerodrome and Knipple Transfer Area to protect instream and riparian habitat. Construction activities (i.e., equipment access, construction of transmission structures, conductor stringing, and access road expansion) will be conducted in a manner that minimizes riparian vegetation effects and maintains fish habitat and stream bank integrity.

The largest aquatic habitat loss is expected in Brucejack Lake. Mitigation of the potential effects from the deposition of tailings and waste rock in Brucejack Lake include minimizing the quantity of waste rock and tailings deposited in the lake by diverting to underground disposal as soon as feasible. In addition, the tailings disposal will be targeted for the deepest region of the lake and will be intended to be deposited from the bottom towards the surface (see Chapter 5, Project Description, for details). As a result, the aquatic habitat lost due to the tailings deposition will be restricted to the deep layers of Brucejack Lake, rather than the more productive shallow littoral areas.

The mitigation and management measures are expected to completely mitigate potential effects from habitat loss in the off-site Project infrastructure areas. As a result, no residual effects from habitat loss in the off-site Project infrastructure areas are predicted and will not be discussed further.

The potential for residual effects on aquatic resources from habitat loss is predicted to exist within the mine site area because of the deposition of tailings and waste rock into Brucejack Lake. Therefore, this residual effect on aquatic resources is assessed in Section 14.6.1.5.

14.6 RESIDUAL EFFECTS ON AQUATIC RESOURCES

Effects on aquatic resources due to atmospheric deposition are considered to be controlled and mitigated to an acceptable level given the proposed management strategies summarized above and presented in detail within the following management plans in Chapter 29, Environmental Management and Monitoring Plans:

- Air Quality Management Plan (Section 29.2);
- Aquatic Effects Monitoring Plan (Section 29.3);
- Metal Leaching/Acid Rock Drainage Management Plan (Section 29.10);
- Soil Management Plan (Section 29.13);
- Spill Prevention and Response Plan (Section 29.14);
- Tailings Management Plan (Section 29.15);
- Waste Rock Management Plan (Section 29.18);

- Water Management Plan (Section 29.19); and
- Closure and Reclamation (Chapter 30).

The potential and likelihood for residual effects varies with Project area (i.e., the mine site area or off-site Project infrastructure areas). In the off-site Project infrastructure areas, residual effects on aquatic resources may occur due to changes in water quality from ML/ARD. Despite management and mitigation, residual effects on aquatic resources in the mine site area may occur due to the following effects categories:

- erosion and sedimentation;
- changes in surface water quantity;
- changes in surface water quality from nutrient loading and ML/ARD;
- changes in sediment quality; and
- habitat loss.

The assessment of residual effects after mitigation applies to the quantitative and qualitative information to establish the significance of Project effects on aquatic resources. The aquatic resources assessment draws on the assessment of Project effects on other VCs, including:

- air quality (via dust deposition; Chapter 7);
- hydrogeology (ground water quality and quantity; Chapter 9);
- hydrology (surface water quantity; Chapter 10); and
- surface water quality (Chapter 13).

The surface water quality assessment is particularly important because surface water quality describes the environment in which aquatic organisms live, and the majority of Project effects on aquatic resource will be mediated by changes in water quality. The surface water quality effects assessment applies BC water quality guidelines and science-based environmental benchmarks (SBEBs) that are specifically intended for the protection of aquatic organisms like primary producers and secondary producers (Section 13.6.1.2, Sensitivity Analyses: Water Quality Modelling Cases). The assessment of residual effects combines quantitative predictive modelling, when available, with the site-specific information available from the baseline sampling program, scientific studies, and professional judgment.

14.6.1 Residual Effects in the Mine Site Area

14.6.1.1 Erosion and Sedimentation

Residual effects on aquatic resources may occur due to erosion and sedimentation resulting from Project activities during the Construction, Operation, and Closure phases. Primarily, residual effects from erosion and sediment will occur during the Construction and Closure phases as a result of the disturbance of ground cover leading to increasing runoff of sediment, and during the Operation and Closure phases due to the discharge of suspended material from Brucejack Lake from tailings and waste rock deposition. Mitigation and management measures are predicted to be effective, including the construction of water and erosion management structures, routine monitoring of runoff for excess sediment, turbidity curtains for in-water works and waste rock deposition. It is possible, however, that suspended sediment concentrations could be greater than BC water quality guidelines for the protection of aquatic life on occasion (see Section 13.6.1, Predictive Water Quality Modelling).

The Project-related increases in the concentration of suspended material due to erosion of disturbed surfaces are expected to be restricted to the periods when the water and erosion management infrastructure is under construction or being decommissioned. Also, the increases in sediment concentrations will be restricted to periods of significant overland flow, which will occur during freshet and sporadic rainfall events. As a result, the increases in sediment concentrations, which may be greater than baseline values and water quality guidelines, will likely be transient and sporadic.

The residual effects on aquatic resources from suspended material discharged from Brucejack Lake are predicted to be minor. Predictive modelling of suspended sediment concentrations in Brucejack Lake during the Operation and Closure phases indicate the suspended sediments from tailings will increase lake discharge concentrations by less than 1 mg/L (Section 13.6.2), which is less than the analytical detection limits of suspended sediment assays and less than natural variation (Section 13.3.4). The contribution of suspended sediments from waste rock deposition into Brucejack Lake may be greater than the contribution from tailings, but will be further mitigated by turbidity curtains and other mitigation measures (Section 13.6.2). Waste rock deposition will also happen intermittently and the frequency of deposition will decrease throughout the Project as underground disposal becomes available.

The residual effects from erosion and sedimentation in the mine site area are predicted to be restricted to Brucejack Creek. Any material transported by Brucejack Creek will be combined with the sediments entrained under the Sulphurets Glacier, and the baseline sampling program indicates that Brucejack Creek is a negligible contributor to the overall sediment loading (Section 13.3.4). Any contribution of sediments from Project activities will be negligible in comparison to the natural sources of sediments from the Sulphurets Glacier and downstream.

14.6.1.2 Changes in Surface Water Quantity

Predictive study results for surface water hydrology (Chapter 10) assessed the effects of Project activities within the Brucejack watershed (downstream of Brucejack Lake, Brucejack Creek) and the far-field downstream receiving environment assessment locations (within the RSA), Sulphurets Lake (SL-H1), Sulphurets Creek (SC-H1), and Unuk River at the international border (UR2). Results indicate that activities within the Brucejack watershed (mine site area), Project activities are not predicted to reduce mean annual flows in Brucejack Creek beyond the range of data and modelling uncertainty (BJL-H1 in Chapter 10, BJ-2 in Chapter 13). The predicted increases in annual flows are generally less than 11% in the modelled scenarios, with the exception of the high underground hydraulic connectivity scenario, which predicted increases of up to 20% during the Construction phase and up to 25% during the Operation phase. The hydrology modelling also considered changes to stream flows during the low flow periods in winter. During the Construction and Operation phases, low flows were predicted to increase by up to 54%, although even with these increases, the predicted flows are up to 20× lower than predicted flows during August or September. In contrast, March low flows were predicted to decrease by up to 24% in the Closure phase and could potential affect aquatic resources due to the loss of aquatic habitat.

These predicted changes in surface water quantity would be confined to Brucejack Creek. The low flow reductions at the downstream receiving environment assessment points (i.e., Sulphurets Lake, less than 3%; Chapter 10) are within the reasonable range of data and modelling uncertainty. Further downstream in the Unuk River, the reductions in surface water quantity were estimated to be 0.2%, which is less than the data and modelling uncertainty range (Chapter 10). The duration of these low flow reductions is limited to the Closure phase (i.e., two years).

14.6.1.3 Changes in Surface Water Quality

Potential for residual effects on aquatic resources due to changes in surface water quality were assessed using quantitative water quality modelling (Section 13.6.3) and qualitative methods that combine available data with scientific literature and professional judgment. Water quality modelling was conducted to predict the total concentrations of the various metals, nutrients, and anions of Brucejack Lake and of the downstream receiving environment; therefore, any compounds that were identified by the model as having concentrations greater than guideline limits downstream of the mine site area into upper Brucejack Creek and further downstream receiving waters will be considered as having residual effects. In ecological risk assessment, the calculation of a hazard quotient (HQ) can be a useful screening tool for determining the potential for a chemical to cause toxicity in receptors (e.g., aquatic organisms) in the receiving environment. An HQ is most often calculated as a ratio of the concentration of a chemical (either a measured or predicted concentration) compared to the relevant guideline value. An HQ of greater than 1.0 can indicate that there may be a potential for effects in receptors, while an HQ of less than 1.0 is considered to not carry additional risk of toxicity to receptors. For naturally elevated metals, hazard quotients are calculated relative to baseline concentrations, if baseline concentrations were naturally greater than guidelines.

The screening process for contaminants of potential concern (COPC), outlined in Section 13.6.1.2, identifies and screens the results of the quantitative predictive water quality model for the specific compounds and elements with potential effects on aquatic organisms using hazard quotients. The effects assessment for aquatic resources considers the predictions from the water quality model at BJ 200m D/S are representative of the conditions in the Brucejack Creek receiving environment and are applicable to the conditions in Brucejack Lake. For clarity, the discussion will focus on Brucejack Creek.

Metal Leaching/Acid Rock Drainage

The predictive water quality model for the Brucejack Creek receiving environment indicates that concentrations of some metals may be greater than BC water quality guidelines or SBEBs for the protection of aquatic life (Table 14.6-1; see Section 13.6.1.2, Sensitivity Analyses: Water Quality Modelling Cases, for details). The screening identifies the following three metal elements that are predicted to have receiving environment concentrations greater than the applicable BC water quality guidelines or SBEBs for the protection of aquatic life: arsenic, chromium, and zinc.

Table 14.6-1. Summary of Metal Concentrations Greater than Thresholds for the Protection of Aquatic Life in Brucejack Creek from the Predictive Water Quality Modelling

Metal	Project Phase	Season	Baseline Concentration (mean, mg/L)	Guideline Threshold (mg/L)	Predicted Concentration[a] (mean, mg/L)
Aluminum	Construction	High Flow	0.352	0.05[b]	0.059
	Operation	Low Flow	0.071		0.056
		High Flow	0.352		0.077
	Closure	Low Flow	0.071		0.067
		High Flow	0.352		0.081
	Post-closure	Low Flow	0.071		0.074
		High Flow	0.352		0.09
Arsenic	Construction	Low Flow	0.0022	0.005[b]	0.0063
		High Flow	0.0018		0.0051
	Operation	Low Flow	0.0022		0.0068
		High Flow	0.0018		0.0062
	Closure	Low Flow	0.0022		0.0059
		High Flow	0.0018		0.0048
	Post-closure	Low Flow	0.0022		0.0054
		High Flow	0.0018		0.0040
Chromium	Operation	Low Flow	0.00009	0.001[b]	0.0011
Zinc	Operation	Low Flow	0.0034	0.0185[c]	0.0206

[a] *Predicted values from conservative model simulating high underground water flows (High K; see Section 13.6.1, Predictive Water Quality Modelling, for details).*
[b] *BC water quality guideline (criteria) for the protection of aquatic life (BC MOE 2001).*
[c] *Science-based environmental benchmark (see Section 13.6.1, Predictive Water Quality Modelling, for details).*

The predicted concentrations of arsenic are near or greater than the BC water quality guidelines for the protection of aquatic life across all phases of the Project (Table 14.6-1; see Section 13.6.2 for details). However, the greatest predicted concentration (0.0068 mg/L, for maximum concentrations in the Operation phase at site BJ 200m D/S in Brucejack Creek) is substantially less than the safety factor (10×) implemented for the arsenic guideline for the protection of aquatic life (CCME 2001). The maximum predicted arsenic concentrations, therefore, are more than five-fold less than the lowest observed concentration with a significant biological effect. Therefore, biological effects of primary and secondary producers are possible, but the magnitude of the effects is likely to be small and sublethal. The smallest biological effect used in the derivation of the CCME water quality guideline for arsenic was a significant reduction in growth rate over 14 days in a freshwater alga (*Scenedesmus obliqus*) exposed to 50 µg/L of arsenate (As-V; Vocke et al. 1980; CCME 2001). Other observations of significant effects to primary and secondary producers occurred at higher arsenic concentrations (CCME 2001). Based on this observation, the only anticipated effect to aquatic resources due to the modest predicted increase in arsenic concentrations is, conservatively, a minor reduction in growth and productivity.

The predicted concentrations of chromium are near or greater than the BC water quality guidelines during low flow periods in the Operation phase of the Project. The low flow period, which occurs in winter, would be a period of lowest biological activity, which may help mitigate some of the effects of increased chromium or zinc concentrations but it is possible some biological effects will occur. The predicted concentration of total chromium is 10% greater than the guideline for hexavalent chromium, but it is probable that only 10% to 60% of the total chromium will be in the hexavalent form (Pawlisz et al. 1997; CCME 1999). The trivalent form is substantially less toxic to aquatic organisms than the hexavalent form. Therefore, it is probable that the concentration of hexavalent chromium will be less than the 0.001 mg/L guideline threshold. As a result, minor to negligible effects on aquatic organisms are predicted from Project-related chromium loading in the Brucejack Creek receiving environment.

In the conservative high-underground-flow case of the predictive models, zinc concentrations are predicted to be greater than the science-based environmental benchmark during low-flow periods during the Operation phase of the Project (Table 14.6-1; Section 13.6.2, Residual Effects on Water Quality: Mine Site Area and Receiving Environment). Sublethal or lethal effects to aquatic organisms may occur during periods of low flow as a result of this predicted increase in zinc concentrations. Low temperatures are often associated with decreased rates of metal uptake or decreased sensitivity to metal toxicity, which may mitigate some of the effects from the increased concentrations of zinc (McLusky and Hagerman 1987; Bervoets, Blust, and Verheyen 1996; Heugens 2003). To be conservative, some effects from increased zinc concentrations on aquatic organisms could occur during low flow periods in the Operation phase. The most probable effects will be decreased growth and survival rates, which in turn may reduce productivity. However, the magnitude of these predicted effects will be mitigated by the low temperatures and the naturally low growth rates that occur during the winter. Furthermore, the decrease in zinc concentrations during the high flow season, which coincides with the productive growth season in summer, will likely reduce any inhibitory effects and permit the natural growth and productivity of aquatic organisms.

<u>Nutrient Loading</u>

Potential residual effects on aquatic resources from introducing nitrogenous and phosphorus compounds into the aquatic environment are toxicity (for inorganic nitrogen compounds), increasing primary production and biomass, and alterations to the community composition of primary producers and secondary producers (as discussed in Section 14.4.3.1).

In the mine site area, the water quality model predicts that all forms of nitrogenous compounds (ammonia, nitrate, and nitrite) will be below BC water quality guidelines or SBEBs at all downstream sites during all the years modelled (Table 14.6-2; Section 13.6.2). Therefore, no sublethal or lethal effects from nitrogenous compounds on aquatic organisms are predicted for the immediate receiving environment in Brucejack Creek, or further downstream in the Sulphurets and Unuk watersheds.

Table 14.6-2. Summary of Predicted Nutrient Concentrations in Brucejack Creek

Nutrient	Project Phase	Season	Baseline Concentration (mean, mg/L)	Guideline Threshold (mg/L)	Predicted Concentration[a] (mean, mg/L)
Ammonia	Construction	Low Flow	0.099	1.86[b]	0.6
		High Flow	0.009		0.37
	Operation	Low Flow	0.099		0.39
		High Flow	0.009		0.39
	Closure	Low Flow	0.099		0.17
		High Flow	0.009		0.2
	Post-closure	Low Flow	0.099		0.07
		High Flow	0.009		0.14
Nitrite	Construction	Low Flow	0.0005	0.18[c]	0.0070
		High Flow	0.0005		0.0047
	Operation	Low Flow	0.0005		0.0090
		High Flow	0.0005		0.0083
	Closure	Low Flow	0.0005		0.0061
		High Flow	0.0005		0.0052
	Post-closure	Low Flow	0.0005		0.0029
		High Flow	0.0005		0.0029
Nitrate	Construction	Low Flow	0.012	3[b]	2.87
		High Flow	0.005		1.69
	Operation	Low Flow	0.012		0.51
		High Flow	0.005		0.45
	Closure	Low Flow	0.012		0.15
		High Flow	0.005		0.14
	Post-closure	Low Flow	0.012		0.11
		High Flow	0.005		0.11
Total Phosphorus	Construction	Low Flow	0.006	0.020[d]	0.001
		High Flow	0.016		0.014
	Operation	Low Flow	0.006		0.010
		High Flow	0.016		0.016
	Closure	Low Flow	0.006		0.008
		High Flow	0.016		0.016
	Post-closure	Low Flow	0.006		0.007
		High Flow	0.016		0.015

[a] Predicted values from conservative model simulating high underground water flows (High K; see Section 13.6.1, Predictive Water Quality Modelling, for details).
[b] Approved and working BC water quality guidelines (BC MOE 2001).
[c] Science-based environmental benchmark (see Section 13.6.1, Predictive Water Quality Modelling, for details).
[d] Total phosphorus threshold based on the mesotrophic trigger range for total phosphorus (0.010 to 0.020 mg/L) determined by the baseline concentrations during the open water season (high flow; Environment Canada [2004]).

The other residual effects from nutrient loading involve the stimulation of primary production, with subsequent increases in primary producer biomass, alterations in community structure, and changes to trophic dynamics and secondary producer communities (Section 14.4.3.1). Both nitrogen and phosphorus are required nutrients for the growth and productivity of primary producers, and Project activities have the potential for increasing the loading of both elements into the freshwater environment. The predictive water quality modelling combines natural and Project-related source terms to predict the concentration of phosphorus and the most significant nitrogenous compounds (Section 13.6.3; Table 14.6-2).

Phosphorus is an important element for the growth and productivity of aquatic organisms. The assessment of the potential effects from phosphorus on the aquatic resources in Brucejack Creek follows the framework for phosphorus management published by Environment Canada (2004) and is supported by information from the baseline sampling program. The goal of phosphorus management programs is to prevent or minimize the accumulation of primary producer biomass and related secondary effects. The phosphorus guidance framework consists of using reference or baseline phosphorus concentrations to describe the current or unaffected status of the ecosystem in terms of trigger ranges of total phosphorus. These trigger ranges are associated with categories of natural ecosystem function that are termed trophic levels—these trophic levels range from low-biomass, low-productivity oligotrophic ecosystems to rich, high-biomass eutrophic ecosystems. Once the current or baseline trigger range is established, the predicted concentration of phosphorus is assessed against the maximum acceptable concentration within the baseline trigger range. If the upper limit of the baseline trigger range is predicted to be surpassed, then there is a potential risk of effects on the aquatic ecosystem. The guidelines recommend that total phosphorus should not: 1) be greater than predefined "trigger ranges"; and 2) increase more than 50% over baseline reference levels (CCME 2004; Environment Canada 2004). In the context of the seasonality of the environment at Brucejack Creek, the most sensitive period for phosphorus is the period between June and September. No toxic effects are anticipated from phosphorus during the winter season and the application of the EC guidance framework is focused on the processes of primary productivity that occur during the open water, high flow season (Environment Canada 2004).

The baseline phosphorus data for Brucejack Creek shows total phosphorus concentrations to fall in the mesotrophic trigger range between 0.010 and 0.020 mg/L during the open-water, high-flow season (Table 14.6-2; Section 13.3.4, Characterization of Surface Water Quality Baseline Condition). Therefore, for the assessment of potential phosphorus effects, the threshold for potential phosphorus effects on primary production is considered to be 0.020 mg/L.

Primary producer biomass is controlled not only by the supply of phosphorus, but also by the interval between high flow conditions, by the supply of other nutrients like nitrogen, or grazing by herbivores (Feminella and Hawkins 1995; Biggs 2000; Stelzer and Lamberti 2001). The period between high flows during the Project, which can scour and displace primary producers, is predicted to remain similar to the natural flow regime and exert the same controlling effects on primary producer biomass (Chapter 10; Biggs 2000). The resident herbivore secondary producer community is not predicted to be affected by lethal or sublethal effects from nitrogenous compounds (see above). It is likely, therefore, that any grazing control of primary producer biomass exerted by the secondary producer community would continue to act to limit the accumulation of primary producer biomass.

Environmental effects of nitrogen and phosphorus are inter-related because both phosphorus and nitrogen are required nutrients for the growth of primary producers. The discharge from Brucejack Lake does contain nitrogen nutrients (e.g., nitrate, nitrite, and ammonia; Table 14.6-2; see Section 13.6.2, Residual Effects on Water Quality: Mine Site Area and Receiving Environment). Significant accumulation of primary producer biomass generally occurs at dissolved inorganic nitrogen (the sum of nitrate, nitrite, and ammonia) concentrations greater than 0.04 mg/L and total phosphorus concentrations greater than 0.03 mg/L (Dodds, Smith, and Lohman 2002). Although the predicted concentration of dissolved inorganic nitrogen is greater than this threshold, the predicted phosphorus concentration will remain within the mesotrophic trigger range. Therefore, nutrient concentrations are predicted to remain below these thresholds and no significant accumulation of primary producer biomass is expected.

It is possible that primary producer biomass levels may increase relative to baseline values in Brucejack Creek because of the additional loading of phosphorus and nitrogenous nutrients, but this increase will likely be mitigated by the following:

- phosphorus concentrations are predicted to remain within the baseline total phosphorus trigger range (mesotrophic);
- phosphorus concentrations are predicted to remain less than or equal to 50% of the baseline total phosphorus concentrations;
- the flow regime and the potential for scouring of primary producer biomass are predicted to follow baseline patterns; and
- grazing pressure from the secondary producer community is predicted to remain at levels similar to baseline conditions.

The increase in biomass is not predicted to be greater than the BC water quality criteria (10 µg/cm^2; BC MOE 2001) because baseline primary producer biomass was generally less than 2 µg chl *a*/cm^2 (Section 14.3.4.1) and the factors discussed above will likely mitigate increases in biomass to be substantially less than a 5-fold increase.

Changes in primary producer community structure are not expected. Substantial variation in the relative abundance of different periphyton groups was observed in the baseline program; diatoms and cyanobacteria are natural components of the primary producer community in Brucejack Creek. The expected increase in loading of nitrogenous compounds (Table 14.6-2) relative to phosphorus would be predicted to favour diatoms over cyanobacteria, but other factors including the interval between high flow events and grazing also exert significant controls over community structure (Feminella and Hawkins 1995; Biggs 2000). Furthermore, nutrient ratios are not necessarily the best predictors for changes in periphyton community structure (Francoeur et al. 1999; Stelzer and Lamberti 2001); rather specific data on the nutrients limiting growth are the best predictors of changes in community structure. Furthermore, these limiting-nutrient conditions shift with changes in the environment, including flow regime and temperature.

No mid- or far-field effects from nutrient loading are predicted. The increases in nutrients to Brucejack Creek will be substantially diluted once flows reach Sulphurets Creek (see Section 13.6.2.3, Sulphurets and Unuk Watershed). The heavy sediment loads from the Sulphurets Glacier, as discussed in the environmental settings in Section 14.3.4.2, cause significant light-limitation in Sulphurets Lake and downstream into Sulphurets Creek, which will further mitigate any potential nutrient-related primary producer growth. No acute or chronic toxicity from nitrogenous compounds are expected because concentrations will be less than the water quality guidelines for the protection of aquatic life (Section 13.6.2, Residual Effects on Water Quality: Mine Site Area and Receiving Environment; BC MOE 2014).

14.6.1.4 Residual Effects due to Changes in Sediment Quality

Discharges from the Mine Site WTP and from the outlet of Brucejack Creek have the potential to alter sediment quality, which may in turn affect aquatic organisms that live in, on, or near sedimentary materials. The predictive water quality model indicated that the concentrations of the following metals will increase in Brucejack Lake and downstream in Brucejack Creek during the Construction, Operation, Closure, and Post-closure phases of the Project: aluminum, arsenic, copper, iron, manganese, molybdenum, mercury, nickel, selenium, and zinc (Section 13.6.1, Predictive Water Quality Modelling). Many of these metals will adsorb to particles and may be transported to the sediments. In parallel, chemical processes in the sediments related to oxygen concentrations and reduction/oxidation reactions will solubilize and release metals from the sediments back into the water. The sediments in Brucejack Creek in the mine site area have naturally elevated concentrations of several metals (see Section 14.3.4.1) as a result of proximity to metal-bearing surficial deposits. Observations from Brucejack Creek have sediment concentrations greater than BC sediment quality guidelines for the protection of aquatic life for the following metals: arsenic, cadmium, copper, iron, lead, manganese, mercury, selenium, silver, and zinc. Based on the naturally elevated concentrations of metals in the sediment in the receiving environment, it is predicted that any increases due to the modest predicted increases in the water column metals would be within the natural variability of the environment.

Further downstream in the receiving environment, Sulphurets Lake and Sulphurets Creek sediment quality shows similar naturally elevated metal concentrations (Section 14.3.4.2). The natural sources of metals mobilized by Sulphurets Glacier and natural weathering processes in the Sulphurets catchment are expected to contribute metals to the freshwater environment and to the sediments. The relatively small increases in water metal concentrations predicted in the water quality model (Section 13.6.2, Residual Effects on Water Quality: Mine Site Area and Receiving Environment) are not predicted to result in substantial changes in sediment metal concentrations in the mid- and far-field receiving environment relative to the observed naturally elevated sediment metal concentrations (Section 14.3.4.2).

14.6.1.5 Residual Effects due to Habitat Loss

The deposition of waste rock and tailings into Brucejack Lake is predicted to result in the loss of habitat. The overall footprint of the tailings and waste rock at the end of the Operation phase will occupy the majority of the lake bottom (over 50%), with a new bottom depth of 48 m at the edges of the tailings deposition area and a depth of 38 m at the peak of the deposition cone (Figure 5.11-2, Chapter 5, Project Description). Although the material will be colonized by primary and secondary producers over time, the deposition will represent an immediate loss of the habitat.

No other habitat losses are predicted in the mine site area or in the downstream receiving environment.

14.6.1.6 Summary of Residual Effects in the Mine Site Area

Table 14.6-3 presents a summary of the residual effects assessed for aquatic resources in the mine site area.

14.6.2 Residual Effects in Off-site Project Infrastructure Areas

14.6.2.1 Residual effects due to Erosion and Sedimentation

Erosion and sedimentation associated with Project activities in the off-site infrastructure areas may still result in loading of the freshwater environment with suspended material after the implementation of mitigation measures and BMPs. However, periods of substantial sediment transport are naturally part of the ecosystem in Knipple Lake, Bowser River, Wildfire Creek, and associated watersheds (Chapter 13). The dynamic surface water flow regime in the region, which results in a large freshet flows, naturally deposits significant suspended material in the freshwater environment. In addition, glacial meltwater is frequently very high in suspended material, and this meltwater is responsible for the very high suspended sediment concentrations in Knipple Lake.

Any additional suspended material loading resulting from Project activities is anticipated to have minor, incremental effects against this background of natural erosion and sedimentation processes. With the application of BMPs and mitigation measures, the effects from Project-associated erosion and sedimentation will be indistinguishable from natural variation.

Table 14.6-3. Summary of Predicted Residual Effects on Aquatic Resources in the Mine Site Area

Sub-component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect[1]	Description of Mitigation Measure(s)	Description of Residual Effect
Effects from Erosion and Sedimentation	Construction, Operation, Closure	All Project components during Construction and site decommissioning phases; during Operation, main components are surface water diversions for contact and non-contact water, deposition of waste rock and tailings in Brucejack Lake; Post-closure include un-reclaimed surface disturbances and discharge from the lake outlet.	Sublethal and lethal potential effects to aquatic organisms due to increased suspended material concentrations and deposition.	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; • tailings deposition to the deepest section of Brucejack Lake (eastern portion of lake), with subaqueous discharge designed to add tailings to the deepest area; and • implementation of the Soils Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Localized increases in suspended sediment concentrations with potential sublethal effects on aquatic organisms.
Changes in Surface Water Quantity	Closure	Changes in water balance due to water management.	Changes in flow in Brucejack Creek resulting in potential decrease in available habitat.	• Use of BMPs and engineered water management structures to maintain natural drainage networks, as much as feasible; • diversion of non-contact water into existing water courses; and • Implementation of Water Management Plan (Section 29.19).	Potential ~50% increase in low flow period stream discharges during Construction and Operation, and a potential 24% decrease in winter flows during Closure. Localized changes in the aquatic habitat due to changes in stream flow.
Changes in Surface Water Quality (ML/ARD)	Construction, Operation, Closure, Post-closure	WTP and STP effluent discharges into Brucejack Creek (Construction) and Brucejack Lake (Operation, Closure) as well as waste rock and tailings deposition upstream in Brucejack Lake (discharge from lake outlet).	Change of water quality, due to chemical loadings upstream at the lake outlet (ML/ARD, WTP and STP discharges, groundwater interactions and seepage), resulting in biological effects to aquatic organisms.	• Implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Tailings Management Plan (Section 29.15), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3); and • collection and treatment of seepage from underground workings.	Sublethal effects to aquatic organisms due to increases in arsenic concentrations in Brucejack Creek receiving environment.
Changes in Surface Water Quality (ML/ARD)	Operation, Closure	WTP and STP effluent discharges into Brucejack Creek (Construction) and Brucejack Lake (Operation, Closure) as well as waste rock and tailings deposition upstream in Brucejack Lake (discharge from lake outlet).	Change of water quality due to chemical loadings upstream at the lake outlet (ML/ARD, WTP and STP discharges, groundwater interactions and seepage), resulting in biological effects to aquatic organisms.	• Implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Tailings Management Plan (Section 29.15), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3); and • collection and treatment of seepage from underground workings.	Sublethal and lethal effects to aquatic organisms due to increases in chromium and zinc concentrations.
Changes in Surface Water Quality (Nutrient Loading)	Construction, Operation, Closure	Leaching of blasting residues used during pad construction (e.g., mill site, laydown areas), as well as waste rock.	Change of water quality due to leaching of blasting residues on disturbed rock material/ waste rock deposition upstream at Brucejack Lake	• Implementation of Waste Rock Management Plan (Section 29.18), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3); and • collection and treatment of seepage from underground workings.	Increases in primary productivity due to increased nutrients in the environment; increase mitigated by continued grazing and other environmental processes. Increases to primary productivity expected to be restricted to the immediate receiving environment in Brucejack Creek only. No expected effects from toxicity of nitrogenous compounds.
Changes in Sediment Quality	Construction, Operation, Closure, Post-closure	Project activities and components related to erosion and sedimentation, particularly during surface disturbances during Construction and decommissioning, as well as discharges from STP and WTP, and the effects of waste rock and tailings disposal in Brucejack Lake.	Changes in sediment quality due to increased loading of sediment to freshwater environment as well as increases in metal loading from metals transported in discharge from Brucejack Lake.	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; • collection and treatment of seepage from underground workings; and • implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Soils Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Localized increases in the sediment concentrations of some metals due to increased loading. Increases predicted to be within the range of natural variation due to natural sources in environment.
Habitat Loss	Construction, Operation, Closure	Deposition of tailings and waste rock in Brucejack Lake.	Loss of habitat from deposition of material into lake.	• Tailings deposition to the deepest section of Brucejack Lake (eastern portion of lake), with subaqueous discharge designed to add tailings to the deepest area.	Loss of benthic habitat in Brucejack Lake by the end of Project life.

[1] "Cause-effect" refers to the relationship between the Project component/physical activity that is causing the change or effect in the condition of the receptor VC, and the actual change or effect that results.

14.6.2.2 Residual effects due to Changes in Surface Water Quality

The residual effects from ML/ARD associated with Project activities in the off-site Project infrastructure areas is assessed qualitatively because of the short duration and small scope of Project activities associated with the access road upgrade and upgrading and operation of the Bowser Aerodrome. Mitigation and management measures, including monitoring for ML/ARD, outlined in the ML/ARD Management Plan (Section 29.10) will minimize the effects on surface water quality. The exposure of new rock will be minimized, and most materials have been shown to have minimal potentials for acid generation. Any ML/ARD effects are anticipated to be indistinguishable from the natural variation in pH and metal concentrations in the off-site infrastructure areas, particularly within the glacially-headed Bowser River watershed.

Changes in water quality due to nutrient loading are expected to have minimal effects on aquatic resources in the off-site infrastructure area. General strategies and BMPs for managing nitrogen loading are as described above for the mine site area (Section 14.5.3.3). Blasting, which is the primary source of nitrogenous nutrients, will be minimal in off-site areas (Chapter 5, Project Description). Seepage from septic fields are not expected to contribute any nutrients to the freshwater environment (Section 14.5.2.3). Blasting residues primarily enter the freshwater environment via overland flow and runoff; these processes will generally occur during the freshet in spring and storm events in the fall. As a result, any deposited nutrients will be diluted by the significant flows during those periods and flushed relatively quickly from the system. Furthermore, the receiving environment has low natural nitrogen concentrations and a high assimilative capacity for the addition of nitrogen compounds (Section 13.5.4.3, Chapter 13). Any effects from nutrient loading on aquatic resources are, therefore, predicted to within the range of natural variation, restricted to the immediate receiving environment of runoff from disturbed areas with active blasting, and restricted to the periods immediately after significant ground disturbance and blasting. The restoration of ground cover, re-vegetation, and the implementation of water management infrastructure is anticipated to mitigate any remaining residual effects.

14.6.2.3 Summary of Residual Effects in Off-site Project Infrastructure Areas

Table 14.6-4 presents a summary of the residual effects assessed for aquatic resources in the off-site Project infrastructure areas.

Table 14.6-4. Summary of Predicted Residual Effects on Aquatic Resources in the Off-site Project Infrastructure Areas

Sub-component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect[1]	Description of Mitigation Measure(s)	Description of Residual Effect
Erosion and Sedimentation	Construction, Operation, Closure	Construction, operation, and decommissioning of the Brucejack Access Road, and Bowser Aerodrome	Sublethal and lethal potential effects to aquatic organisms due to increased suspended material concentrations and deposition.	Use of BMPs to minimize sediment entry to waterbodies; dust suppression on roads; and implementation of the Soils Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Localized increases in suspended sediment concentrations within the range of natural variation.

(continued)

Table 14.6-4. Summary of Predicted Residual Effects on Aquatic Resources in the Off-site Project Infrastructure Areas (completed)

Sub-component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect[1]	Description of Mitigation Measure(s)	Description of Residual Effect
Changes in Surface Water Quality	Construction, Operation, Closure	Construction, operation, and decommissioning of the Brucejack Access Road, and Bowser Aerodrome	Change of water quality from weathering of rock from (un-reclaimed) surface disturbances, which results in effects on aquatic organisms Leaching of blasting residues	Implementation of ML/ARD Management Plan, Waste Rock Management Plan, Tailings Management Plan, Water Management Plan, and Aquatic Effects Monitoring Plan	Localized changes in pH, or increases in metal or nutrient concentrations within the range of natural variation

[1] "Cause-effect" refers to the relationship between the Project component/physical activity that is causing the change or effect in the condition of the receptor VC, and the actual change or effect that results.

14.7 CHARACTERIZING RESIDUAL EFFECTS ON AQUATIC RESOURCES

The residual effects to aquatic resources from Project activities are assessed on the basis of the following standard criteria:

- *Magnitude:* the expected magnitude or severity of the residual effect.
- *Geographic Extent:* the spatial scale over which the residual effect is expected to occur.
- *Duration:* the length of time the effect lasts.
- *Frequency:* how often the effect occurs.
- *Reversibility*: the degree to which the effect is reversible.
- *Resiliency:* the capacity of the aquatic resources VC to resist or recover from major changes in structure and function following disturbances, without undergoing a shift to a vastly different regime.
- *Ecological or Social Context:* the current condition of the aquatic resources VC and its sensitivity.

Details on the methodology and application of the residual effects characterization criteria are described in Section 6.6.1 of Chapter 6, Assessment Methodology. The characterization criteria applied for the assessment of residual effects on aquatic resources is detailed in Table 14.7-1. The characterization for each residual effect identified in Sections 14.6.1 and 14.6.2 are detailed in Sections 14.7.1 and 14.7.2 below.

14.7.1 Residual Effects Characterization for Aquatic Resources in the Mine Site Area

14.7.1.1 Residual Effects from Erosion and Sedimentation

The residual effects from erosion and sedimentation are predicted to be **moderate** in magnitude because it is possible that suspended sediment concentrations will be greater than BC water quality guidelines during some periods of Project activity (Section 14.6.1.1; Table 14.6-3). During the Construction and Closure phases, the water management infrastructure may not be complete, which creates the potential for mobilized sediments to be transported into the freshwater environment despite the continued application of BMPs for ground disturbance. However, the duration of the increases in suspended material concentrations is predicted to be **short term** and **sporadic** because of the limited duration of activities causing ground disturbance, the implementation of re-vegetation and other mitigation for erosion prevention, and the limited duration of overland runoff in the Brucejack area. The residual effect is predicted to be **local** and restricted to the Brucejack watershed. Aquatic communities are known to recover from inputs of fine sediment within five years, and this resiliency will be aided by the dynamic flow regime that will flush excess sediments from the system (Wallace 1990; Wood and Armitage 1997). As a result, the effects to aquatic resources are concluded to be **reversible medium term** and have a **high** resiliency. The aquatic ecosystem in the Brucejack watershed is described as oligotrophic (Section 14.3.3) and exhibits no unique traits; the aquatic resources are concluded to have **low** ecological context.

14.7.1.2 Residual Effects from Changes in Surface Water Quantity

The residual effects from surface water quantity are predicted to be **minor** in magnitude. The annual mean flows in Brucejack Creek are not predicted to change substantially, whereas low flow stream discharges are predicted to increase during the Construction and Operation phases (~50%) and decrease during the Closure phase (24%; Section 14.6.1.2; Table 14.6-3). The effects of these large relative changes are attenuated by the low absolute flows that occur during winter in Brucejack Creek. The organisms that over-winter in Brucejack Creek are adapted to the cold and dark of the winter period as well as the naturally low stream discharge rates. Even substantial changes in the relative stream flow would not likely have significant effects on senescent and over-wintering organisms in the sediments of Brucejack Creek.

The residual effects from predicted changes in surface water quantity are predicted to be **medium term** and **regular** because of the seasonal patterns in flow. The residual effect is predicted to be **local** and restricted to the Brucejack watershed. Aquatic communities will re-colonize the habitat once flows return to normal (Wallace 1990). As a result, the effects to aquatic resources are concluded to be **reversible medium term** and have a **high** resiliency. The aquatic ecosystem in the Brucejack watershed is described as oligotrophic (Section 14.3.3) and exhibits no unique traits; the aquatic resources are concluded to have **low** ecological context.

14.7.1.3 Residual Effects from Changes in Surface Water Quality

<u>Metal Leaching/Acid Rock Drainage</u>

The residual effects from ML/ARD are predicted to be **moderate** in magnitude because it is possible that the concentrations of arsenic, chromium, and zinc will be greater than BC water quality guidelines or SBEBs during some periods of Project activity (Section 14.6.1.3; Table 14.6-3). However, the expected increases in concentration of all metals are modest, and generally are not significantly greater than the applicable thresholds. Furthermore, mitigating factors such as low temperatures may further reduce the biological effects of the elevated metal concentrations that occur during the low-productivity winter period. The duration of the increases in metal concentrations is predicted to be **medium term** because the increases are associated with at least the Operation phase, and **sporadic** because the increases are associated with low-flow conditions or are associated with the conservative high-underflow case (Section 13.7.2.1, Characterizing Residual Effects: Mine Site Area). The residual effect is predicted to be **local** and restricted to the Brucejack watershed. The effects to aquatic resources are concluded to be **reversible medium term** because the effects will end with the closure of the Project and have a **high** resiliency. The aquatic ecosystem in the Brucejack watershed is described as oligotrophic (Section 14.3.3) and exhibits no unique traits; the aquatic resources are concluded to have **low** ecological context.

Nutrient Loading

The residual effects from nutrient loading are predicted to be **minor** in magnitude because phosphorus concentrations are predicted to remain within the baseline trophic trigger range (Section 14.6.1.3; Table 14.6-3). No toxic effects from nitrogenous compounds are predicted. No substantial effects associated with increased primary production due to nutrient loading are expected because of the maintenance of phosphorus concentrations similar to baseline conditions and the continued presence of naturally mitigating processes such as periods of high flow and grazing pressure. The residual effect is predicted to be **local** and restricted to the Brucejack watershed. As a result, the effects to aquatic resources are concluded to be **reversible short term** and have a **high** resiliency. The aquatic ecosystem in the Brucejack watershed is described as oligotrophic (Section 14.3.3) and exhibits no unique traits; the aquatic resources are concluded to have **low** ecological context.

14.7.1.4 Residual Effects from Changes in Sediment Quality

The residual effects from changes in sediment quality are predicted to be **minor** in magnitude because the sediments in the receiving environment have substantial natural metal content and the relatively low magnitude and medium duration of predicted increases in surface water metal concentrations (Section 14.6.1.4; Table 14.6-3; Section 13.6.1, Predictive Water Quality Modelling). Any increases in sediment metal concentrations associated with the deposition of material or exchange between the water and sediments are predicted to be **local** and restricted to the Brucejack watershed. However, if sediment concentrations do increase as a result of the Project, the residence time of the metals could be **medium term**. As a result, the effects to aquatic resources are predicted to be **reversible long term,** but this prediction is conservative because re-mobilization during freshet and high flow events could serve to re-distribute metal-bearing sediments. However, with the reclamation of the biophysical system after the Project, the natural processes of burial, geochemical immobilization, and exchange with the overlying water will make the metals unavailable to resident aquatic organisms. The resiliency is predicted to be **neutral**. The aquatic ecosystem in the Brucejack watershed is described as oligotrophic (Section 14.3.3) and exhibits no unique traits; the aquatic resources are concluded to have **low** ecological context.

14.7.1.5 Residual Effects from Habitat Loss

The residual effects from habitat loss in Brucejack Lake are predicted to be **major** in magnitude because of the extent of the lake environment covered by waste rock and tailings deposition (Section 14.6.1.5; Table 14.6-3). The duration of the habitat loss will be **far future** and **continuous** because of the extent of habitat that will need to be re-colonized. The residual effect is predicted to be **local** and restricted to Brucejack Lake. Aquatic organisms will re-colonize and re-establish communities, even after complete smothering, but the process is dependent on the productivity of the system (Wallace 1990; Wood and Armitage 1997; Burd, Macdonald, and Boyd 2000). In oligotrophic Brucejack Lake, the process may take a substantial length of time, and may be complicated by presence of elevated metals associated with the waste rock and tailings. As a result, the effects to aquatic resources are concluded to be **reversible long term** and have a **low** resiliency. The aquatic ecosystem in the Brucejack watershed is described as oligotrophic (Section 14.3.3) and exhibits no unique traits; the aquatic resources are concluded to have **low** ecological context. The abundances of benthic organisms in Brucejack Lake are very low (Section 14.3.4.1), particularly in the deeper areas that will be primarily affected by tailings deposition.

Table 14.7-1. Definitions of Characterization Criteria for Residual Effects on Aquatic Resources

Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Resiliency	Ecological Context
Low: The magnitude of effect is within the range of natural variation in the abundance or community composition of the primary and secondary producer communities and/or the value of a pathway indicator[1] is less than guideline or threshold value for the protection of aquatic life.	**Short-term:** Effect lasts approximately 1 year or less.	**Once:** The effect that occurs once or infrequently during any phase of the Project.	**Local:** The effect is limited to the immediate freshwater receiving environment in the Brucejack watershed (mine site area), or the immediate receiving environment near Project infrastructure (off-site Project infrastructure areas).	**Reversible short-term:** The effect can be reversed in less than 2 years.	**Low:** Aquatic resources are not expected to be resilient following disturbances.	**Low:** Aquatic resources have little or no unique attributes or ecological value in the geographic area.
Moderate: The magnitude of effect exceeds by less than 30% the limits of natural variation and/or the value of a pathway indicator is less than 30% greater than guideline or threshold value for the protection of aquatic life.	**Medium-term:** Effect lasts more than a year but less than eleven years (50% of the expected life of the Project).	**Sporadic:** The effect that occurs at sporadic or intermittent intervals during any phase of the Project.	**Landscape:** The effect extends beyond the Brucejack watershed into the Sulphurets/Unuk watershed (mine site area), or into portions of the RSA near Project infrastructure (off-site Project infrastructure areas). Effects do not extend across the entire RSA.	**Reversible medium-term:** The effect is reversible within the life of the Project (less than 20 years).	**Neutral:** Aquatic resources are expected to be moderately resilient and recover to a state similar to pre-disturbance.	**Neutral:** Aquatic resources have some unique attributes or some ecological value in the geographic area.
High: The magnitude of effect exceeds by more than 30% the limits of natural variation and/or the value of a pathway indicator is more than 30% greater than guideline or threshold value for the protection of aquatic life.	**Long-term:** Effect lasts more than eleven years but less than thirty years.	**Regular:** The effect that occurs on a periodic basis during any phase of the Project.	**Regional:** The effect extends across the RSA.	**Reversible long-term:** The effect can be reversed after many years (20+ years).	**High:** Aquatic resources are expected to be resilient and completely recover following disturbances.	**High:** Aquatic resources have some unique attributes or some ecological value in the geographic area.
	Far future: Effect lasts more thirty years.	**Continuous:** The effect that occurs regularly during any phase of the Project and beyond.	**Beyond Regional:** The effect extends beyond the RSA and possibly across or beyond the province (transboundary effects).	**Permanent:** The effect cannot be reversed.		

[1] For example, phosphorus concentration is an indicator of the trophic status of a freshwater environment.

14.7.1.6 Significance of Residual Effects in the Mine Site Area

A significance conclusion is assigned for each residual effect based on the characterization of residual effect criteria (see Section 6.6, Residual Effects, for details). Generally, “not significant” residual effects have the following characteristics:

- minor or moderate magnitudes;
- local geographic extents;
- short- to medium-term durations;
- sporadic frequencies; and
- the receptor VC is resilient and predicted to recover from any changes.

Effects to receptors with unique or significant ecological values are more likely to be considered “significant” because of the value of the VC to stakeholders.

The residual effects on aquatic resources due to Project activities in the mine site area from erosion and sedimentation, habitat loss, and changes to surface water quantity, surface water quality, and sediment quality are predicted to be **not significant** (Table 14.7-2). The majority of residual effects are assessed to be minor or moderate in magnitude and all effects are restricted to the Brucejack watershed.

14.7.1.7 Characterization of Likelihood and Confidence for Residual Effects on Aquatic Resources in the Mine Site Area

Confidence, which is interpreted as scientific uncertainty, is an estimate of the scientific understanding of the residual effects. The residual effects were assessed for their reliability to portray the certainty in the predicted outcome, based on the baseline information, the quantitative and qualitative assessment of the pathways of potential effects, the results of predictive modelling when available, and the analytical methods used in the characterization.

The confidence associated with an assessment is considered low (less than 50% confidence) if:

- the cause-effect relationship between the Project and aquatic resources is poorly understood;
- data for the Project area may be incomplete; or
- uncertainty associated with synergistic and/or additive interactions between environmental effects may exist.

Medium confidence (50 to 80% confidence) assessments are characterized by:

- the cause-effect relationship between the Project and aquatic resources is not fully understood; or
- data for the Project area is incomplete:

The confidence in an assessment is considered high (greater than 80% confidence) when there is a low degree of uncertainty in understanding the cause-effect relationship between the Project and aquatic resources, and all necessary data is available for the Project area.

The confidence in the significance predictions and mitigation measures being followed were rated as high for all residual effects (Table 14.7-2). While uncertainty exists in every prediction of future change, the approach used to assess the effects on aquatic resources was developed to incorporate quantitative data from baseline reports and literature reviews as well as predictive water quality modelling. The baseline status of the freshwater receiving environment is well established, the pathways of interactions between the Project and aquatic resources are well understood, and the predictive modelling provides quantitative estimates of the most significant changes in the freshwater environment. Based upon the certainty associated with the significance conclusions, a more detailed risk assessment is not necessary.

Table 14.7-2. Characterization of the Significance, Confidence, and Likelihood of Residual Effects on Aquatic Resources in the Mine Site Area

Residual Effects	Evaluation Criteria							Likelihood *(low, medium, high)*	Significance of Adverse Residual Effects *(not significant, significant)*	Confidence *(low, medium, high)*
	Magnitude *(low, moderate, high)*	Duration *(short-term, medium-term, long-term, far future)*	Frequency *(once, sporadic, regular, continuous)*	Geographic Extent *(local, landscape, regional, beyond regional)*	Reversibility *(reversible short-term, reversible long-term, irreversible)*	Resiliency *(low, neutral, high)*	Context *(low, neutral, high)*			
Effects from Erosion and Sedimentation	Moderate	Short-term	Sporadic	Local	Reversible medium-term	High	Low	Medium	Not significant	High
Changes in Surface Water Quantity	Low	Medium-term	Regular	Local	Reversible medium-term	High	Low	Medium	Not significant	High
Changes in Surface Water Quality (ML/ARD)	Moderate	Medium-term	Sporadic	Local	Reversible medium-term	High	Low	Medium	Not significant	High
Changes in Surface Water Quality (Nutrient Loading)	Low	Medium-term	Sporadic	Local	Reversible short-term	High	Low	Medium	Not significant	High
Changes in Sediment Quality	Low	Medium-term	Sporadic	Local	Reversible long-term	High	Low	Low	Not significant	High
Habitat Loss	High	Far future	Continuous	Local	Reversible long-term	Low	Low	High	Not significant	High

14.7.2 Residual Effects Characterization for Aquatic Resources in the Off-site Project Infrastructure Areas

14.7.2.1 Residual Effects from Erosion and Sedimentation

The residual effects on aquatic resources from erosion and sedimentation associated with Project activities in the off-site infrastructure areas are predicted to be **minor** in magnitude because of the application of BMPs and mitigation measures and the high natural variation in suspended material concentrations in the receiving environment. Furthermore, any Project-associated suspended material in the freshwater environment would be **sporadic** and **short term**, and fully **reversible** because the effects will be associated with short-term Project activities, the planned implementation of mitigation and restoration measures, and the expected **high** resiliency of aquatic resources to minor sedimentation events. The aquatic ecosystem in the receiving environments associated with off-site Project infrastructure vary in productivity (Section 14.3.3), and some areas have been identified as significant aquatic habitat (e.g., Bowser Lake; see Chapter 15, Assessment of Potential Fish and Fish Habitat Effects). However, no unique features have been observed for the primary producers, secondary producers, or sediment environments in the Project LSA. As a result, a **neutral** context of aquatic resources has been assigned.

14.7.2.2 Residual Effects from Changes in Surface Water Quality

The residual effects from ML/ARD and nutrient loading are predicted to be **minor** in magnitude. However, any effects would be short term, because of the application of mitigation and management measures and the **short-term** duration (less than one season) of ground disturbance activities related to the construction of laydown areas, the upgrading of the road and Bowser Aerodrome, and decommissioning activities. The effects are predicted to be **sporadic** because any ML/ARD or nutrient loading would be associated with periods of significant overland flow, and will be mitigated by installation of water and erosion management structures, re-vegetation, and routine monitoring. The residual effect is predicted to be **local** and restricted to the immediate vicinity of the infrastructure. The effects to aquatic resources are concluded to be **reversible short term** because the effects will end with the end of the specific ground-disturbance activities and aquatic resources are expected to have a **high** resiliency.

14.7.2.3 Significance of Residual Effects on Aquatic Resources in the Off-site Project Infrastructure Areas

Significance conclusions for the residual effects on aquatic resources from changes in surface water quality due to erosion and changes in surface water quality are assigned based on the characterization of residual effect criteria (Table 14.7-3). The residual effects on aquatic resources are predicted to be **not significant**. The spatial and temporal extent of effects to aquatic resources is predicted to be small and mitigation and management measures are predicted to be effective. The probability of residual effects is estimated to be low because of the commitment to effective mitigation and management measures in the construction, maintenance, and decommissioning of off-site Project infrastructure.

14.7.2.4 Characterization of Likelihood and Confidence for Residual Effects on Aquatic Resources in the Off-site Project Infrastructure Areas

The confidence in the significance prediction is assessed as **high** for residual effects (Table 14.7-3). The baseline conditions in the receiving environment are well-characterized and the pathways of interaction between the Project and the aquatic resources are understood. BMPs will be followed at all times, and mitigation and management measures will be applied when feasible. The residual effects are expected to be not significant because of the limited extent of Project activities and the effectiveness of the mitigation and management measures, so a more detailed risk assessment is not necessary.

Table 14.7-3. Characterization of the Significance, Confidence, and Likelihood of Residual Effects on Aquatic Resources in the Off-site Project Infrastructure Areas

Residual Effects	Evaluation Criteria									
	Magnitude *(low, moderate, high)*	**Duration** *(short-term, medium-term, long-term, far future)*	**Frequency** *(once, sporadic, regular, continuous)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short-term, reversible long-term, irreversible)*	**Resiliency** *(low, neutral, high)*	**Context** *(low, neutral, high)*	**Likelihood** *(low, medium, high)*	**Significance of Adverse Residual Effects** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Erosion and Sedimentation	Low	Short-term	Sporadic	Local	Reversible short-term	High	Neutral	Low	Not significant	High
Changes in Surface Water Quality (ML/ARD and nutrient loading)	Low	Short-term	Sporadic	Local	Reversible short-term	High	Neutral	Low	Not significant	High

14.8 SUMMARY OF RESIDUAL EFFECTS ON AQUATIC RESOURCES

Table 14.8-1 presents a summary of residual effects, mitigation, and significance on the aquatic resources VC. All identified residual effects in Table 14.8-1 will be carried forward to the cumulative effects assessment (CEA).

Table 14.8-1. Summary of Residual Effects, Mitigation, and Significance on Aquatic Resources

Residual Effects	Project Phase(s)	Mitigation Measures	Significance
Mine Site Area			
Erosion and sedimentation	Construction, Operation, Closure, Post-closure	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; and • implementation of Soil Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Not significant
Changes in surface water quantity	Closure	• Use of BMPs and engineered water management structures to maintain natural drainage networks, as much as feasible; • diversion of non-contact water into existing water courses; and • implementation of Water Management Plan (Section 29.19)	Not significant
Changes in surface water quality	Construction, Operation, Closure, Post-closure	• Implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Tailings Management Plan (Section 29.15), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3); and • collection and treatment of seepage from underground workings.	Not significant
Changes in sediment quality	Construction, Operation, Closure, Post-closure	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; • collection and treatment of seepage from underground workings; and • implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Soil Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Not significant
Habitat loss	Construction, Operation, Closure	• Tailings deposition to the deepest section of Brucejack Lake (eastern portion of lake), with subaqueous discharged designed to add tailings to the deepest area.	Not significant
Off-site Project Infrastructure Areas			
Erosion and sedimentation	Construction, Operation, Closure	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; and • implementation of Soil Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Not significant
Changes in surface water quality	Construction, Operation, Closure	• Implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Tailings Management Plan (Section 29.15), Water Management Plan (Section 29.19), and Aquatic Effects Monitoring Plan (Section 29.3).	Not significant

14.9 CUMULATIVE EFFECTS ASSESSMENT FOR AQUATIC RESOURCES

Cumulative effects are defined in this Application/EIS as "effects which are likely to result from the designated project in combination with other projects and activities that have been or will be carried out". This definition follows that in section 19(1) of the *Canadian Environmental Assessment Act, 2012* (2012) and is consistent with the International Finance Corporation Good Practice Note on Cumulative Impact Assessment, which refers to consideration of other existing, planned and/or reasonably foreseeable future projects and developments (IFC 2013). CEA is a requirement of the AIR (BC EAO 2014) and the EIS Guidelines and is necessary for the proponent to comply with the *Canadian Environmental Assessment Act, 2012* (2012) and the BC *Environmental Assessment Act* (2002a).

The Canadian Environmental Assessment Agency (CEA Agency) issued an Operational Policy Statement in May 2013 entitled *Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act 2012* (CEA Agency 2013), which provides a method for undertaking CEA. Recently the British Columbia Environmental Assessment Office (BC EAO) also released the updated *Guideline for the Selection of Valued Components and the Assessment of Potential Effects* (BC EAO 2013), which includes advice for determining the need for a cumulative impact assessment. The CEA assessment methodology adopted in this Application/EIS therefore follows the guidance of the CEA Agency as outlined above, as well as the selection criteria in BC EAO (2013).

The method involves the following key steps which are further discussed in the proceeding sub-sections (Figure 14.9-1):

- scoping;
- analysis;
- identification of mitigation measures;
- identification of residual cumulative effects; and
- determination of significance.

14.9.1 Establishing the Scope of the Cumulative Effects Assessment

The scoping process involves identification of the intermediate components and receptor VCs for which residual effects are predicted, definition of the spatio-temporal boundaries of the assessment, and an examination of the relationship between the residual effects of the Project and those of other projects and activities. The residual effects from the Project on aquatic resources — identified, described, and characterized in Sections 14.5 to 14.7 — are brought forward for assessment for cumulative effects.

14.9.1.1 Identifying Intermediate Components and Receptor Valued Components for the Cumulative Effects Assessment

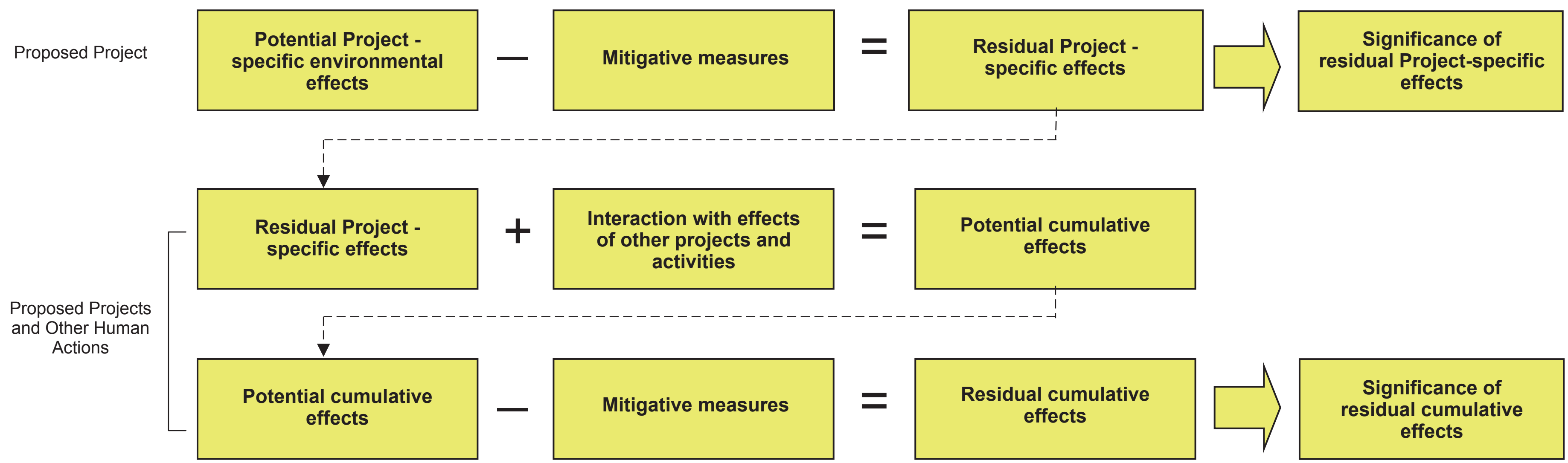
The CEA considers the residual effects on the aquatic resources VC predicted to occur after consideration of mitigation measures, regardless of whether those residual environmental effects are predicted to be significant.

Intermediate components and receptor VCs included in the Aquatic Resources CEA were selected using four criteria following BC EAO (2013):

- there must be a residual environmental effect of the project being proposed;
- that environmental effect must be demonstrated to interact cumulatively with the environmental effects from other projects or activities;

Figure 14.9-1

Approach to Cumulative Effects Assessment



- it must be known that the other projects or activities have been or will be carried out and are not hypothetical; and
- the cumulative environmental effect must be likely to occur.

The residual effects on aquatic resources included in this CEA are:

- erosion and sedimentation in the mine site area;
- changes in surface water quantity in the mine site area;
- changes in surface water quality, due to ML/ARD and nutrient loading in the mine site area;
- changes in sediment quality in the mine site area;
- habitat loss in the mine site area;
- erosion and sedimentation in the off-site infrastructure areas; and
- changes in surface water quality in the off-site infrastructure areas.

The residual effects on aquatic resources in the mine site area are predicted to result from increased erosion and transport of suspended material in the aquatic environment (Section 14.6.1.1), water management (Section 14.6.1.2), the operation of the STP and WTP (Sections 14.6.1.3 and 14.6.1.4), and the deposition of tailings and waste rock in Brucejack Lake (Sections 14.6.1.3, 14.6.1.4, and 14.6.1.5). The analysis of residual effects in the mine site area are supported by predictive modelling studies for air quality (Chapter 7), hydrology and the site water balance (Chapter 10), and surface water quality (Chapter 13). The residual effects to surface water quality in the off-site infrastructure areas are predicted to result from processes related to the development, operation, and decommissioning of infrastructure at the transfers areas, the Bowser Aerodrome, and along the access road (Sections 14.6.2.1 and 14.6.2.2).

14.9.1.2 Potential Interaction of Projects and Activities with the Brucejack Gold Mine Project for Aquatic Resources

A review of the interaction between potential effects of the Project on aquatic resources and effects of other projects and activities was undertaken. The review assessed the projects and activities identified in Section 6.9.2 of the Assessment Methodology (Chapter 6), including:

- regional projects and activities that are likely to affect aquatic resources, even if they are located outside the direct zone of influence of the Project;
- effects of past and present projects and activities that are expected to continue into the future (i.e., beyond the effects reflected in the existing conditions of aquatic resources); and
- activities not limited to other reviewable projects, if those activities are likely to affect aquatic resources cumulatively (e.g., forestry, mineral exploration, commercial recreational activities).

A matrix identifying the potential cumulative effect interactions for aquatic resources is provided in Table 14.9-1 below.

14.9.1.3 Spatio-temporal Boundaries of the Cumulative Effects Assessment

The CEA boundaries define the maximum extent of the effects assessment. They encompass the areas within, and times during which, the Project is expected to interact with aquatic resources and with other projects and activities, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the Aquatic Resources CEA, and encompasses possible direct, indirect, and induced effects of the Project on aquatic resources. The boundaries are consistent with the boundaries applied for the assessment of effects on surface water quality because of the close biophysical connections between the two VCs.

Table 14.9-1. Potential Cumulative Effect Interactions for Aquatic Resources

Projects and Activities	Aquatic Resources
Historical	
Eskay Creek Mine	
Galore Creek Mine	
Goldwedge Mine	
Granduc Mine (Past Producer)	
Johnny Mountain Mine	
Kitsault Mine (Past Producer)	
Silbak Premier Mine	
Snip Mine	
Snowfield Exploration Project	
Sulphurets Advanced Exploration Project	
Swamp Point Aggregate Mine	
Present	
Brucejack Exploration	
Forrest Kerr Hydroelectric Power	
Long Lake Hydroelectric	
McLymont Creek Hydroelectric Project	
Northwest Transmission Line	
Red Chris Mine	
Reasonably Foreseeable Future	
Arctos Anthracite Coal Mine	
Bear River Gravel	
Bronson Slope Mine	
Coastal GasLink Pipeline Project	
Galore Creek Mine	
Granduc Copper Mine	
KSM Project	
Kinskuch Hydroelectric Project	
Kitsault Mine	
Kutcho Mine	
LNG Canada Export Terminal Project	
Northern Gateway Pipeline Project	
Prince Rupert Gas Transmission Project	

(continued)

Table 14.9-1. Potential Cumulative Effect Interactions for Aquatic Resources (completed)

Projects and Activities	Aquatic Resources
Reasonably Foreseeable Future (cont'd)	
Prince Rupert LNG Project	
Schaft Creek Mine	
Spectra Energy Transmission Line Project	
Storie Moly Mine	
Treaty Creek Hydroelectric Project	
Turnagain Mine	
Volcano Hydroelectric Project	
Land Use Activities - All Stages (past, present, future)	
Parks and Protected Areas	
Guide Outfitting	
Aboriginal Harvest (fishing, hunting/trapping, plant gathering)	
Hunting	
Trapping	
Commercial Recreation (including fishing)	
Forestry	
Transportation	

Notes:
Black = likely interaction between Brucejack Gold Mine Project and other project or activity
Grey = possible interaction between Brucejack Gold Mine Project and other project or activity
White = unlikely interaction between Brucejack Gold Mine Project and other project or activity

Spatial Boundaries

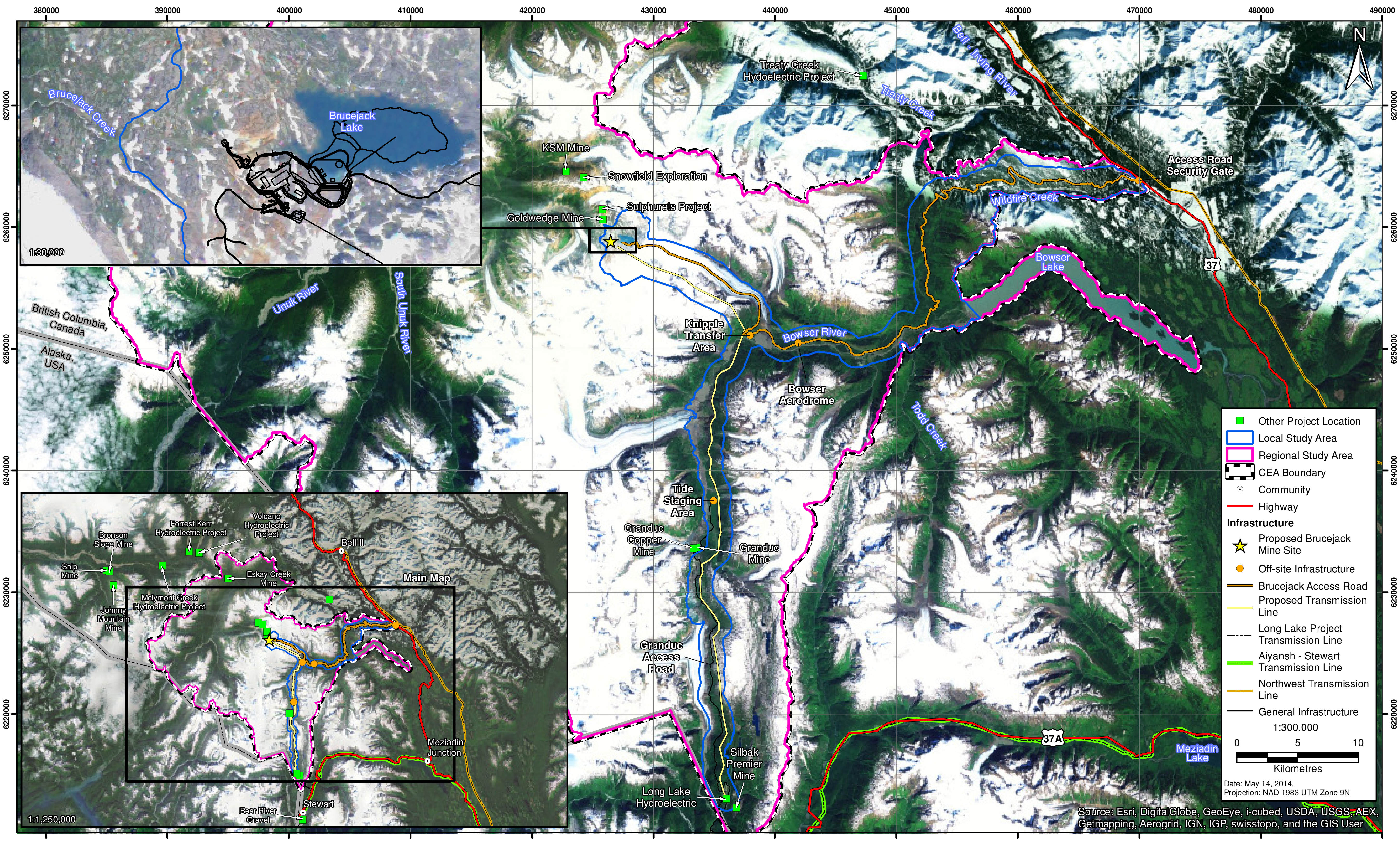
Cumulative effects scoping considered past, present, and future actions for watersheds downstream of the Project (Figure 14.9-2). Watersheds with the potential to be affected by Project activities include the Unuk River, Sulphurets Creek, Bell-Irving River, and Bowser River watersheds. Past, present, and/or potential future activities may combine to affect surface water quality in the LSA and RSA, in CEA boundaries, or in downstream watersheds. The surface water quality CEA boundary is the same as the RSA. The RSA was selected based upon watersheds, upstream, and downstream of the Project with a potential for direct effects. Projects that are located outside of the identified watershed boundaries were excluded from the CEA.

The past projects and human activities that may affect surface water quality and spatially overlap potential effects from the Project are (Figure 14.9-2):

- the Eskay Creek Mine (effluent flows into the Unuk River);
- Sulphurets Advanced Exploration Project (waste rock deposition along Brucejack Creek, reclamation activities);
- the Granduc Mine (concentrator effluent flowed into the Bowser River Valley to Bowser Lake; access corridor overlaps);
- the Snowfield Exploration Project; and
- Silbak Premier Mine (in Salmon River watershed).

Figure 14.9-2

Aquatic Resources Cumulative Effects Assessment Boundary Showing All Other Projects and Activities Potentially Affecting Aquatic Resources in the Vicinity of the Brucejack Gold Mine Project



Present and future projects and human activities that may affect surface water quality and spatially overlap potential effects from the Project are (Figure 14.9-2):

- the Northwest Transmission Line (NTL; access corridor overlaps within Bell-Irving River watershed);
- the Granduc Copper Mine (access corridor overlaps, future mining activities);
- Brucejack Exploration (blasting and drilling program, access road use); and
- the KSM Project (discharge into Sulphurets; development in Sulphurets Creek and Mitchell Creek; access corridor overlaps).

Temporal Boundaries

Effects to aquatic resources from past projects and human activities may temporally overlap with potential effects from the Project, if the effects from past activities persists in the aquatic environment or if the aquatic organisms or sediment quality have not recovered from past effects.

Temporal linkages for past human actions within the watersheds potentially affected by the proposed Project were considered in the development of the baseline program. Past human actions with a temporal linkage to potential aquatic resources effects include:

- the Eskay Creek Mine;
- Silbak Premier Mine;
- Sulphurets Advanced Exploration Project; and
- the Granduc Mine.

Present and future projects and human activities with potential effects to aquatic resources that could overlap temporally with potential effects from the Project are:

- the Granduc Copper Mine;
- Brucejack Exploration and Bulk Sample Program; and
- the KSM Project.

14.9.1.4 Potential for Cumulative Effects

The cumulative effects analysis for aquatic resources considers the spatial and temporal overlap with other projects and human activities and the type of potential cumulative effect. The types of cumulative effects include direct physical and chemical interactions, nibbling loss, spatial or temporal crowding, synergistic effects based on the interaction of biophysical processes, additive effects, and effects due to induced growth or other human activities (see Chapter 6, Assessment Methodology, for more details). Table 14.9-2 describes the potential cumulative effects of Project-related effects on aquatic resources with past, present, and reasonably foreseeable future activities.

Advanced exploration and bulk sample mining at Sulphurets Project between 1986 and 1990 resulted in the placement of tailing materials in Brucejack Lake and waste rock deposition along Brucejack Creek which both drain west to the Sulphurets drainage. The Eskay Creek Mine operated between 1995 and 2008 and tailings material and waste rock stored in Albino and Tom MacKay lakes and mine site drainage to Ketchum Creek flow to the Unuk River. Further detail on the effect of past human actions on the water quality baseline is provided in Section 13.3 of Chapter 13, Assessment of Potential Surface Water Quality Effects). The effects of these historical activities are already considered in the existing environment analysis for aquatic resources and surface water quality (Section 14.3; Section 13.3); therefore, activities associated the Sulphurets Project will not be considered further in the CEA for surface water quality.

Table 14.9-2. Potential Cumulative Effects between the Brucejack Gold Mine Project Aquatic Resources and Other Projects and Activities

	Brucejack Gold Mine Project	Past Project or Activity	Existing Project or Activity	Reasonably Foreseeable Future Project or Activity	Type of Potential Cumulative Effect
Mine Site Area and Receiving Environment					
Effects from erosion and sedimentation	X	-	-	KSM Project	Additive
Changes in surface water quantity	X	-	-	KSM Project	Additive
Changes of surface water quality due to ML/ARD and nutrient loading	X	-	-	KSM Project	Additive
Changes in sediment quality	X	-	-	KSM Project	Additive
Habitat loss	X	-	-	KSM Project	Additive
Off-site Areas (off-site Project infrastructure)					
Effects from erosion and sedimentation	X	-	NTL	-	Additive
Effects from erosion and sedimentation	X	-	-	Granduc Copper Mine	Additive
Changes in surface water quality	X	-	NTL	-	Additive
Changes in surface water quality	X	-	-	Granduc Copper Mine	Additive

The Granduc Mine operated between 1970 and 1978 and between 1980 and 1984 and uncontained tailing materials were washed down the Bowser River Valley into Bowser Lake (Section 13.3 of Chapter 13, Assessment of Potential Surface Water Quality Effects). No additional cumulative effects related to this project would be expected with development of the Brucejack Gold Mine Project beyond what was already considered in baseline studies; therefore, activities associated with the historic Granduc Mine will not be considered further in the CEA for aquatic resources.

The proposed new activities at the Granduc Copper Mine include exploration drilling with the aim of redeveloping the mine (Marketwire 2010; Scales 2012). Castle Resources is currently working on environmental studies and permitting and the proposed mine is planned to begin the operations phase in 2016, if approved, which indicates that a temporal overlap is possible. The drainage from the proposed Granduc Copper Mine is to the Bowser River, Bowser Lake, and ultimately to the Bell-Irving River, suggesting that there is potential for cumulative spatial interaction between the proposed Granduc Copper Mine and off-site Project infrastructure. The project is still in the very early planning stages and no information data on expected water quality effects are available.

The Snowfield Project is located north-east of the Brucejack Gold Mine Project. The Snowfield deposit area drains downstream to Mitchell Creek, which is a tributary to Sulphurets Creek, downstream of the Brucejack Gold Mine Project. A Preliminary Economic Assessment was completed in 2010 that explored the value of combining the Brucejack Gold Mine Project and Snowfield Project (Wardrop Engineering 2010). The Snowfield Project proponent has no current plans to advance development; therefore, the Snowfield Project was excluded from the aquatic resources CEA.

The NTL will be an approximately 344 km electricity transmission line (BC Hydro 2012). The 287-kV-capacity line will generally follow the Highway 37 corridor, running from the Skeena Substation at Terrace and connecting with a new substation near Bob Quinn Lake (BC Hydro 2012) and parallels the eastern aquatic resources cumulative effects boundary (Figure 14.9-2). BC Hydro received an EA Certificate in February 2011 and construction began in January 2012. The project is expected to be operational in 2014. The transmission line will extend the existing provincial electrical grid into northwestern British Columbia making mining, power and other resource projects in these remote regions more economically feasible. Any potential effects from the NTL are considered to occur at the boundary of the aquatic resources RSA.

Brucejack exploration activities commenced in 2011 and have included a drilling program, bulk sampling program, construction of an exploration access road from Highway 37 to the west end of Bowser Lake, as well as the rehabilitation of an existing access road from the west end of Bowser Lake to the Brucejack Mine Site. Further detail on the effect of past human actions on the water quality baseline is provided in Section 13.3 of Chapter 13, Assessment of Potential Surface Water Quality Effects). No additional cumulative effects related to these activities are expected with development of the Brucejack Gold Mine Project beyond what was already considered in baseline studies; therefore, activities associated with Brucejack exploration activities will not be considered further in the CEA for aquatic resources.

The KSM Project is a gold/copper project located downstream of the Brucejack Gold Mine Project within the Sulphurets Creek watershed, which is a tributary of the Unuk River. The KSM Project is currently in the environmental assessment process. The KSM Project has the potential to interact with residual effects from the Brucejack Gold Mine Project; therefore the KSM Project was included in the aquatic resources CEA.

14.9.2 Analysis of Cumulative Effects

Cumulative effects on aquatic resources can occur when potential Project effects combine with effects caused by other projects. When effects from the Project and other activities combine, the effect of the initial effect can increase due to cumulative or synergistic/antagonistic responses. Cumulative effects from past, present, or potential future activities, along with the Project, were assessed to determine the overall effect to aquatic resources in the LSA and RSA. The analysis of potential cumulative effects considers available information on the extent and magnitude of effects from other human activities with the predictions from the Project effects assessment for each residual effect (Sections 14.9.2.1 through 14.9.2.5).

14.9.2.1 Cumulative Effects on Erosion and Sedimentation in the Mine Site Area

The mine area of the KSM Project is located within the cumulative effects boundary (Sulphurets Creek and Unuk River watersheds), while the processing and tailings management area of the KSM Project is located outside of the cumulative effects boundary (Teigen Creek, Treaty Creek). Therefore, only the mine area of the KSM Project is included in the cumulative effects assessment, since identified potential effects within processing and tailings management area watersheds would not have an interaction with the proposed Brucejack Gold Mine Project. No significant effects from erosion and sedimentation from the KSM Project mine site in the Sulphurets/Unuk watersheds were predicted because of the application of mitigation and management measures. However, the potential for some erosion and sedimentation was predicted, with the subsequent potential for non-significant effects to aquatic resources.

The residual effects from erosion and sedimentation from the Project are predicted to be restricted to the Brucejack watershed (Section 14.7.1.1). Therefore, there is no spatial or temporal overlap between the Brucejack Gold Mine Project and KSM Project, and no potential for cumulative effects is predicted and no further analysis is required.

14.9.2.2 Cumulative Effects on Surface Water Quantity in the Mine Site Area

The KSM Project was predicted to have no significant effects on water quantity in the Sulphurets/Unuk watersheds. However, no spatial or temporal overlap between the Brucejack Gold Mine Project and

KSM Project is predicted because the residual effects from changes in water quantity for the Brucejack Gold Mine Project are restricted to the Brucejack watershed. Therefore, no potential for cumulative effects from changes in surface water quantity are predicted, and no further analysis is required.

14.9.2.3 Cumulative Effects on Surface Water Quality in the Mine Site Area

The KSM Project identified residual cumulative effects on surface water quality as a result of changes in metal concentrations (selenium) downstream of the mine area, but it was not expected to be significant due to the mitigation plan (see Section 13.9.2 of Chapter 13, Assessment of Potential Surface Water Quality Effects). However, no spatial or temporal overlap between the Brucejack Gold Mine Project and KSM Project is predicted because the residual effects from changes in water quality for the Brucejack Gold Mine Project are restricted to the Brucejack watershed. Therefore, no potential for cumulative effects from changes in surface water quality are predicted, and no further analysis is required.

14.9.2.4 Cumulative Effects on Sediment Quality in the Mine Site Area

No spatial or temporal overlap between the Brucejack Gold Mine Project and KSM Project for sediment, surface water quantity, or surface water quality have been identified (Sections 14.9.2.1 to 14.9.2.3). Therefore, no overlap exists between potential residual effects to sedimentation, and no cumulative effects are predicted. No further analysis is conducted for potential cumulative effects to sediment quality.

14.9.2.5 Cumulative Effects on Habitat Loss in the Mine Site Area

The residual effects of habitat loss are restricted to Brucejack Lake (Section 14.7.1.5). There is no expected biological connectivity for aquatic resources between Brucejack Lake and waterbodies potentially affected by the KSM Project because Brucejack Lake is the headwaters for Brucejack Creek. Primary and secondary producers are not expected to travel the long distances (over 10 km; Figure 14.9-2) between waterbodies. Therefore, there is no spatial or temporal overlap for the potential cumulative effects of habitat loss, and no further analysis is conducted.

14.9.2.6 Cumulative Effects in the Off-site Infrastructure Areas

The residual effects in the off-site infrastructure areas from erosion and sedimentation, ML/ARD and nutrient loading are predicted to be short-term effects related to the disturbance of ground cover and blasting (Section 14.7.2). There will be no potential cumulative effect from interactions between the Project activities in the Bowser River watershed and the activities at the Granduc Mine because it is unlikely that there will be any temporal overlap as Project residual effects in the Bowser watershed are predicted to be fully reversible and short term (Section 14.7.2). The Granduc Mine, which is still in the early planning stages, would only be starting activities in 2016, which is after the expected completion of significant ground disturbance activities related to Brucejack Gold Mine Project activities in the Bowser watershed. Furthermore, details on the scope and extent of Granduc Mine activities are not available.

The potential residual effects from the NTL are not predicted to have any temporal interaction with Project-related effects associated with off-site Project infrastructure. The NTL occurs at the far eastern edge of the cumulative effects RSA, and no biophysical association with the local and sporadic residual effects from Project activities are expected to reach the edge of the RSA (Section 14.7.2). Based on the absence of temporal or spatial overlap with the NTL and Granduc Mine, no cumulative effects are predicted for erosion and sediment or for changes in surface water quality in the off-site infrastructure areas, and no further analysis is conducted.

14.9.3 Mitigation Measures to Address Cumulative Effects

Extensive mitigation and management measures to eliminate, manage, or minimize Project effects on aquatic resources are detailed in Section 14.5.2. Furthermore, the Aquatic Effects Monitoring Plan (Section 29.3) will be used to detect un-anticipated effects on aquatic resources and will implement additional mitigation and management measures as necessary. No overlap between Project-related residual effects and any other human activities has been predicted (Section 14.9.2) and therefore additional cumulative effects mitigation and management measures are not required.

14.9.4 Cumulative Residual Effects for Aquatic Resources

Cumulative residual effects are those effects remaining after the implementation of all mitigation measures and are summarized in Table 14.9-3. No residual effects were identified and characterization of cumulative effects was assessed as **not applicable (N/A**).

Table 14.9-3. Summary of Cumulative Residual Effects on Aquatic Resources

Sub-component	Timing of Cumulative Residual Effect[1]	Description of Cause-Effect[2]	Description of Additional Mitigation	Description of Cumulative Residual Effect
Erosion and sedimentation in the mine site area	N/A	N/A	N/A	N/A
Changes in surface water quantity in the mine site area	N/A	N/A	N/A	N/A
Changes in surface water quality in the mine site area	N/A	N/A	N/A	N/A
Changes in sediment quality in the mine site area	N/A	N/A	N/A	N/A
Habitat loss in the mine site area	N/A	N/A	N/A	N/A
Erosion and sedimentation in the off-site Project infrastructure area	N/A	N/A	N/A	N/A
Changes in surface water quality in the off-site Project infrastructure area	N/A	N/A	N/A	N/A

[1] *Refers to the Project phase or other timeframe during which the effect will be experienced by aquatic resources.*
[2] *"Cause-effect" refers to the relationship between the Project component/physical activity that is causing the change or effect in the condition of aquatic resources, and the actual change or effect that results.*

14.9.5 Characterizing Cumulative Residual Effects, Significance, Likelihood, and Confidence for Aquatic Resources

The cumulative residual effects for aquatic resources are characterized by considering the Project's incremental contribution to the cumulative residual effect under two scenarios:

- Future case without the Project: a consideration of residual effects from all other past, existing, and future projects and activities on a sub-component <u>without</u> the Brucejack Gold Mine Project.
- Future case with the Project: a consideration of all residual effects from past, existing, and future projects and activities on a sub-component <u>with</u> the Brucejack Gold Mine Project.

This approach helps predict the relative influence of the Project on the residual cumulative effect for the aquatic resources VC, while also considering the role of other projects and activities in causing that effect.

No overlap is predicted to occur between the residual effects of the Project and any other human activities. The majority of residual effects are restricted to the Brucejack watershed, which is a high-alpine watershed with minimal human activities outside of the Project. The residual effects associated with off-site Project infrastructure areas are predicted to be sporadic and short term, which are predicted to minimize any interactions. No residual cumulative effects have therefore been identified, and the significance determination is not conducted. The confidence is this prediction regarding cumulative effects is high, based on the state of current knowledge of human activities in the CEA RSA (Table 14.9-4).

Table 14.9-4. Significance Determination of Cumulative Residual Effects for Aquatic Resources Future Case with the Project

Cumulative Residual Effects	Cumulative Residual Effects Characterization Criteria									
	Magnitude *(low, moderate, high)*	**Duration** *(short-term, medium-term, long-term, far future)*	**Frequency** *(once, sporadic, regular, continuous)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short-term, reversible long-term, irreversible)*	**Resiliency** *(low, neutral, high)*	**Context** *(low, neutral, high)*	**Likelihood** *(low, medium, high)*	**Significance of Adverse Cumulative Residual Effects** *(not significant, significant)*	**Confidence** *(low, medium, high)*
N/A	N/A							N/A	N/A	N/A

14.10 CONCLUSION OF EFFECTS ASSESSMENT FOR PROJECT EFFECTS ON AQUATIC RESOURCES

Aquatic resources describe the aquatic organisms forming the base of the aquatic foodweb. Primary producers, which include phytoplankton, periphyton, and aquatic plants, are photosynthetic organisms that use nutrients and sunlight to produce energy, and these organisms are important food sources to aquatic invertebrates and fish. Secondary producers are the aquatic invertebrates that feed on detritus, primary producers, and other secondary producers and are crucial components of the aquatic foodweb. Both primary and secondary producers are sensitive to changes to their environment because of their short life-histories, relative lack of mobility, and dynamic trophic interactions.

The proposed Project could affect aquatic resources thorough the physical and chemical alteration of their habitat (i.e., changes to surface water quality, surface water quality, and sediment quality). These affects could occur during the Construction, Operation, Closure, and Post closure phases. A pre-development aquatic resources baseline was established to allow for the prediction, assessment, mitigation and management of potential Project-related effects (Section 14.3). Generally, the Project area is characterized by low productivity aquatic communities with low abundances of aquatic organisms, which is typical for high-altitude ecosystems in the region.

The effects assessment for aquatic resources is dependent on the analyses for other biophysical components of the environment. The effects assessments for the following VCs are used extensively in the aquatic resources effects assessment to describe mitigation and management measures, describe the extent and magnitude of residual effects, and establish the significance of residual effects:

- air quality (via dust deposition; Chapter 7);
- hydrogeology (groundwater quality and quantity; Chapter 9);
- hydrology (surface water quantity; Chapter 10); and
- surface water quality (Chapter 13).

Extensive mitigation and management plans for Project effects on the freshwater environment are included in the design for the proposed Brucejack Gold Mine Project. Additional mitigation strategies include measures to avoid, reduce, and monitor adverse effects to surface water quality. These measures include the implementation of the following environmental plans (Chapter 29):

- Section 29.3, Aquatic Effects Monitoring Plan;
- Section 29.7, Hazardous Materials Management Plan;
- Section 29.10, ML/ARD Management Plan;
- Section 29.13, Soil Environment Management Plan;
- Section 29.14, Spill Prevention and Response Plan;
- Section 29.19, Water Management Plan; and
- Chapter 30, Closure and Reclamation.

Monitoring programs will include triggers for risk assessment of potential effects, which will ensure detection of measureable alterations in productive capacity, allow for identification of potential causes, and include the provision of additional mitigation or adaptive management strategies. Please see Chapter 29 for all environmental management plans.

The key assumptions of the aquatic resources effects assessment are:

- all guidelines, mitigation and management plans, BMPs, regulations, and operating standards designed to eliminate, minimize, and manage effects to surface water quantity, surface water quality, and aquatic resources are followed; and
- the quantitative modelling efforts for surface water quantity and surface water quality are accurate and representative of the effects of the Project.

The potential and likelihood for residual effects varies with Project area (i.e., the mine site area or off-site Project infrastructure areas). In the off-site Project infrastructure areas, residual effects on aquatic resources may occur due to:

- erosion and sedimentation; and
- changes in water quality from ML/ARD and nutrient loading.

Despite management and mitigation, residual effects on aquatic resources in the mine site area could occur due to the following effects categories:

- erosion and sedimentation;
- changes in surface water quantity;
- changes in surface water quality from nutrient loading and ML/ARD;
- changes in sediment quality; and
- habitat loss.

Table 14.10-1 presents a summary of the residuals effects on aquatic resources from Project activities. The residual effects from erosion and sedimentation that are predicted to remain after the implementation of mitigation and management measures are associated with ground disturbances leading to the transport of material into the freshwater environment in the Construction, Operation, Closure, and Post-closure phases. BMPs and water management structures will be effective in controlling erosion and sedimentation, but to be conservative, it is predicted that some effects to aquatic organisms will occur from increases in the concentration of suspended material and the deposition of material in the freshwater environment. However, these effects will be sporadic and restricted to the immediate receiving environment of Brucejack Creek, and aquatic resources are expected to recover. The residual effect on aquatic resources from erosion and sedimentation is predicted to be not significant.

The residual effects from changes in surface water quantity, predicted from the quantitative site water balance model, will result in a short-term decrease in the available aquatic habitat in Brucejack Creek during the Closure phase. This decrease will be restricted to less than two years, and aquatic resources are predicted to fully recover. The residual effect on aquatic resources from these predicted changes in surface water quantity is assessed to be not significant.

The residual effects from changes in surface water quality, predicted from the quantitative water quality models, are associated with increases in the concentrations of arsenic, chromium, and zinc due to ML/ARD and increases in nutrient concentrations from blasting residues and operation of the STP.

Table 14.10-1. Summary of Project and Cumulative Residual Effects, Mitigation, and Significance for Aquatic Resources in the Mine Site Area and Off-site Project Infrastructure Areas

Residual Effects	Project Phase(s)	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Mine Site Area				
Erosion and sedimentation	Construction, Operation, Closure, Post-closure	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; • tailings deposition to the deepest section of Brucejack Lake (eastern portion of lake), with subaqueous discharge designed to add tailings to the deepest area into sand filter; and • implementation of Soil Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Not significant	N/A
Changes in surface water quantity	Closure	• Use of BMPs and engineered water management structures to maintain natural drainage networks, as much as feasible; • diversion of non-contact water into existing water courses; and • implementation of Water Management Plan (Section 29.19).	Not significant	N/A
Changes in surface water quality	Construction, Operation, Closure, Post-closure	• Implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Tailings Management Plan (Section 29.15), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3); and • collection and treatment of seepage from underground workings.	Not significant	N/A
Changes in sediment quality	Construction, Operation, Closure, Post-closure	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; • collection and treatment of site contact water and seepage from underground workings; and • implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Soil Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Not significant	N/A
Habitat loss	Construction, Operation, Closure	• Tailings deposition to the deepest section of Brucejack Lake (eastern portion of lake), with subaqueous discharge designed to add tailings to the deepest area into sand filter.	Not significant	N/A
Off-site Project Infrastructure areas				
Erosion and sedimentation	Construction, Operation, Closure	• Use of BMPs to minimize sediment entry to waterbodies; • dust suppression on roads; • tailings deposition to the deepest section of Brucejack Lake (eastern portion of lake), with subaqueous discharge designed to add tailings to the deepest area into sand filter; and • implementation of Soil Management Plan (Section 29.13), Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3).	Not significant	N/A
Changes in surface water quality	Construction, Operation, Closure	• Implementation of ML/ARD Management Plan (Section 29.10), Waste Rock Management Plan (Section 29.18), Tailings Management Plan (Section 29.15), Water Management Plan (Section 29.19), and Aquatic Effects Monitoring Plan (Section 29.3)	Not significant	N/A

Although the increases in metal concentrations may be greater than relevant BC water quality guidelines, the subsequent effects on aquatic organisms are predicted to be modest, short-lived, and aquatic resources are predicted to fully recover once metal concentrations in Brucejack Creek decrease. The predicted increases in nutrient concentrations are not predicted to substantially change the biomass and productivity of primary producers because phosphorus levels are not predicted to change substantially compared to baseline conditions and because other biophysical processes such as dynamic flows and grazing are predicted to continue to exert control on the primary producer community. The residual effects on aquatic resources from ML/ARD and nutrient loading are predicted to be not significant.

The residual effects from changes in sediment quality are predicted to be minor because of the elevated natural sediment metal concentrations and the relatively small predicted changes in water quality, suspended sediment concentrations and stream flows. The potential for additional changes from the Project are minor and predicted to be within the range of natural variation when the natural background of sediment metal concentrations are considered. Therefore, the residual effects on aquatic resources from changes in sediment quality are predicted to be not significant.

The residual effects from habitat loss are predicted to result from the deposition of waste rock and tailings in Brucejack Lake. This habitat loss will occur across the majority of the bottom of the lake, and will only be reversible by natural re-colonization over longer time scales. However, the ecological context of Brucejack Lake is low—it is a typical high-alpine, fishless lake with no known unique ecological features. As a result, the residual effect is considered to be not significant.

In the off-site Project infrastructure areas, the residual effects from erosion and sedimentation, ML/ARD, and nutrient loading are predicted to be not significant. Although Project activities may result in short-term increases in the concentrations of suspended material, metals, or nutrients, the mitigation and management measures are predicted to be largely effective, and the increases will be short-term and spatially restricted to the freshwater environment local to the Project infrastructure. Aquatic resources are predicted to be resilient to these modest changes in sediment loading and water quality.

Based on the environmental effects assessment, the residual effects of Project activities on aquatic resources for the mine site area is assessed as not significant, and the residual effect for off-site Project infrastructure areas is assessed as not significant.

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2002a. *Environmental Assessment Act*, SBC. C. 43.

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