13. SURFACE WATER QUALITY EFFECTS ASSESSMENT

13.1 INTRODUCTION

Surface water quality is a vital component of the biophysical and human environment and is protected under provincial and federal legislation. The physical and chemical constituents of water are important in determining aquatic ecosystem productivity, fish and aquatic life habitat quality, and toxicity. Surface water is highly valued by First Nations, local residents, and the provincial and federal governments.

This chapter presents the baseline surface water quality conditions, effects scoping process, and assessment of potential effects on surface water quality as a result of the proposed Harper Creek Project (the Project). It is based on baseline data collected for the Project, which is presented in Appendices 13-A and 13-B. Surface water quality is a Valued Component (VC) that is used to inform the effects assessment for other VCs (e.g., fish and fish habitat, wildlife and wildlife habitat, vegetation, aquatic resources, groundwater quality, and human health). This chapter follows the effects assessment methodology described in Chapter 8 of this Application for an Environmental Assessment Certificate / Environmental Impact Statement (Application/EIS).

13.2 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 surface water quality effects (summarized in Table 13.2-1).

Table 13.2-1. Surface Water Quality Legislation, Regulations, Policy, Standards, and Guidelines

Name	Level of Government	Description
BC *Water Act* (1996b)	Provincial	Under the British Columbia (BC) *Water Act*, the ownership of water is vested in the Crown; the Act provides statutes governing the allocation of water licences and controls the use of freshwater in the province of BC. The Act also includes explicit environmental protection for waters flowing in a stream, lake, or other surface body of water.
Canada Water Act (1985a)	Federal	Management of the water resources including research and the planning and implementation of programs relating to the conservation, development, and utilization of water resources.
Environmental Management Act (2003)	Provincial	Prohibits pollution of the environment and requires authorization to introduce waste into the environment for "prescribed" industries, trades, businesses, operations, and activities.

(continued)

Table 13.2-1. Surface Water Legislation, Regulations, Policy, Standards, and Guidelines (continued)

Name	Level of Government	Description
Fisheries Act (1985b)	Federal	The *Measures to Avoid Causing Harm to Fish and Fish Habitat* guidance (DFO 2013) supports changes made to the *Fisheries Act* (1985) in 2012. The changes to the *Fisheries Act* include a prohibition against causing serious harm to fish that are part of or support a commercial, recreational, or Aboriginal fishery (Section 35 of the *Fisheries Act*); provisions for flow and passage (Sections 20 and 21 of the *Fisheries Act*); and a framework for regulatory decision-making (Sections 6 and 6.1 of the *Fisheries Act*). These provisions guide the Minister's decision-making process in order to provide for sustainable and productive fisheries. Section 36(3) of the Act states "no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish." The Metal Mining Effluent Regulations (MMER; SOR/2002-222) regulate the deposition of mine effluent and specify authorized limits for deleterious substances listed in Schedule 4. 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 effect monitoring (EEM) requirements to evaluate the potential effects of effluent on fish, fish habitat, and the use of fisheries resources.
Mines Act (1996a)	Provincial	The BC *Mines Act* and its associated Health, Safety and Reclamation Code for Mines in BC (BC MEMPR 2008) 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 (ML/ARD), and prevention of erosion and sediment release. Watercourses are required to be reclaimed, and the Ministry of Energy and Mines (BC MEM) has the authority to require monitoring and/or remediation programs to protect watercourses and water quality.
BC Water Quality Guidelines (WQG; Approved and Working; BC MOE 2006, 2014)	Provincial	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, drinking water supply, and wildlife water supply.
CCME Water Quality Guidelines (CCME 2014)	Federal	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 Canadian Council of Ministers of the Environment (CCME) recommendations and EQGs should not be regarded as blanket values for national environmental quality (CCME 1999); users of EQGs consider local conditions and other supporting information (e.g., site-specific background concentrations of naturally occurring substances) during the implementation. Science-based, site-specific criteria, guidelines, objectives, or standards may, therefore, differ from the Canadian EQGs.

(continued)

Table 13.2-1. Surface Water Legislation, Regulations, Policy, Standards, and Guidelines (completed)

Name	Level of Government	Description
Guidelines for Canadian Drinking Water Quality (Health Canada 2012)	Federal	Guidelines established based on current, published scientific research related to health effects, aesthetic effects, and operational considerations. Criteria include exposure leading to adverse health effects in humans, frequently detected in Canadian drinking water supplies and could be detected at a level that is of possible human health significance.
Policy for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia (BC MEM and BC MOE 1998)	Provincial	Provides guidance on determining the potential for ML/ARD, and measures to prevent or reduce its occurrence to satisfy conditions of the *Mines Act* (1996a).
Guidelines for Metal Leaching and Acid Rock Drainage in British Columbia (Price and Errington 1998)	Provincial (BC MEM)	Describes generic requirements and outlines common errors, omissions, and constraints. Assist mines in developing comprehensive proposals that include the necessary documentation and consideration of risk for sound environmental management.
Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (Price 2009)	Federal	Guidance on the strengths and potential limitations of different procedures, analyses, tests, and criteria used to predict future drainage chemistry.
Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators (BC MOE 2012a)	Provincial	Outlines and defines the baseline study requirements and information considerations necessary to propose a mineral development project in BC. Covers information requirements for surficial hydrology, water quality (physical and chemical parameters), aquatic sediments, tissue residues, and aquatic life.

13.3 SCOPING THE EFFECTS ASSESSMENT

13.3.1 Valued Components

The British Columbia Environmental Assessment Office (BC EAO) define VCs as components "that are considered important by the proponent, public, First Nations, scientists, and government agencies involved in the assessment process" (BC EAO 2013). To be included in the Application/EIS, there must be a perceived likelihood that the VC will be affected by the proposed Project. VCs proposed for assessment were identified in the Application Information Requirements (AIR; BC EAO 2011) and in the CEA Agency (2011) Background Information scoping document.

13.3.1.1 Consultation Feedback on Proposed Valued Components

VCs are scoped into the EA based on potential Project interactions that were identified as issues or concerns raised during the EA pre-application phase and through consultation activities with Aboriginal communities, government agencies, the public, and stakeholders (refer to Chapter 3, Information Distribution and Consultation, Appendices 3-F, 3-J, and 3-L), in addition to scientific knowledge, past experience on other mining projects, and professional judgment.

Surface water quality is a critical component of the biological and physical environment and a change in surface water quality could adversely affect other valued ecosystem components such as fish and fish habitat, aquatic resources, wildlife and wildlife habitat, wetlands, groundwater quality, and human health. Surface water quality was selected as a VC based on issues raised during consultation and the potential for Project-related effects. Surface water quality is highly valued by First Nations, local residents, and government agencies. The Simpcw First Nation (SFN), Neskonlith Indian Band (NIB), and Adams Lake Indian Band (ALIB) raised issues related to the downstream effects of water quality, including in Harper and Baker creeks and the North Thompson River, groundwater seepage into the downstream receiving environment, and potential ML/ARD affecting water quality. Provincial and federal government agencies raised issues related to ML/ARD effects, groundwater seepage, downstream water quality effects (including in the initial dilution zone), and sedimentation and erosion. Issues raised by the public included the potential for ML/ARD to affect water quality. A summary of how scoping feedback was incorporated into the selection of assessment subject areas and VCs is summarized below in Table 13.3-1.

Table 13.3-1. Consultation Feedback on Proposed Valued Component(s)

Subject Area	Feedback by*			Issues Raised	Proponent Response
	AG	G	P/S		
Surface Water	X	X	X	ML/ARD effects on water quality	The model used to assess effects on water quality included source terms developed from characterization of ML/ARD potential.
	X	X		Groundwater seepage from Project Site into nearby waterways	The model used to assess effects on water quality included groundwater seepage from the tailings management facility (TMF) and open pit.
	X			Downstream effects on water quality	Water quality in waterbodies downstream of the Project was assessed.
		X		Water quality effects in the initial dilution zone	Effects on water quality immediately downstream of Project components were assessed.
		X		Sediment or particulates in surface runoff	Effects on water quality due to sedimentation or erosion were assessed.

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

Proposed Project components and activities have the potential to affect surface water quality during Construction, Operations, Closure, and Post-Closure (Table 13.3-2). Note that potential interactions between the Project and surface water quality resulting from spills and accidents involving large quantities of water, hazardous materials, concentrate, fuel, tailings, and/or sediment are not considered in the assessment of effects on the surface water quality VC, as these are related to occurrences of low likelihood outside of normal operating conditions. These occurrences are addressed in Chapter 26 (Environmental Effects of Accidents and Malfunctions) as well as in the Spill Prevention and Response Plan (Section 24.15).

Table 13.3-2. **Identification and Rationale for Selection of Surface Water Quality as a Valued Component**

Category	Project Components and Activities	Surface Water Quality
Construction		
Concrete production	Concrete batch plant installation, operation and decommissioning	
Dangerous goods and hazardous materials	Hazardous materials storage, transport, and off-site disposal	
	Spills and emergency management	
Environmental management and monitoring	Construction of fish habitat offsetting sites	X
Equipment	On-site equipment and vehicle use: heavy machinery and trucks	
Explosives	Explosives storage and use	X
Fuel supply, storage and distribution	Fuel supply, storage and distribution	
Open pit	Open pit development - drilling, blasting, hauling and dumping	X
Potable water supply	Process and potable water supply, distribution and storage	
Power supply	Auxiliary electricity - diesel generators	
	Power line and site distribution line construction: vegetation clearing, access, poles, conductors, tie-in	X
Processing	Plant construction: mill building, mill feed conveyor, truck shop, warehouse, substation, and pipelines	X
	Primary crusher and overland feed conveyor installation	
Procurement and labour	Employment and labour	
	Procurement of goods and services	
Project Site development	Aggregate sources/ borrow sites: drilling, blasting, extraction, hauling, crushing	X
	Clearing vegetation, stripping and stockpiling topsoil and overburden, soil salvage handling and storage	X
	Earth moving: excavation, drilling, grading, trenching, backfilling	X
Rail load-out facility	Rail load-out facility upgrade and site preparation	X
Roads	New TMF access road construction: widening, clearing, earth moving, culvert installation using non-PAG material	X

(continued)

Table 13.3-2. Identification and Rationale for Selection of Surface Water Quality Valued Components (continued)

Category	Project Components and Activities	Surface Water Quality
Construction *(cont'd)*		
Roads	Road upgrades, maintenance and use: haul and access roads	X
Stockpiles	Coarse ore stockpile construction	X
	Non-PAG Waste Rock Stockpile construction	X
	PAG and Non-PAG Low-grade ore stockpiles foundation construction	X
	PAG Waste Rock stockpiles foundation construction	X
Tailings management	Coffer dam and South TMF embankment construction	X
	Tailings distribution system construction	X
Temporary construction camp	Construction camp construction, operation, and decommissioning	X
Traffic	Traffic delivering equipment, materials and personnel to site	X
Waste disposal	Waste management: garbage, incinerator and sewage waste facilities	X
Water management	Ditches, sumps, pipelines, pump systems, reclaim system and snow clearing/stockpiling	
	Water management pond, sediment pond, diversion channels and collection channels construction	X
Operations 1		
Concentrate transport	Concentrate transport by road from mine to rail loadout	
Dangerous goods and hazardous materials	Explosives storage and use	X
	Hazardous materials storage, transport, and off-site disposal	
	Spills and emergency management	
Environmental management and monitoring	Fish habitat offsetting site monitoring and maintenance	X
Equipment fleet	Mine site mobile equipment (excluding mining fleet) and vehicle use	
Fuel supply, storage and distribution	Fuel storage and distribution	
Mining	Mine pit operations: blast, shovel and haul	X
Ore processing	Ore crushing, milling, conveyance and processing	X

(continued)

Table 13.3-2. Identification and Rationale for Selection of Surface Water Quality Valued Components (continued)

Category	Project Components and Activities	Surface Water Quality
Operations 1 ***(cont'd)***		
Potable water supply	Process and potable water supply, distribution and storage	
Power supply	Backup diesel generators	
	Electrical power distribution	
Processing	Plant operation: mill building, truck shop, warehouse and pipelines	
Procurement and labour	Employment and labour	
	Procurement of goods and services	
Rail load-out facility	Rail-load out activity (loading of concentrate; movement of rail cars on siding)	
Reclamation and decommissioning	Progressive mine reclamation	X
Stockpiles	Construction of Non-PAG tailings beaches	X
	Construction of PAG and Non-PAG Low Grade Ore Stockpile	X
	Non-PAG Waste Rock Stockpiling	X
	Overburden stockpiling	X
Tailings management	Reclaim barge and pumping from TMF to Plant Site	X
	South TMF embankment construction	X
	Sub-aqueous deposition of PAG waste rock into TMF	X
	Tailings transport and storage in TMF	X
	Treatment and recycling of supernatant TMF water	X
Traffic	Traffic delivering equipment, materials and personnel to site	
Waste disposal	Waste management: garbage and sewage waste facilities	X
Water management	Monitoring and maintenance of mine drainage and seepage	X
	Surface water management and diversions systems including snow stockpiling/clearing	
Processing	Low grade ore crushing, milling and processing	X

(continued)

Table 13.3-2. **Identification and Rationale for Selection of Surface Water Quality Valued Components (continued)**

Category	Project Components and Activities	Surface Water Quality
Operations 2	***Includes the Operations 1 non-mining Project Components and Activities, with the addition of these activities:***	
Reclamation and decommissioning	Partial reclamation of Non-PAG waste rock stockpile	X
	Partial reclamation of TMF tailings beaches and embankments	X
Tailings management	Construction of North TMF embankment and beach	X
	Deposit of low grade ore tailings into open pit	X
Water management	Surface water management	
Closure		
Environmental management and monitoring	Environmental monitoring including surface and groundwater monitoring	
	Monitoring and maintenance of mine drainage, seepage, and discharge	X
	Reclamation monitoring and maintenance	X
Open pit	Filling of open pit with water and storage of water as a pit lake	X
Procurement and labour	Employment and labour	
	Procurement of goods and services	
Reclamation and decommissioning	Decommissioning of rail concentrate loadout area	X
	Partial decommissioning and reclamation of mine site roads	X
	Decommissioning and removal of plant site, processing plant and mill, substation, conveyor, primary crusher, and ancillary infrastructure (e.g., explosives facility, truck shop)	X
	Decommissioning of diversion channels and distribution pipelines	X
	Decommissioning of reclaim barge	
	Reclamation of Non-PAG LGO stockpile, overburden stockpile and Non-PAG waste rock stockpile	X
	Reclamation of TMF embankments and beaches	X
	Removal of contaminated soil	X
	Use of topsoil for reclamation	X

(continued)

Table 13.3-2. Identification and Rationale for Selection of Surface Water Quality Valued Components (completed)

Category	Project Components and Activities	Surface Water Quality
Closure ***(cont'd)***		
Stockpiles	Storage of waste rock in the non-PAG waste rock stockpile	X
Tailings management	Construction and activation of TMF closure spillway	X
	Maintenance and monitoring of TMF	X
	Storage of water in the TMF and groundwater seepage	X
	Sub-aqueous tailing and waste rock storage in TMF	X
	TMF discharge to T-Creek	X
Waste disposal	Solid waste management	
Post-Closure		
Environmental management and monitoring	Environmental monitoring including surface and groundwater monitoring	
	Monitoring and maintenance of mine drainage, seepage, and discharge	X
	Reclamation monitoring and maintenance	X
Open pit	Construction of emergency spillway on open pit	X
	Storage of water as a pit lake	X
Procurement and labour	Procurement of goods and services	
Stockpiles	Storage of waste rock in the non-PAG waste rock stockpile	X
Tailings management	Storage of water in the TMF and groundwater seepage	X
	Sub-aqueous tailing and waste rock storage	X
	TMF discharge	X

Note: a column is marked with an X when it has been determined that the Project component or activity could potentially interact with the VC.

Through a review of relevant regulations and guidelines, scientific literature, other recent Application/EIS documents in BC, as well as professional experience and judgement, surface water was selected for inclusion as a single VC, rather than assessing individual physical or chemical components (Table 13.3-3). No potential VCs were excluded from further assessment.

Table 13.3-3. Valued Components Selected for Assessment

Assessment Category	Subject Area	Valued Components
Environment	Surface water	Surface water quality

13.3.2 Defining Assessment Boundaries

Assessment boundaries define the maximum limit within which the effects assessment and supporting studies (e.g., predictive models) are conducted. Boundaries encompass where and when the Project is expected to interact with the VCs, any political, social, and economic constraints, and limitations in predicting or measuring changes. Boundaries relevant to surface water quality are described below.

13.3.2.1 Temporal Boundaries

Temporal boundaries, provided in Table 13.3-4, are the time periods considered in the assessment for various Project phases and activities. Temporal boundaries reflect those periods during which planned Project activities are reasonably expected to potentially affect a VC. Potential effects to surface water quality will be considered for each phase of the Project as described in Table 13.3-4.

Table 13.3-4. Temporal Boundaries used in the Assessment for Surface Water Quality

Phase	Project Year	Length of Phase	Description of Activities
Construction	-2 and -1	2 years	Pre-construction and construction activities
Operations 1	1 - 23	23 years	Active mining in the open pit from Year 1 through to Year 23.
Operations 2	24 - 28	5 years	Low-grade ore (LGO) processing from the end of active mining through to the end of Year 28.
Closure	29 – 35	7 years	Active closure and reclamation activities while the open pit and TMF are filling.
Post-Closure	36 onwards	50 years	Steady-state, long-term closure condition following active closure, with ongoing monitoring.

13.3.2.2 Spatial Boundaries

<u>Project Site</u>

The Project Site is defined by a buffer of 500 metres (m) around the primary Project components. Project components include the open pit; the open pit haul road, primary crusher, and ore conveyor; mill plant site with ore processing facilities and intake/outtake pipelines; tailings management facility (TMF); overburden, topsoil, potentially acid-generating (PAG) waste rock, non-PAG waste rock stockpiles; and non-PAG and PAG low-grade ore stockpiles.

Local Study Area

The surface water quality local study area (LSA) was selected to focus on the Project Site and infrastructure and surrounding area within which there is a reasonable potential for immediate direct and indirect effects on surface water quality due to an interaction with Project components or activities. he surface water quality LSA (Figure 13.3-1) includes the Harper Creek watershed to its confluence with the Barrière River, and Baker Creek and Jones Creek watersheds to their confluence with the North Thompson River. The LSA includes a 500-m buffer around the linear Project components (e.g., roads) that are outside of the Project Site. Within the LSA, the Project has the potential to have quantifiable effects on surface water quality.

Regional Study Area

The surface water quality RSA was selected as the spatial area within which there is potential for direct and indirect interaction and/or cumulative effects to occur. The RSA encompasses the LSA and includes the Barrière River watershed to its mouth and the North Thompson River watershed to Birch Island (Figure 13.3-1).

13.3.2.3 Administrative and Technical Boundaries

No administrative or technical boundaries were applied to the surface water quality effects assessment.

13.4 BASELINE CONDITIONS

13.4.1 Regional and Historical Setting

The Project is located within the Shuswap Highlands in the western foothills of the Columbia Mountains, a transitional region between the interior plateaus and the Rocky Mountain ranges. The Shuswap Highland region is generally characterized by gently or moderately sloping plateau areas rising from 1,220 metres above sea level (masl) to over 2,135 masl, and is intersected by a system of rivers and dotted with numerous lakes.

The Project is primarily located on the watershed divide between Harper Creek and the North Thompson River at elevations between approximately 1,600 masl and 1,800 masl (KP 2013). Figure 13.3-1 shows the location of both waterways with respect to the Project location. The majority of the proposed infrastructure is exclusively in the Harper Creek watershed (which includes the subwatersheds of P Creek and T Creek); however, a portion of the open pit, overburden stockpiles and water management activities will overlap in the Baker Creek and Jones Creek watersheds (Figure 13.4-1). Additionally, a portion of the surface runoff from the mine's access road and power line corridors also flows into Avery and Chuck creeks. Avery Creek is approximately 4 km to the east of the Project Site and is physically separated from the direct influence of the Project Site, but is adjacent to the two proposed power line options. Chuck Creek is further east of Avery Creek and is also physically separated from the direct influence of the Project Site approximately 7 km, but is adjacent to the existing Vavenby Mountain FSR and the mine access road.

Figure 13.3-1

Project Site, Local and Regional Study Areas for the Surface Water Quality Effects Assessment

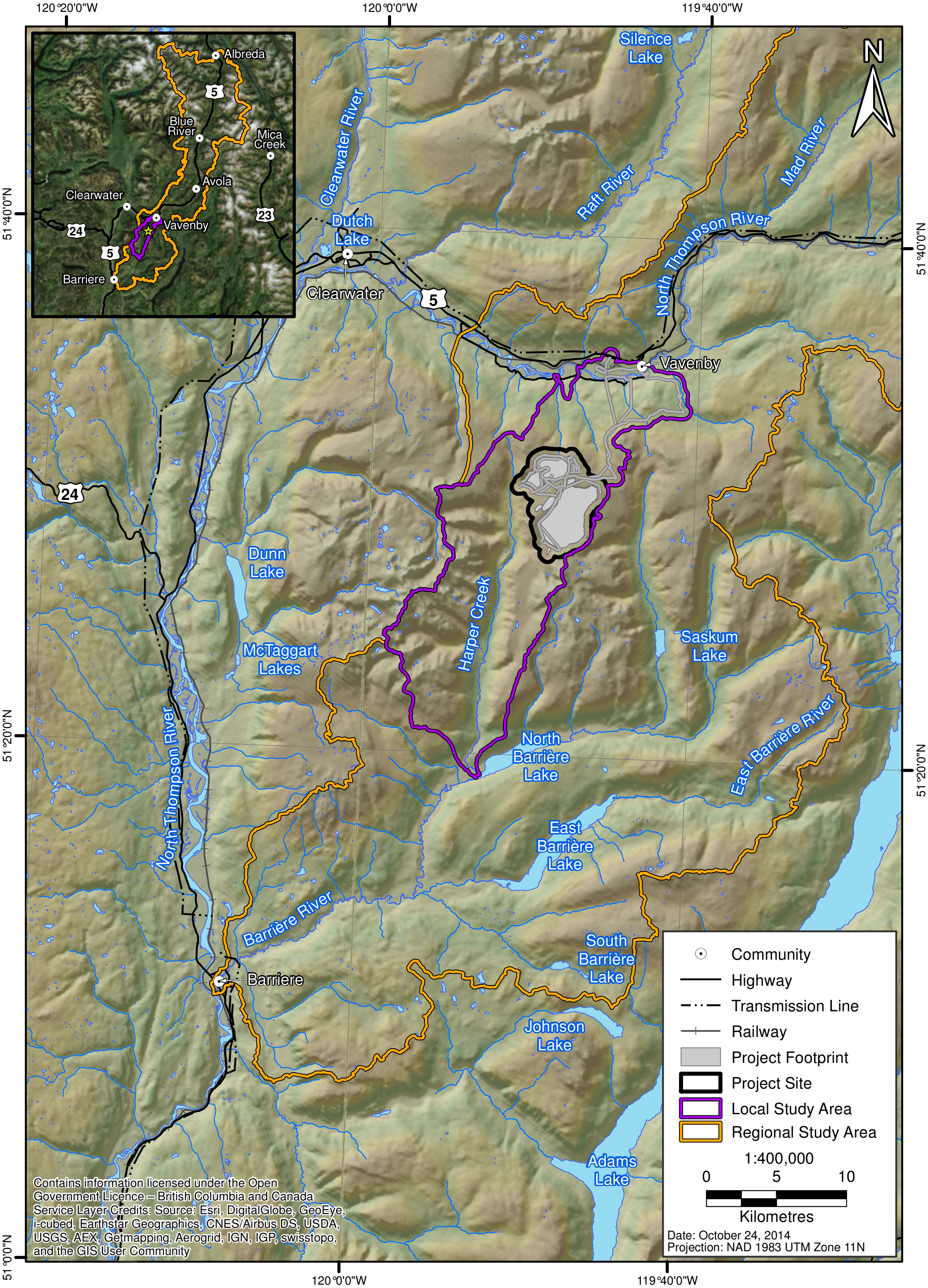
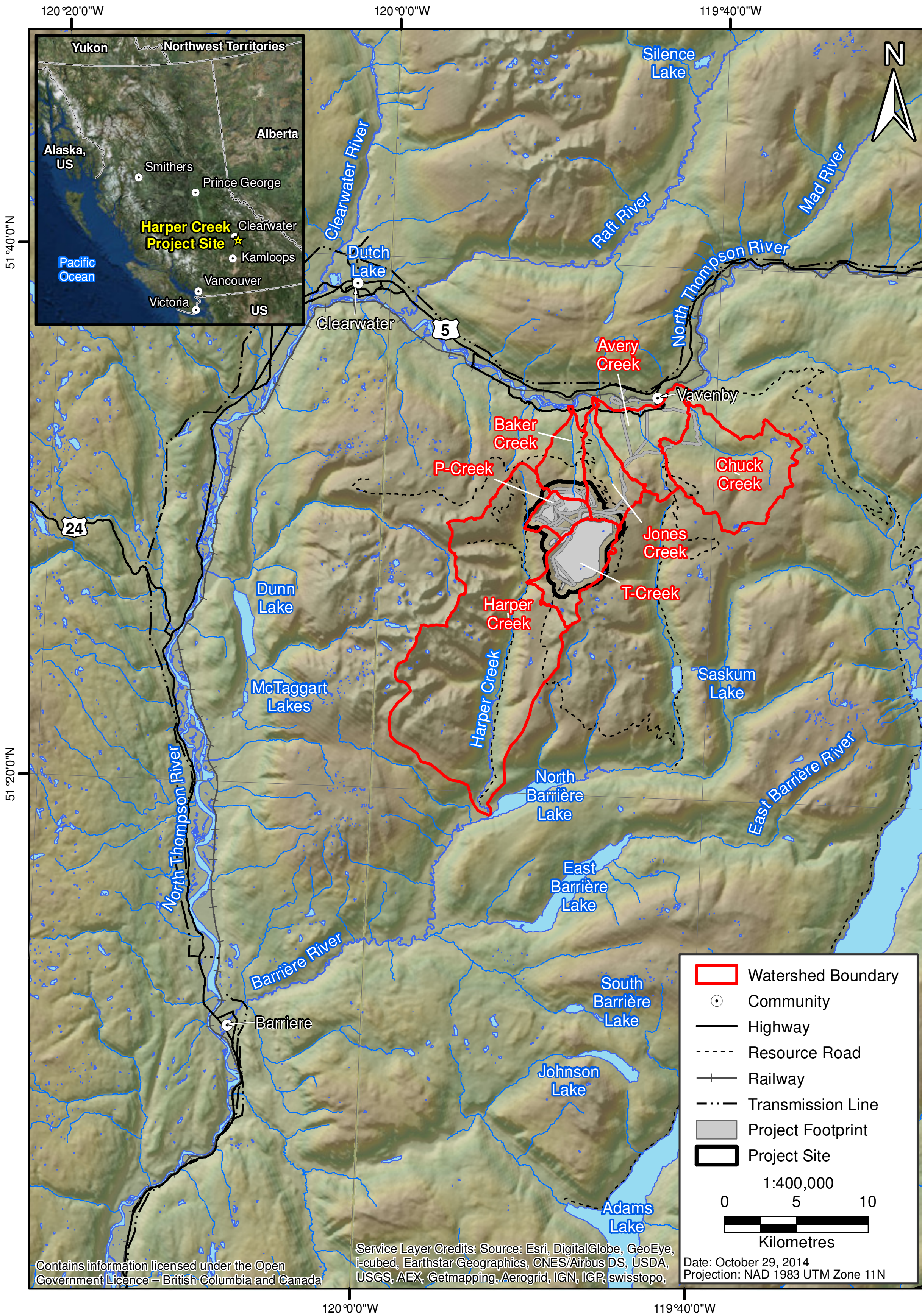


Figure 13.4-1

Project Location and Surrounding Watersheds



Harper Creek flows south from the Project Site approximately 25 km and discharges into the western end of North Barrière Lake, upstream of the lake outlet. Its watershed is approximately 186 square kilometres (km^{2}) in area and is defined by steep mountain catchments, with the main stem channel confined by valley hill slopes throughout much of its length. The catchment is covered in coniferous forest with extensive logging on the east side of the watershed (see Figure 18.4-6 in Chapter 18, Commercial and Non-commercial Land Use Effects Assessment). The west side of the watershed consists of higher mountains with some exposed rock in alpine regions. The Barrière River flows in a southerly direction along the eastern extent of the Project area and through Saskum Lake before heading west into North Barrière Lake. The Barrière River ultimately receives water from the Harper Creek watershed when it exits the lake. From the lake it flows in a southwesterly direction for approximately 25 km, and then merges with the North Thompson River roughly 58 km north-northeast of Kamloops, BC. Jones and Baker creeks both drain smaller (17.6 km^2 and 14.3 km^2, respectively) north-facing watersheds and flow approximately 5 km from their headwaters at the mine site to the North Thompson River. Both catchments are covered in coniferous forest with some logging activity. Additionally, some farming activity is present in the lower section of the watersheds and a few small intakes remove water from the lower sections of Baker Creek and Jones Creek for irrigation (see Figure 18.4-11). The North Thompson River is the largest river system common to all surface waters down-gradient from the Project. In general, the Project Site drains south through Harper Creek and the Barrière River to the North Thompson River at the town of Barriere, or north through Baker Creek or Jones Creek to the North Thompson River near Vavenby (Figure 13.3-1).

The region is underlain predominantly by gneiss, granite, granodiorite, and quartz monzonite bedrock (KP 2013). An inclusion of phyllite, limestone, greenstone, and schist bedrock is found in the lower North Thompson River area and some basalt bedrock is found in the Clearwater River area. Additional geology information is presented in Chapter 5, Project Description. Elevations range from slightly below 500 masl, along the North Thompson River, to slightly above 2,000 masl in the Saskum Plateau area.

Weather systems in the region typically track from west to east; precipitation and runoff generally increase with elevation as weather systems are forced up and over the Columbia Mountains. Temperatures are cool with a mean annual temperature near 0°C. Minimum (winter) and maximum (summer) mean monthly temperatures in the vicinity around the Project Site are approximately -10°C (December) and 10°C (July) respectively. The mean annual precipitation at the Project Site is estimated to be near 1,050 millimetres (mm), with 40% falling as rain and 60% as snow (KP 2013; Appendix 9-B).

Regional runoff patterns are characterized by the various seasonal inputs: low flows during the winter months (December to March), when precipitation falls almost exclusively as snow; high flows during the spring and early summer (April to June) due to the snowmelt freshet; low flows during the dry late summer months (July to August); and moderate flows during the fall months (September to November), as precipitation increases. The change in runoff with elevation is also quite evident with lower runoff from lower-elevation watersheds and an earlier onset of the spring freshet from warm spring temperatures arriving earlier at the lower elevations. The annual hydrograph in the region has a unimodal shape, with the majority of runoff occurring in May and June during the snowmelt freshet (KP 2013; Appendix 12-C).

13.4.2 Baseline Studies

13.4.2.1 Data Sources

Baseline surface water quality data have been collected for the Project since June 2007. Data presented in this section are drawn from the following sources:

- Harper Creek Project: Surface Water Quality Baseline Report (Appendix 13-A), which presents data collected from June 2007 through January 2014; and
- Harper Creek Project: 2014 Baseline Data Update (Appendix 13-B), which presents data collected from February 2014 to June 2014.

Data collection is ongoing; however, only data collected through June 2014 have been included within this description of baseline studies. Historical surface water quality data were not available to supplement the site-specific water quality baseline program; however, site-specific data collection exceeds the requirements outlined in provincial guidance documents (BC MOE 2012b).

13.4.2.2 Methods

The primary objective of the baseline study was to characterize the spatial and temporal variability of surface water quality in the lakes and streams of the RSA that comprise the surface waters downstream of the proposed Project infrastructure and activities. Sampling was focused on watercourses that have the potential to be affected by Project activities.

<u>Sampling Locations</u>

Nineteen creek and river sites have been actively sampled as part of the baseline surface water program (Figure 13.4-1; Table 13.4-1). In addition, one site on North Barrière Lake has also been included in the baseline program due to its proximity to the Project.

The waterbodies were characterized in three principal study areas based on both differing aquatic environmental characteristics and potential effects from Project activities:

1. The Harper Creek area, which primarily includes Harper Creek and is connected to the P Creek and T Creek watersheds (sites H4P, H5, H2, H3T, and H1).
2. The Barrière River and North Barrière Lake area (sites S1, S2, NB1/2, and B1).
3. The North Thompson area, which contains the Baker Creek and Jones Creek watersheds and includes the five creeks and rivers to the north of the Project (North Thompson River, Baker Creek, Jones Creek, Avery Creek, and Chuck Creek).

Figure 13.4-2

Surface Water Quality Sampling Locations, 2007 to 2014

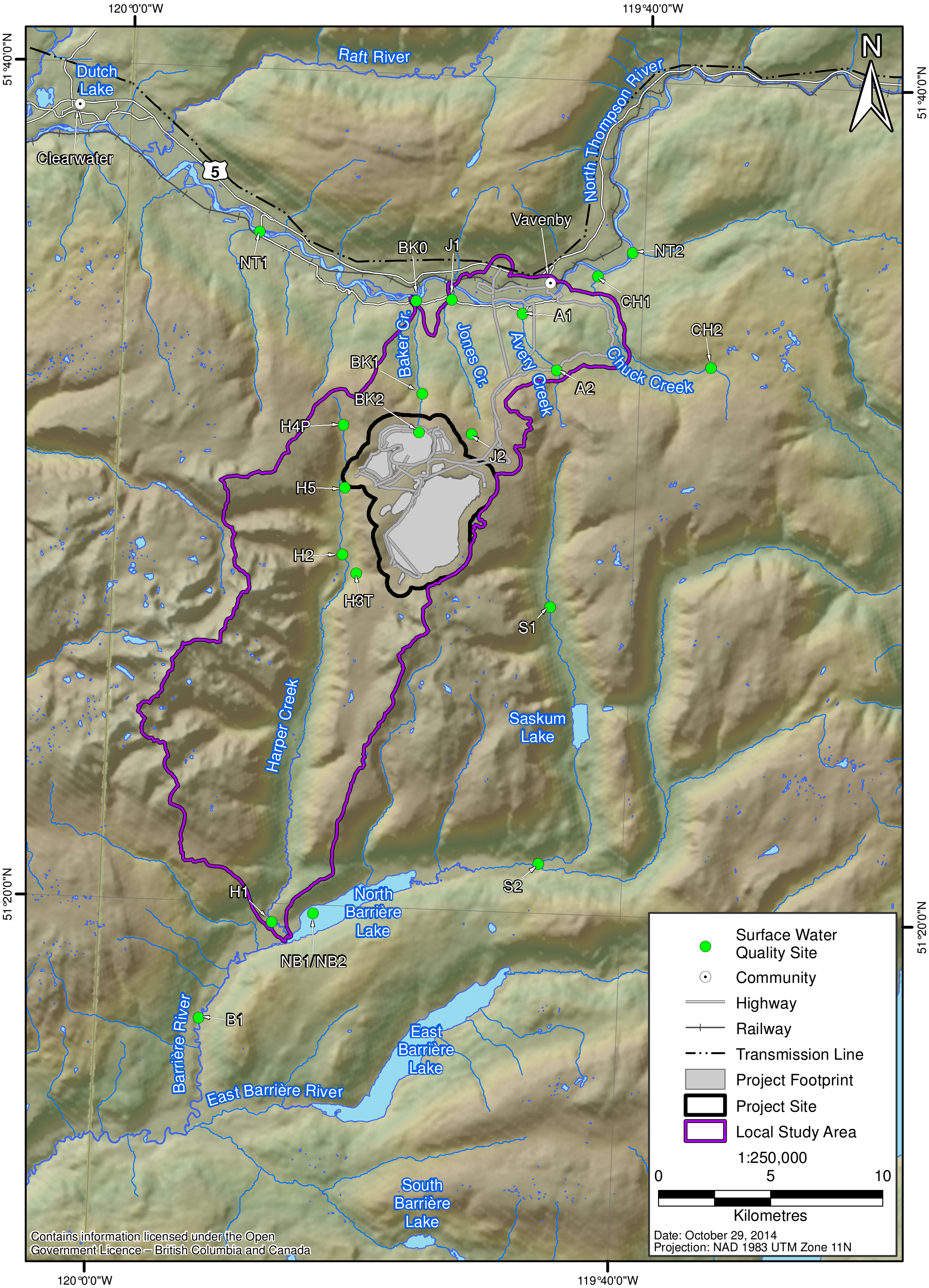


Table 13.4-1. Surface Water Quality Sampling Locations, 2007 to 2014

Area	Site ID	Easting*	Northing*	Site Description
Harper Creek	H4P	301901	5712179	Northern tributary to Upper Harper Creek, above main pit location
	H5	301963	5709396	On P Creek tributary flowing from main pit to Upper Harper Creek
	H2	301854	5706430	Upper Harper Creek, above T Creek inflow
	H3T	302453	5705574	On T Creek tributary flowing from TMF to Upper Harper Creek
	H1	298703	5690094	Lower Harper Creek, off the upstream side of the bridge, near the water gauge
	S1	311128	5704065	Upper Barrière River, upstream of Saskum Lake
	S2	310596	5692641	Mid Barrière River, downstream of Saskum Lake at Fennell Creek tributary
	NB1	300530	5690441	North Barrière Lake (Deep)
	NB2	300530	5690441	North Barrière Lake (Shallow)
	B1	295425	5685822	Lower Barrière River, downstream of North Barrière Lake
North Thompson	NT2	314795	5719814	North Thompson River, East Extent
	CH2	318296	5714728	Upper Chuck Creek
	CH1	313260	5718777	Lower Chuck Creek
	A2	311413	5714619	Upper Avery Creek
	A1	309888	5717130	Lower Avery Creek
	J2	307608	5711771	Upper Jones Creek
	J1	306725	5717764	Lower Jones Creek
	BK2	305246	5711864	Upper/Upper Baker
	BK1	305401	5713585	Upper Baker Creek
	BK0	305137	5717702	Lower Baker Creek
	NT1	298175	5720784	North Thompson River, West extent

Harper Creek Area

Three sites were sampled along the Harper Creek mainstem: upstream of potential effects from Project-related facilities (site H4P), downstream of its confluence with P Creek and upstream of its confluence with T-Creek (H2), and in its lower reaches immediately upstream of its discharge into the western end of North Barrière Lake (H1). P Creek and T Creek, which drain the western extent of the proposed open pit area and the TMF, were also sampled in their lower reaches (H5 and H3T; Table 13.4-1).

Barrière River and North Barrière Lake Area

Three sites were sampled along the Barrière River: upstream of potential effects from Project-related activities (S1 and S2), and downstream of North Barrière Lake and its inflow from Harper Creek (B1). One site was also sampled within North Barrière Lake, at both shallow (NB2) and deep (NB1) depths (Table 13.4-1).

North Thompson Area

The North Thompson River was sampled both upstream (NT2) and downstream (NT1) of tributaries that drain from the Project Site to the north. Tributaries sampled include (from east to west): Avery Creek (A2 and A1), Chuck Creek (CH2 and CH1), Jones Creek (J2 and J1), and Baker Creek (BK2, BK1, and BK0). Tributaries sampled included those that receive runoff from the proposed Project Site (Jones and Baker) and those that receive a portion of the runoff from access road (Chuck Creek) and power line (Avery Creek) corridors. Each tributary was sampled in its upper and lower reaches.

Surface Water Quality Sampling Methodology

Surface water quality sampling methodologies are described in detail in the baseline report (Appendix 13-A). Physical limnology (temperature, dissolved oxygen, and conductivity) and surface water quality data were collected from 19 creek/river sites and one lake sampling site upstream and downstream of the Project Site. A minimum of two years of water quality data were collected for all surface waterbodies potentially affected by Project infrastructure and up to seven years of data exist for some sites (see Appendices 13-A and 13-B for details).

The surface water quality program and sampling protocols were implemented following the specific guidelines for field sampling:

- the *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia* (RIC 1998);
- the British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-emission, Water, Wastewater, Soil, Sediment and Biological Samples (BC MWLAP 2003); and
- the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2012).

In situ physical variables were routinely measured for each stream station using three different regularly calibrated instruments: a Hannah pH meter to measure temperature, pH, and conductivity; a LaMotte 2020e turbidity meter to measure turbidity; and an Oxyguard Handy Gamma DO probe to measure dissolved oxygen. Lake temperature, specific conductivity, and dissolved oxygen data were collected using a YSI 650 handheld logger and multi-parameter sonde. Lake profiles were collected from the lake surface to approximately 45 m in depth in 2011 and 49 m in depth in 2012.

Stream water quality samples were collected by inserting the bottle neck into the water with the bottle faced downstream, then turning the bottle under water so that it faced upstream. The bottle remained submerged until full. Dissolved metals were filtered using a 60-mL syringe fitted with a 0.45-µm filter. Nitrile gloves were worn during the sampling. North Barrière Lake water samples were collected using a Van Dorn sampler in 2011 and a Kemmerer sampler in 2012. The quality assurance and quality control (QA/QC) program for the baseline included the use of sample blanks and sample replication as outlined in Appendix 13-A, Surface Water Quality Baseline Report.

Water samples were submitted to Cantest Ltd. (2008 to 2009), Maxxam Analytics (2008, 2011 to 2012), or ALS laboratories (2007 to 2008, 2012 to 2014) in Vancouver, BC for the analysis of physical variables, dissolved anions, nutrients, total metals, dissolved metals, cyanides, and organic carbon.

Surface Water Quality Sampling Data Analysis

Surface water quality samples were compared to available federal and BC guidelines for the protection of freshwater aquatic life (Table 13.4-2; BC MOE 2006, 2014; CCME 2014), drinking water (Table 13.4-3; BC MOE 2006; Health Canada 2012; BC MOE 2014), and wildlife water supply (Table 13.4-4; BC MOE 2006, 2014).

Table 13.4-2. Federal and Provincial Water Quality Guidelines for the Protection of Freshwater Aquatic Life

Parameter	CCME Guideline for the Protection of Freshwater Aquatic Life[a]	BC Water Quality Guidelines[b]
Physical Tests		
pH	6.5 to 9.0	6.5 to 9.0
Total Suspended Solids	Dependent on background levels[c]	Dependent on background levels[k]
Turbidity (NTU)	Dependent on background levels[d]	Dependent on background levels[l]
Anions		
Chloride (Cl)	640 short-term; 120 long-term	600 maximum; 150 30-day
Fluoride (F)	0.12[e]	Hardness dependent[m]
Sulphate (SO_4)	-	Hardness dependent[n]
Nutrients		
Ammonia, Total (as N)	pH- and temperature-dependent	pH- and temperature-dependent
Nitrate (as N)	124 short-term; 3 long-term	32.8 maximum; 3.0 30-day
Nitrite (as N)	0.06	Chloride dependent[o]
Phosphorus (P)-Total	Trigger ranges[f]	-
Cyanides		
Cyanide, Weak Acid Dissociable	-	0.01 maximum; 0.005 30-day
Cyanide, Free	0.005	-
Organic / Inorganic Carbon		
Total Organic Carbon	-	Dependent on background levels[p]
Total Metals		
Aluminum (Al)	0.005 if pH < 6.5; 0.1 if pH ≥ 6.5	-
Antimony (Sb)	-	0.02[w]
Arsenic (As)	0.005	0.005
Barium (Ba)	-	5 maximum; 1 30-day [w]
Beryllium (Be)	-	0.0053[w]
Boron (B)	29 short-term; 1.5 long-term	1.2
Cadmium (Cd)	Hardness dependent[g]	Hardness dependent[w,x]
Chromium (Cr)	0.001 (Cr(VI)); 0.0089 (Cr(III)[e])	0.001 (Cr(VI)); 0.0089 (Cr(III)[w])

(continued)

Table 13.4-2. Federal and Provincial Water Quality Guidelines for the Protection of Freshwater Aquatic Life (continued)

Parameter	CCME Guideline for the Protection of Freshwater Aquatic Life[a]	BC Water Quality Guidelines[b]
Total Metals *(cont'd)*		
Cobalt (Co)	-	0.11 maximum; 0.004 30-day
Copper (Cu)	Hardness dependent[h]	Hardness dependent[q]
Iron (Fe)	0.3	1
Lead (Pb)	Hardness dependent[i]	Hardness dependent[r]
Lithium (Li)	-	0.87 maximum; 0.096 chronic [w]
Manganese (Mn)	-	Hardness dependent[s]
Mercury (Hg)	0.000026	0.00002 if MeHg = 0.5% THg 0.00001 if MeHg = 1.0% of THg 0.00000125 if MeHg = 8.0% of THg
Molybdenum (Mo)	0.073[e]	2 maximum; ≤1 30-day
Nickel (Ni)	Hardness dependent[j]	Hardness dependent [w,y]
Selenium (Se)	0.001	0.002
Silver (Ag)	0.0001	Hardness dependent[t]
Thallium (Tl)	0.0008	0.0003 objective; 0.0008 30-day [w]
Uranium (U)	0.033 short-term; 0.015 long-term	0.3 maximum; 0.5 objective [w]
Vanadium (V)	-	0.006[w]
Zinc (Zn)	0.03	Hardness dependent[u]
Dissolved Metals		
Aluminum (Al)	-	pH-dependent[v]
Iron (Fe)	-	0.35
Cadmium (Cd)		Hardness dependent[‡]

Notes:

[a] Canadian water quality guideline for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, accessed June 2014; all units are in mg/L unless otherwise noted.

[b] British Columbia guideline for the protection of freshwater aquatic life, accessed June 2014.

[c] TSS - in clear flow, maximum increase of 25 mg/L from background levels for short-term exposure (e.g. 24 h period). Maximum average increase of 5 mg/L from background levels for long-term exposure (e.g. 30 d period). In high flow, maximum increase of 25 mg/L from background levels between 25-250 mg/L. If background is ≥250 mg/L, TSS should not increase more than 10% of background levels.

[d] Turbidity - in clear flow maximum increase of 8 NTUs from background levels for short-term exposure (e.g. 24 h period). Maximum average increase of 2 NTUs from background levels for a long-term exposure (e.g. 30 d period). In high flow, maximum increase of 8 NTUs from background levels between 8 to 80 NTUs. If background is > 80 NTUs, turbidity should not increase more than 10%.

[e] Interim guideline.

[f] Phosphorus - trigger ranges: <0.004 mg/L ultra-oligotrophic; 0.004-0.01 mg/L oligotrophic; 0.01-0.02 mg/L mesotrophic; 0.02-0.035 mg/L meso-eutrophic; 0.035-0.1 mg/L eutrophic; >0.1 mg/L hyper-eutrophic.

[g] Cadmium - short-term cadmium concentration = $10^{1.016[\log(hardness)]-1.71}$ */ 1000 mg/L. If hardness is <5.3 mg/L, the guideline is 0.00011 mg/L; if hardness is >360 mg/L, the guideline is 0.0077 mg/L. Long-term cadmium concentration =* $10^{0.83[\log(hardness)]-2.46}$ */ 1000 mg/L. If hardness is <17 mg/L, the guideline is 0.00004 mg/L; if hardness is >280 mg/L, the guideline is 0.00037 mg/L.*

(continued)

Table 13.4-2. Federal and Provincial Water Quality Guidelines for the Protection of Freshwater Aquatic Life (completed)

[h] *Copper - copper concentration =* $e^{0.8545[\ln(hardness)]-1.465}$ ** 0.0002 mg/L. If hardness is <82 mg/L, the guideline is 0.002 mg/L; if hardness is >180 mg/L, the guideline is 0.004 mg/L. If water hardness is not known, the guideline is 0.002 mg/L.*

[i] *Lead - lead concentration =* $e^{1.273[\ln(hardness)]-4.705}$ */ 1000 mg/L. If hardness is ≤60 mg/L, the guideline is 0.001 mg/L; if hardness is >180 mg/L, the guideline is 0.007 mg/L. If water hardness is not known, the guideline is 0.001 mg/L.*

[j] *Nickel - nickel concentration =* $e^{0.76[\ln(hardness)]+1.06}$ */ 1000 mg/L. If hardness is ≤60 mg/L, the guideline is 0.025 mg/L; if hardness is >180 mg/L, the guideline is 0.15 mg/L. If water hardness is not known, the guideline is 0.025 mg/L.*

[k] *TSS - in clear waters, change from background for 24-h period is 25 mg/L and 5 mg/L for 30-day period; if background is 25-100 mg/L then change from background of 10 mg/L; if background > 100 mg/L then change from background of 10%.*

[l] *Turbidity - in clear waters, change from background for 24-h period is 8 NTU and 2 NTU for 30-day period; if background is 8-50 NTU then change from background is 5 NTU; if background > 50 NTU then change from background of 10%.*

[m] *Fluoride - if hardness (as* $CaCO_3$*) is 10 mg/L the maximum concentration is 0.4 mg/L; otherwise* $LC_{50} = -51.73 + 92.57 \log_{10}$ *(hardness) * 0.01 mg/L.*

[n] *Sulphate - if hardness is very soft (0-30 mg/L) the guideline is 128 mg/L; if soft to moderately soft (31-75 mg/L) then 218 mg/L; if moderately soft/hard to hard (76-180 mg/L) then 309 mg/L; if very hard (181-250 mg/L) then 429 mg/L; if hardness >250 mg/L then the guideline needs to be determined based on site water.*

[o] *Nitrite - maximum guideline: if chloride <2 mg/L the guideline is 0.06 mg/L, if chloride 2-4 mg/L then 0.12 mg/L, if chloride 4-6 mg/L then 0.18 mg/L, if chloride 6-8 mg/L then 0.24 mg/L, if chloride 8-10 mg/L then 0.3 mg/L and if chloride >10 mg/L then 0.6 mg/L. 30-day guideline: if chloride <2 mg/L the guideline is 0.02 mg/L, if chloride 2-4 mg/L then 0.04 mg/L, if chloride 4-6 mg/L then 0.06 mg/L, if chloride 6-8 mg/L then 0.08 mg/L, if chloride 8-10 mg/L then 0.1 mg/L and if chloride >10 mg/L then 0.2 mg/L.*

[p] *Organic carbon (total and dissolved) - the 30-day median ± 20% of the median background concentration.*

[q] *Copper - the maximum concentration is 0.094(hardness)+2 / 1000 mg/L. If average water hardness (as* $CaCO_3$*) ≤ 50 mg/L the 30-day mean is ≤ 0.002 mg/L; if average water hardness is > 50 mg/L the 30-day mean is ≤ 0.00004(mean hardness) mg/L.*

[r] *Lead - if hardness (as* $CaCO_3$*) is ≤ 8 mg/L the maximum concentration is 0.003 mg/L; if hardness is > 8 mg/L the maximum concentration is* $e^{1.273\ln(hardness)-1.460}$ */ 1000 mg/L and the 30-day mean is 3.31+*$e^{1.273\ln(mean[hardness])-4.704}$ */ 1000 mg/L.*

[s] *Manganese - manganese concentration maximum = 0.01102(hardness)+0.54 mg/L and the 30-day mean concentration = 0.0044(hardness)+0.605 mg/L.*

[t] *Silver - if hardness is ≤ 100 mg/L the maximum concentration is 0.0001 mg/L and the 30-day mean is 0.00005 mg/L; if hardness > 100 mg/L the maximum concentration is 0.003 mg/L and the 30-day mean is 0.0015 mg/L.*

[u] *Zinc - 30-day mean concentration = 7.5 + 0.75(hardness - 90) / 1000 mg/L; maximum concentration = 33 + 0.75(hardness - 90) / 1000 mg/L.*

[v] *Dissolved aluminum - if pH ≥ 6.5 the maximum concentration is 0.1 mg/L and the 30-day mean is 0.05 mg/L; if pH < 6.5 the maximum concentration is* $e^{(1.209 - 2.426pH + 0.286 K)}$ *mg/L where K = (pH)*^{2} *and the 30-day mean is* $e^{1.6 - 3.327 (median\ pH) + 0.402 K)}$ *mg/L where K = (median pH)*^{2}*.*

[w] *Working guideline*

[x] *Cadium -* $10^{0.86(\log(hardness)-3.2}$ */ 1000 mg/L.*

[y] *Nickel - If hardness is ≤60 mg/L, the guideline is 0.025 mg/L; if hardness is 60-120 mg/L, the guideline is 0.065 mg/L; if hardness is 120-180 mg/L, the guideline is 0.11 mg/L; if hardness >180 mg/L, the guideline is 0.15 mg/L.*

[‡] *Dissolved cadium (Draft guideline June 2014)- (long-term 30-day average)=* $e^{0.762\times \ln(Hardness)-6.07}$ */ 1000 mg/L; (short-term maximum)=* $e^{1.04\times \ln(Hardness)-5.87}$ */ 1000 mg/L.*

Summary statistics were calculated using the mean of each duplicate pair where duplicate samples were collected. These means were also used during screening against provincial and federal water quality guidelines. Values below detection limits were replaced with half the detection limit in all analyses. If sample results were below analytical detection and analytical detection limits were greater than provincial or federal guidelines, the data were excluded from the guideline screening process.

Table 13.4-3. Federal and Provincial Water Quality Guidelines for Drinking Water

Parameter	Health Canada[a]	British Columbia[b]
Physical Tests		
pH	6.5 - 8.5	6.5 - 8.5
Total Dissolved Solids	500[c]	-
Turbidity (NTU)	0.1	Background dependent[e]
Anions		
Chloride (Cl)	250[c]	250
Fluoride (F)	1.5	maximum 1.5; 1 30-day
Sulphate (SO_4)	500[c]	500
Nutrients		
Nitrate (as N)	10	-
Nitrite (as N)	1	1
Nitrate+Nitrite (as N)	-	10
Phosphorus, Total	-	0.01
Cyanides		
Cyanide, Total	0.2	-
Cyanide, Strong-acid dissociable + Thiocyanate	-	0.2
Total Metals		
Aluminum (Al)	0.1[d]	-
Antimony	0.006	-
Arsenic (As)	0.01	0.025[f]
Barium (Ba)	1	-
Boron (B)	5	5
Cadmium (Cd)	0.005	-
Chromium (Cr)	0.05	-
Copper (Cu)	1[c]	0.5
Iron (Fe)	0.3[c]	-
Lead (Pb)	0.01	0.05
Manganese (Mn)	0.05[c]	-
Mercury (Hg)	0.001	0.001
Molybdenum (Mo)	-	0.25
Selenium (Se)	0.01	0.01
Sodium (Na)	200[c]	-
Thallium (Tl)	-	0.002[g]
Uranium (U)	0.02	-
Zinc (Zn)	5[c]	5
Dissolved Metals		
Aluminum (Al)	-	0.2

(continued)

Table 13.4-3. Federal and Provincial Water Quality Guidelines for Drinking Water (completed)

Notes:
[a] Health Canada guidelines for drinking water quality, accessed September 2014. All units in mg/L unless otherwise noted.
[b] British Columbia guideline for drinking water supply, accessed September 2014.
[c] Aesthetic objective
[d] Operational guidance value for conventional treatment; <0.2 mg/L for other treatment types.
[e] Raw drinking water with treatment to remove particulates: change from background of 5 NTU when background is ≤50 NTU; change from background of 10% when background is >50 NTU. Raw drinking water without treatment to remove particulates: change from background of 1 NTU when background is ≤5 NTU; change from background of 5 NTU at any time.
[f] Interim guideline.
[g] Working guideline.

Table 13.4-4. Provincial Water Quality Guidelines for Wildlife Water Supply

Parameter	Maximum	30-Day Mean
Anions		
Chloride	600	-
Fluoride	1.5	1
Nutrients		
Nitrate (as N)	100	-
Nitrite (as N)	10	-
Organic Carbon		
Total Organic Carbon	Dependent on background levels[a]	-
Total Metals		
Aluminum (Al)	5	-
Arsenic (As)	0.025[b]	-
Boron (B)	5	-
Copper (Cu)	0.3	-
Lead (Pb)	0.1	-
Mercury (Hg)	-	0.00002 if MeHg = 0.5% THg 0.00001 if MeHg = 1.0% of THg 0.00000125 if MeHg = 8.0% of THg
Molybdenum (Mo)	0.05	-
Selenium (Se)	0.002	-

Notes:
All units in mg/L.
[b] Organic carbon (total and dissolved) - the 30-day median ±20% of the median background concentration.
[a] Interim guideline.

13.4.3 Existing Conditions

Surface water quality data baseline data collected for the Project are available in Appendices 13-A and 13-B, and summarized below in the context of the Harper Creek, the Barrière River and North Barrière Lake area and North Thompson areas.

Harper Creek Area

Harper Creek area stream temperatures exhibited expected seasonal temperature variations with highs recorded in June to August and lows recorded during December to March. Higher-altitude sites were cooler compared to downstream sites, particularly during summer. For example, in Harper Creek the difference between the highest elevation site (H4P) and lowest elevation site (H1) was over 4°C during the months of July and August (Appendix 13-A). Dissolved oxygen concentrations were similar among sites and varied seasonally but were consistently greater than the CCME and BC guideline for the protection of aquatic life (6.5 mg/L; BC MOE 2006, 2014; CCME 2014).

Study streams had near-neutral to slightly alkaline pH (median range 7.45 to 7.94) with varying sensitivities to acid inputs (median alkalinity range of 17 mg/L $CaCO_3$ to 66 mg/L $CaCO_3$). Waters were soft to moderately hard (median range 10 mg/L $CaCO_3$ to 88 mg/L $CaCO_3$ hardness). Anions measured in the baseline program included chloride, fluoride, and sulphate; concentrations were generally low in the Harper Creek area, with sulphate being generally dominant (median range 1.4 mg/L to 10.4 mg/L). Waters were very clear within the Harper Creek area throughout the sampling years. TSS concentrations were often below analytical detection and median turbidity ranged from 0.2 NTU to 0.4 NTU among Harper Creek sites (Table 13.4-5). Temporally, pH, alkalinity, and concentrations of anions were generally lowest during freshet high flows (May to July) and greatest during low-flow periods, which likely reflected increased discharge of tributaries during the freshet period, as well as snow melt and heavy rainfall events that diluted concentrations of major ions. Conversely turbidity was highest during the freshet period (May to June) due to the greater volumes of discharge within streams. Spatially, pH, total alkalinity, hardness, and sulphate concentrations decreased with downstream distance from the Project Site. Alkalinity and water hardness were similar to that of the area but low in comparison to most creek tributaries in the North Thompson area. Concentrations of cyanide species (total, free, and WAD) were low at all sites and generally below detection limits.

During most sampling events, the waters in the Harper Creek area were nutrient poor and ultra-oligotrophic to oligotrophic (phosphorus < 0.004 – 0.01 mg/L) but reached mesotrophic to eutrophic status at times. Nitrate generally made up the greatest concentration of inorganic nitrogen, followed by ammonia and nitrite, which were often below analytical detection at Harper Creek area sites. Nitrate tended to decrease downstream within the Harper Creek area from site H4P (median 0.2040 mg/L) to site H1 (median 0.0445 mg/L; Table 13.4-5).

Concentrations of anions, cyanides, and organic carbon were lower than BC and CCME guidelines for the protection of freshwater aquatic life and wildlife water supply at Harper Creek area sites (BC MOE 2006, 2014; CCME 2014). Turbidity and total phosphorus concentrations were greater than Health Canada guidelines for drinking water in a subset of samples from all Harper Creek sites (Health Canada 2012).

Table 13.4-5. Surface Water Quality Summary, 2007 to June 2014

Parameter	Lake Sampling	pH		Conductivity (µS/cm)		Hardness (as $CaCO_3$)		Alkalinity, Total (as $CaCO_3$)		Total Suspended Solids (TSS)		Total Dissolved Solids (TDS)		Turbidity (NTU)		Chloride (Cl)		Fluoride (F)		Sulphate (SO_4)		Total Ammonia (as N)		Nitrate (as N)		Nitrite (as N)		Nitrate + Nitrite (as N)	
Stat	Depth	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Harper Creek Area																													
Site HP4	-	7.94	8.07	130	159	66	81	61	69	0.5	3.0	79.0	95.7	0.2	0.6	0.25	0.52	0.03	0.04	10.4	14.6	0.0025	0.0578	0.2040	0.5370	0.0005	0.0025	0.2085	0.5415
Site H5	-	7.71	7.92	92	116	44	55	35	43	0.5	9.3	55.8	75.9	0.4	3.7	0.25	0.54	0.03	0.04	10.0	15.0	0.0025	0.0337	0.0850	0.1732	0.0005	0.0025	0.0850	0.1732
Site H2	-	7.69	7.87	81	104	36	46	33	41	0.5	5.9	49.0	62.7	0.2	1.7	0.25	0.84	0.03	0.04	7.3	10.5	0.0025	0.0390	0.1275	0.3345	0.0005	0.0025	0.1450	0.3508
Site H3T	-	7.49	7.74	40	52	17	23	17	24	0.5	6.8	31.5	39.7	0.2	1.2	0.25	0.60	0.01	0.03	1.4	2.6	0.0025	0.0510	0.0100	0.1020	0.0005	0.0025	0.0100	0.1044
Site H1	-	7.45	7.88	45	64	18	26	18	29	1.5	6.1	33.0	49.0	0.4	1.6	0.25	0.63	0.04	0.05	2.5	4.0	0.0072	0.0288	0.0445	0.1417	0.0005	0.0025	0.0567	0.1556
Barriere Area																													
Site S1	-	7.69	8.01	72	96	35	45	33	46	1.5	12.9	38.5	56.0	0.4	2.1	0.25	0.84	0.04	0.06	2.3	4.4	0.0100	0.0458	0.1150	0.2575	0.0005	0.0025	0.1070	0.2592
Site S2	-	7.65	7.93	62	84	28	37	28	40	1.5	6.2	41.0	51.0	0.6	1.9	0.25	1.35	0.04	0.06	1.6	2.6	0.0100	0.0360	0.0700	0.1443	0.0010	0.0025	0.0735	0.1155
NB1/2	1 m	7.56	7.61	46	49	19	19	22	24	0.5	0.5	35.0	35.0	0.3	0.3	0.70	0.70	0.04	0.05	1.6	2.1	0.0130	0.0562	0.0100	0.0110	0.0025	0.0025	0.0100	0.0100
	4.5 m	7.65	7.65	48	48	24	24	22	22	0.5	0.5	37.5	37.5	0.4	0.4	0.25	0.25	0.04	0.04	1.8	1.8	0.0052	0.0052	0.0025	0.0025	0.0005	0.0005	0.0026	0.0026
	8 m	7.73	7.73	43	43	21	21	20	20	0.5	0.5	34.0	34.0	0.3	0.3	0.25	0.25	0.04	0.04	1.6	1.6	0.0025	0.0025	0.0025	0.0025	0.0005	0.0005	0.0026	0.0026
	20 m	7.55	7.69	56	61	22	22	31	33	0.5	0.5	-	-	0.3	0.4	0.43	0.58	0.05	0.05	2.4	2.6	0.0180	0.0207	0.0650	0.0695	0.0025	0.0025	0.0650	0.0695
	24.5 m	7.73	7.73	51	51	25	25	23	23	0.5	0.5	41.0	41.0	0.3	0.3	0.25	0.25	0.05	0.05	2.0	2.0	0.0025	0.0025	0.0725	0.0725	0.0005	0.0005	0.0725	0.0725
	25 m	7.61	7.61	54	54	23	23	25	25	0.5	0.5	44.0	44.0	0.4	0.4	0.25	0.25	0.05	0.05	2.1	2.1	0.0025	0.0025	0.0663	0.0663	0.0005	0.0005	-	-
Site B1	-	7.61	7.86	54	66	24	31	24	31	2.4	23.6	36.5	44.8	0.7	4.9	0.25	0.80	0.04	0.05	2.2	4.3	0.0111	0.0358	0.0402	0.0871	0.0025	0.0025	0.0402	0.0871
North Thompson Area																													
Site NT2	-	7.56	7.93	61	107	25	46	19	41	14.9	132.8	42.0	69.0	4.4	22.9	0.25	1.17	0.05	0.11	6.7	11.9	0.0054	0.0294	0.1500	0.2796	0.0005	0.0025	0.1500	0.2796
Site A2	-	8.01	8.19	153	184	81	102	74	96	1.0	4.8	73.5	106.4	0.4	1.5	0.25	0.70	0.02	0.02	3.0	4.9	0.0092	0.0548	0.0448	0.1524	0.0025	0.0025	0.0448	0.1524
Site A1	-	8.10	8.23	210	250	113	138	102	129	1.5	10.2	96.0	148.5	0.2	5.4	0.25	0.83	0.03	0.04	6.9	13.8	0.0100	0.0460	0.0121	0.0470	0.0008	0.0025	0.0100	0.0506
Site CH2	-	7.49	7.97	57	93	31	46	26	43	1.0	20.9	41.0	56.0	0.4	3.3	0.25	0.70	0.04	0.05	3.3	6.3	0.0079	0.0363	0.0100	0.1296	0.0025	0.0025	0.0284	0.1296
Site CH1	-	8.07	8.36	165	262	92	149	71	135	1.0	19.0	70.0	154.3	0.9	4.8	0.25	0.70	0.03	0.04	4.6	10.4	0.0118	0.0390	0.0316	0.1345	0.0025	0.0025	0.0316	0.1345
Site J2	-	7.38	7.67	32	45	16	21	12	16	1.5	5.9	29.0	47.0	0.4	2.5	0.25	0.75	0.01	0.03	3.3	5.6	0.0050	0.0263	0.0100	0.0361	0.0005	0.0025	0.0100	0.0374
Site J1	-	8.11	8.34	220	288	118	165	101	134	1.5	43.2	122.0	177.4	0.5	16.5	0.25	0.67	0.04	0.05	13.6	25.6	0.0039	0.0280	0.0100	0.0790	0.0005	0.0025	0.0100	0.0802
Site BK2	-	7.30	7.42	26	31	13	15	9	13	1.5	7.7	-	-	0.2	1.1	0.25	0.71	0.01	0.02	2.6	3.5	0.0100	0.0730	0.0025	0.0194	0.0005	0.0009	-	-
Site BK1	-	8.14	8.29	187	228	101	125	91	114	1.4	22.4	100.5	134.9	0.3	12.9	0.25	0.80	0.03	0.03	6.6	9.3	0.0025	0.0273	0.0120	0.1248	0.0005	0.0025	0.0102	0.1309
Site BK0	-	8.21	8.37	261	318	132	176	130	152	1.5	40.9	139.5	196.1	0.3	13.4	0.25	0.84	0.04	0.05	12.6	21.2	0.0038	0.0360	0.0100	0.0507	0.0005	0.0025	0.0100	0.0533
Site NT1	-	7.52	7.82	51	107	24	48	17	38	24.7	62.5	43.0	71.4	6.6	23.6	0.25	1.55	0.05	0.10	6.4	12.5	0.0025	0.0369	0.1375	0.2709	0.0005	0.0025	0.1375	0.2709

(continued)

Table 13.4-5. Surface Water Quality Summary, 2007 to June 2014 (continued)

Parameter	Lake Sampling	Total Phosphorus (P)		Cyanide, Total		Cyanide, Weak Acid Dissociable		Cyanide and Thiocya-te		Cyanide, Free		Total Organic Carbon (TOC)		Aluminum, Total (Al)		Aluminum, Dissolved (Al)		Antimony, Total (Sb)		Arsenic, Total (As)		Barium, Total (Ba)		Beryllium, Total (Be)		Boron, Total (B)		Cadmium, Total (Cd)	
Stat	Depth	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Harper Creek Area																															
Site HP4	-	0.0025	0.0089	0.0025	0.0025	0.0025	0.0025	0.0003	0.0005	0.0025	0.0025	2.05	4.03	0.009	0.073	0.006	0.021	0.00005	0.00025	0.00025	0.00178	0.006	0.007	0.00005	0.00014	0.005	0.028	0.00001	0.00002
Site H5	-	0.0025	0.0095	0.0025	0.0025	0.0025	0.0025	0.0003	0.0012	0.0025	0.0025	2.22	4.25	0.025	0.280	0.010	0.038	0.00005	0.00025	0.00019	0.00056	0.009	0.011	0.00005	0.00005	0.005	0.025	0.00003	0.00006
Site H2	-	0.0025	0.0075	0.0025	0.0025	0.0025	0.0025	0.0003	0.0009	0.0025	0.0025	1.91	4.03	0.029	0.152	0.015	0.043	0.00005	0.00025	0.00049	0.00070	0.010	0.011	0.00005	0.00050	0.005	0.050	0.00001	0.00002
Site H3T	-	0.0025	0.0106	0.0025	0.0025	0.0025	0.0025	0.0003	0.0007	0.0025	0.0025	2.56	4.96	0.040	0.184	0.026	0.084	0.00005	0.00025	0.00011	0.00126	0.007	0.010	0.00005	0.00010	0.005	0.025	0.00001	0.00002
Site H1	-	0.0025	0.0103	0.0025	0.0025	0.0025	0.0025	0.0003	0.0011	0.0025	0.0025	1.86	4.05	0.045	0.196	0.025	0.077	0.00005	0.00025	0.00020	0.00097	0.006	0.010	0.00005	0.00050	0.005	0.050	0.00001	0.00003
Barriere Area																															
Site S1	-	0.0025	0.0197	0.0025	0.0025	0.0009	0.0025	0.0003	0.0011	0.0025	0.0025	2.62	3.58	0.035	0.266	0.012	0.046	0.00025	0.00025	0.00019	0.00029	0.008	0.010	0.00005	0.00050	0.025	0.050	0.00001	0.00003
Site S2	-	0.0025	0.0082	0.0025	0.0025	0.0005	0.0025	0.0003	0.0010	0.0025	0.0025	2.80	3.30	0.030	0.224	0.022	0.041	0.00025	0.00025	0.00015	0.00097	0.006	0.010	0.00005	0.00050	0.025	0.050	0.00001	0.00003
NB1/2	1 m	0.0025	0.0028	0.0025	0.0025	0.0003	0.0023	0.0002	0.0002	0.0025	0.0025	3.89	3.89	0.061	0.078	0.046	0.063	0.00025	0.00025	0.00012	0.00019	0.005	0.005	0.00005	0.00005	0.025	0.025	0.00004	0.00007
	4.5 m	0.0031	0.0031	0.0025	0.0025	0.0025	0.0025	-	-	0.0025	0.0025	2.69	2.69	0.040	0.040	0.033	0.033	0.00005	0.00005	0.00014	0.00014	0.005	0.005	0.00005	0.00005	0.005	0.005	0.00001	0.00001
	8 m	0.0028	0.0028	0.0025	0.0025	0.0025	0.0025	-	-	0.0025	0.0025	2.77	2.77	0.049	0.049	0.041	0.041	0.00005	0.00005	0.00014	0.00014	0.005	0.005	0.00005	0.00005	0.005	0.005	0.00001	0.00001
	20 m	0.0025	0.0025	-	-	0.0003	0.0003	0.0002	0.0002	-	-	-	-	0.055	0.059	0.039	0.042	0.00025	0.00025	0.00008	0.00010	0.005	0.005	0.00005	0.00005	0.025	0.025	0.00008	0.00010
	24.5 m	0.0028	0.0028	0.0025	0.0025	0.0025	0.0025	-	-	0.0025	0.0025	2.78	2.78	0.041	0.041	0.034	0.034	0.00005	0.00005	0.00012	0.00012	0.005	0.005	0.00005	0.00005	0.005	0.005	0.00001	0.00001
	25 m	0.0031	0.0031	0.0025	0.0025	0.0025	0.0025	-	-	0.0025	0.0025	3.90	3.90	0.052	0.052	0.031	0.031	0.00005	0.00005	0.00013	0.00013	0.005	0.005	0.00005	0.00005	0.005	0.005	0.00001	0.00001
Site B1	-	0.0025	0.0138	0.0025	0.0025	0.0006	0.0025	0.0003	0.0014	0.0025	0.0025	3.73	4.42	0.090	0.419	0.035	0.066	0.00005	0.00025	0.00019	0.00041	0.006	0.008	0.00005	0.00005	0.025	0.025	0.00001	0.00002
North Thompson Area																															
Site NT2	-	0.0078	0.0531	0.0025	0.0025	0.0025	0.0025	0.0003	0.0013	0.0025	0.0025	0.98	4.26	0.515	1.760	0.026	0.072	0.00005	0.00025	0.00005	0.00020	0.011	0.023	0.00005	0.00005	0.005	0.025	0.00001	0.00003
Site A2	-	0.0025	0.0060	0.0025	0.0025	0.0008	0.0025	0.0003	0.0010	0.0025	0.0025	3.16	4.48	0.041	0.097	0.011	0.027	0.00005	0.00025	0.00020	0.00033	0.018	0.025	0.00005	0.00005	0.025	0.025	0.00001	0.00001
Site A1	-	0.0027	0.0312	0.0025	0.0069	0.0011	0.0025	0.0003	0.0012	0.0025	0.0025	2.69	4.60	0.009	0.199	0.005	0.016	0.00010	0.00025	0.00025	0.00088	0.026	0.035	0.00005	0.00050	0.025	0.050	0.00001	0.00002
Site CH2	-	0.0025	0.0142	0.0025	0.0025	0.0013	0.0025	0.0003	0.0012	0.0025	0.0025	4.19	4.82	0.034	0.358	0.024	0.066	0.00005	0.00025	0.00014	0.00040	0.006	0.015	0.00005	0.00005	0.025	0.025	0.00001	0.00001
Site CH1	-	0.0025	0.0151	0.0025	0.0025	0.0007	0.0025	0.0003	0.0011	0.0025	0.0025	3.35	4.18	0.064	0.424	0.012	0.043	0.00005	0.00025	0.00024	0.00038	0.015	0.020	0.00005	0.00005	0.025	0.025	0.00001	0.00001
Site J2	-	0.0025	0.0086	0.0025	0.0025	0.0025	0.0025	0.0003	0.0010	0.0025	0.0025	3.74	4.80	0.034	0.168	0.024	0.088	0.00008	0.00025	0.00014	0.00032	0.005	0.010	0.00005	0.00050	0.005	0.050	0.00001	0.00002
Site J1	-	0.0025	0.0266	0.0025	0.0025	0.0025	0.0025	0.0003	0.0011	0.0025	0.0025	2.11	3.36	0.013	0.676	0.007	0.023	0.00005	0.00025	0.00025	0.00308	0.011	0.015	0.00005	0.00050	0.005	0.050	0.00001	0.00002
Site BK2	-	0.0028	0.0113	0.0025	0.0074	-	-	-	-	-	-	-	-	0.045	0.171	0.042	0.089	0.00025	0.00025	0.00025	0.00059	0.010	0.010	0.00050	0.00050	0.050	0.050	0.00001	0.00003
Site BK1	-	0.0025	0.0145	0.0025	0.0025	0.0025	0.0025	0.0003	0.0009	0.0025	0.0025	1.84	4.74	0.010	0.463	0.006	0.024	0.00005	0.00025	0.00022	0.00120	0.009	0.011	0.00005	0.00050	0.005	0.050	0.00001	0.00004
Site BK0	-	0.0025	0.0420	0.0025	0.0025	0.0025	0.0025	0.0003	0.0010	0.0025	0.0025	2.01	3.88	0.012	0.310	0.004	0.011	0.00005	0.00025	0.00025	0.00425	0.014	0.017	0.00005	0.00050	0.015	0.050	0.00001	0.00002
Site NT1	-	0.0117	0.0409	0.0025	0.0025	0.0025	0.0025	0.0003	0.0012	0.0025	0.0025	1.34	3.96	0.665	2.044	0.036	0.068	0.00005	0.00025	0.00005	0.00031	0.012	0.024	0.00005	0.00005	0.005	0.025	0.00001	0.00003

(continued)

Table 13.4-5. Surface Water Quality Summary, 2007 to June 2014 (continued)

Parameter	Lake Sampling	Chromium, Total (Cr)		Cobalt, Total (Co)		Copper, Total (Cu)		Iron, Total (Fe)		Iron, Dissolved (Fe)		Lead, Total (Pb)		Lithium, Total (Li)		Manganese, Total (Mn)		Mercury, Total (Hg)		Molybdenum, Total (Mo)		Nickel, Total (Ni)		Selenium, Total (Se)		Silver, Total (Ag)		Sodium, Total (-)	
Stat	Depth	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Harper Creek Area																													
Site HP4	-	0.00008	0.00050	0.00005	0.00025	0.0007	0.0021	0.006	0.073	0.005	0.015	0.00005	0.00026	0.00025	0.00250	0.0006	0.0041	0.00001	0.00001	0.00019	0.00050	0.0003	0.0006	0.00012	0.00024	0.000005	0.000024	0.9	1.2
Site H5	-	0.00016	0.00050	0.00005	0.00026	0.0036	0.0132	0.024	0.537	0.005	0.015	0.00010	0.00043	0.00025	0.00250	0.0014	0.0129	0.00001	0.00001	0.00015	0.00050	0.0005	0.0011	0.00015	0.00025	0.000005	0.000016	0.9	1.3
Site H2	-	0.00013	0.00050	0.00005	0.00025	0.0008	0.0034	0.026	0.217	0.008	0.018	0.00010	0.00025	0.00069	0.00250	0.0018	0.0077	0.00001	0.00001	0.00083	0.00124	0.0003	0.0005	0.00005	0.00050	0.000005	0.000016	1.2	1.9
Site H3T	-	0.00010	0.00050	0.00005	0.00025	0.0006	0.0010	0.021	0.141	0.012	0.036	0.00008	0.00055	0.00025	0.00250	0.0011	0.0112	0.00001	0.00002	0.00070	0.00150	0.0003	0.0005	0.00005	0.00019	0.000005	0.000025	0.9	1.3
Site H1	-	0.00015	0.00050	0.00005	0.00025	0.0005	0.0016	0.020	0.174	0.015	0.030	0.00010	0.00025	0.00158	0.00250	0.0011	0.0072	0.00001	0.00003	0.00196	0.00243	0.0003	0.0005	0.00005	0.00050	0.000005	0.000025	1.0	2.0
Barriere Area																													
Site S1	-	0.00050	0.00050	0.00015	0.00025	0.0005	0.0015	0.034	0.318	0.008	0.018	0.00010	0.00025	0.00250	0.00250	0.0029	0.0176	0.00001	0.00001	0.00200	0.00351	0.0005	0.0005	0.00005	0.00050	0.000010	0.000022	1.0	1.6
Site S2	-	0.00050	0.00050	0.00015	0.00025	0.0005	0.0015	0.043	0.207	0.017	0.030	0.00010	0.00030	0.00250	0.00339	0.0059	0.0171	0.00001	0.00003	0.00124	0.00170	0.0005	0.0005	0.00005	0.00050	0.000010	0.000025	1.2	2.1
NB1/2	1 m	0.00050	0.00050	0.00025	0.00025	0.0007	0.0015	0.038	0.039	0.026	0.060	0.00100	0.00802	0.00250	0.00250	0.0010	0.0018	0.00001	0.00002	0.00100	0.00100	0.0005	0.0005	0.00005	0.00005	0.000010	0.000010	1.1	1.2
	4.5 m	0.00009	0.00009	0.00005	0.00005	0.0012	0.0012	0.024	0.024	0.017	0.017	0.00003	0.00003	0.00169	0.00169	0.0015	0.0015	0.00001	0.00001	0.00120	0.00120	0.0003	0.0003	0.00005	0.00005	0.000005	0.000005	1.2	1.2
	8 m	0.00012	0.00012	0.00005	0.00005	0.0008	0.0008	0.032	0.032	0.021	0.021	0.00003	0.00003	0.00156	0.00156	0.0023	0.0023	0.00001	0.00001	0.00107	0.00107	0.0003	0.0003	0.00005	0.00005	0.000010	0.000010	1.1	1.1
	20 m	0.00050	0.00050	0.00025	0.00025	0.0009	0.0011	0.040	0.047	0.015	0.016	0.00070	0.00088	0.00250	0.00250	0.0025	0.0030	0.00002	0.00002	0.00075	0.00098	0.0008	0.0010	0.00005	0.00005	0.000010	0.000010	1.4	1.4
	24.5 m	0.00014	0.00014	0.00005	0.00005	0.0008	0.0008	0.025	0.025	0.012	0.012	0.00003	0.00003	0.00147	0.00147	0.0029	0.0029	0.00001	0.00001	0.00101	0.00101	0.0003	0.0003	0.00005	0.00005	0.000005	0.000005	1.3	1.3
	25 m	0.00005	0.00005	0.00005	0.00005	0.0003	0.0003	0.054	0.054	0.015	0.015	0.00003	0.00003	0.00159	0.00159	0.0031	0.0031	0.00001	0.00001	0.00102	0.00102	0.0003	0.0003	0.00005	0.00005	0.000005	0.000005	1.0	1.0
Site B1	-	0.00050	0.00074	0.00014	0.00027	0.0008	0.0027	0.080	0.565	0.023	0.035	0.00010	0.00104	0.00151	0.00250	0.0053	0.0175	0.00001	0.00002	0.00100	0.00135	0.0005	0.0010	0.00005	0.00006	0.000005	0.000015	1.3	1.6
North Thompson Area																													
Site NT2	-	0.00100	0.00378	0.00060	0.00172	0.0016	0.0037	0.745	2.662	0.043	0.125	0.00023	0.00099	0.00182	0.00338	0.0164	0.0537	0.00001	0.00001	0.00044	0.00064	0.0020	0.0043	0.00005	0.00008	0.000005	0.000014	0.8	1.9
Site A2	-	0.00023	0.00050	0.00005	0.00025	0.0005	0.0012	0.053	0.184	0.006	0.025	0.00003	0.00010	0.00025	0.00250	0.0038	0.0168	0.00001	0.00001	0.00022	0.00050	0.0003	0.0006	0.00005	0.00010	0.000005	0.000010	0.7	1.0
Site A1	-	0.00050	0.00061	0.00014	0.00027	0.0005	0.0018	0.015	0.466	0.005	0.017	0.00010	0.00028	0.00050	0.00250	0.0007	0.0172	0.00001	0.00001	0.00041	0.00050	0.0005	0.0019	0.00020	0.00050	0.000010	0.000025	0.9	1.1
Site CH2	-	0.00025	0.00275	0.00008	0.00025	0.0006	0.0033	0.115	0.640	0.045	0.072	0.00010	0.00157	0.00025	0.00250	0.0171	0.0367	0.00001	0.00003	0.00003	0.00050	0.0005	0.0010	0.00005	0.00005	0.000005	0.000010	0.8	1.2
Site CH1	-	0.00045	0.00090	0.00013	0.00044	0.0006	0.0015	0.105	0.814	0.005	0.039	0.00010	0.00050	0.00025	0.00250	0.0034	0.0280	0.00001	0.00001	0.00027	0.00050	0.0004	0.0018	0.00005	0.00009	0.000005	0.000010	0.9	1.6
Site J2	-	0.00029	0.00050	0.00014	0.00025	0.0009	0.0020	0.015	0.220	0.015	0.028	0.00010	0.00039	0.00025	0.00250	0.0011	0.0098	0.00001	0.00001	0.00005	0.00050	0.0005	0.0013	0.00005	0.00050	0.000010	0.000025	0.5	1.0
Site J1	-	0.00044	0.00170	0.00015	0.00085	0.0005	0.0027	0.015	1.504	0.005	0.015	0.00025	0.00214	0.00108	0.00250	0.0009	0.0459	0.00001	0.00002	0.00027	0.00050	0.0005	0.0022	0.00024	0.00050	0.000010	0.000025	1.0	1.8
Site BK2	-	0.00050	0.00050	0.00015	0.00015	0.0038	0.0060	0.015	0.201	0.015	0.061	0.00025	0.00036	0.00250	0.00250	0.0006	0.0100	0.00001	0.00001	0.00050	0.00050	0.0005	0.0011	0.00050	0.00050	0.000010	0.000025	1.0	1.0
Site BK1	-	0.00033	0.00083	0.00010	0.00052	0.0005	0.0029	0.015	0.982	0.005	0.016	0.00010	0.00122	0.00025	0.00250	0.0005	0.0280	0.00001	0.00001	0.00029	0.00050	0.0005	0.0022	0.00007	0.00050	0.000005	0.000017	1.0	1.3
Site BK0	-	0.00033	0.00090	0.00011	0.00057	0.0005	0.0024	0.015	0.693	0.005	0.015	0.00010	0.00121	0.00091	0.00250	0.0009	0.0381	0.00001	0.00003	0.00035	0.00050	0.0005	0.0015	0.00020	0.00050	0.000008	0.000025	1.2	2.2
Site NT1	-	0.00129	0.00406	0.00068	0.00182	0.0016	0.0041	0.953	2.921	0.043	0.127	0.00031	0.00118	0.00250	0.00388	0.0193	0.0574	0.00001	0.00002	0.00042	0.00062	0.0023	0.0051	0.00005	0.00005	0.000005	0.000013	0.7	1.9

(continued)

Table 13.4-5. Surface Water Quality Summary, 2007 to June 2014 (completed)

Parameter	Lake Sampling	Thallium, Total (Tl)		Uranium, Total (U)		Va-dium, Total (V)		Zinc, Total (Zn)	
Stat	Depth	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Harper Creek Area									
Site HP4	-	0.000005	0.000033	0.00010	0.00016	0.0005	0.0025	0.0015	0.0030
Site H5	-	0.000005	0.000025	0.00004	0.00006	0.0005	0.0025	0.0025	0.0081
Site H2	-	0.000005	0.000100	0.00035	0.00042	0.0005	0.0106	0.0015	0.0034
Site H3T	-	0.000005	0.000025	0.00024	0.00031	0.0005	0.0025	0.0015	0.0029
Site H1	-	0.000005	0.000100	0.00115	0.00175	0.0005	0.0038	0.0015	0.0026
Barriere Area									
Site S1	-	0.000025	0.000100	0.00208	0.00396	0.0005	0.0125	0.0025	0.0029
Site S2	-	0.000025	0.000100	0.00198	0.00333	0.0005	0.0144	0.0025	0.0025
NB1/2	1 m	0.000025	0.000025	0.00132	0.00139	0.0025	0.0025	0.0110	0.0137
	4.5 m	0.000005	0.000005	0.00139	0.00139	0.0005	0.0005	0.0015	0.0015
	8 m	0.000005	0.000005	0.00132	0.00132	0.0005	0.0005	0.0015	0.0015
	20 m	0.000025	0.000025	0.00125	0.00130	0.0025	0.0025	0.0090	0.0099
	24.5 m	0.000005	0.000005	0.00131	0.00131	0.0005	0.0005	0.0015	0.0015
	25 m	0.000005	0.000005	0.00138	0.00138	0.0005	0.0005	0.0015	0.0015
Site B1	-	0.000005	0.000025	0.00121	0.00140	0.0005	0.0025	0.0025	0.0093
North Thompson Area									
Site NT2	-	0.000023	0.000043	0.00032	0.00056	0.0016	0.0038	0.0025	0.0077
Site A2	-	0.000005	0.000025	0.00015	0.00026	0.0005	0.0025	0.0015	0.0045
Site A1	-	0.000010	0.000100	0.00030	0.00041	0.0005	0.0025	0.0025	0.0040
Site CH2	-	0.000005	0.000025	0.00005	0.00010	0.0005	0.0025	0.0020	0.0058
Site CH1	-	0.000005	0.000025	0.00034	0.00089	0.0005	0.0025	0.0015	0.0025
Site J2	-	0.000008	0.000100	0.00005	0.00010	0.0005	0.0119	0.0025	0.0050
Site J1	-	0.000005	0.000100	0.00067	0.00127	0.0005	0.0075	0.0015	0.0051
Site BK2	-	0.000100	0.000100	0.00010	0.00010	0.0005	0.0114	0.0025	0.0044
Site BK1	-	0.000005	0.000100	0.00019	0.00028	0.0005	0.0100	0.0015	0.0029
Site BK0	-	0.000005	0.000100	0.00061	0.00108	0.0005	0.0044	0.0015	0.0031
Site NT1	-	0.000025	0.000044	0.00030	0.00065	0.0025	0.0037	0.0037	0.0104

Units are mg/L unless otherwise noted.

Values below the a-lytical detection limit were replaced with half of the detection limit for calculations.

In the Harper Creek area, metals were generally similar to or lower than concentrations observed in the Barrière River and North Barrière Lake and North Thompson areas; total molybdenum concentrations at downstream sites were high relative to the North Thompson area and increased downstream from site H4P (median 0.00019 mg/L) to site H1 (0.00196 mg/L). Concentrations of total and dissolved aluminum and iron, and total cadmium, chromium, cobalt, copper, lead, manganese, nickel, and thallium exhibited quite distinct seasonality, with highest concentrations per site generally occurring during high-flow freshet periods.

Total aluminum, cadmium, and copper concentrations were greater than the CCME and BC guidelines for the protection of freshwater aquatic life at all Harper Creek area sites. Dissolved aluminum, and total arsenic, iron, lead, mercury, silver, and zinc concentrations were also greater than aquatic life guidelines but in fewer samples at select sites. The percentage of baseline samples greater than BC or CCME aquatic life guidelines was generally highest at site H5 in P Creek. Concentrations of total aluminum, and occasionally total iron and total mercury, were greater than Health Canada and BC guidelines for metals in drinking water at all Harper Creek area sites. Total mercury concentrations were higher than the guideline for wildlife water supply in a small percentage of samples from downstream sites in T Creek and Harper Creek (H3T and H1, respectively).

Barrière River and North Barrière Lake Area

Stream temperatures exhibited similar seasonal patterns as observed in the Harper Creek area and stream temperatures were warmer at downstream lower-elevation sampling locations, particularly during summer. During the summer months, downstream sites S2 and B1 along the Barrière River were among the warmest streams sampled. Dissolved oxygen concentrations were similar among all sites and varied seasonally but were consistently greater than the CCME and BC guideline for the protection of aquatic life (6.5 mg/L).

North Barrière Lake is a dimictic lake that is ice-covered part of the year, and is surmised to experience two yearly turnover mixing periods in the spring and fall (Appendix 13-A, Surface Water Quality Baseline Report). North Barrière Lake water column was stratified in the late summer and early fall of 2011 and 2012, with a thermocline present between depths of 5 to 20 m. Dissolved oxygen measurements also reflected the stratified layering; concentrations were fairly homogeneous in the top 15 m to 20 m of the water column. Dissolved oxygen concentrations were greater than the 6.5 mg/L BC and CCME guideline throughout the majority of the water column. Deeper dissolved oxygen concentrations gradually decreased below BC and CCME guidelines below depths of approximately 35 m. Lower dissolved oxygen concentrations at depth likely reflected the strong oxygen uptake by decomposing organic matter in the sediment coupled to a lack of strong vertical mixing with the remainder of the water column, which would prevent the renewal of dissolved oxygen from the surface waters.

Barriere area stream and lake waters were neutral to slightly alkaline (median range 7.55 to 7.73) similar to other areas and had low sensitivity to acid inputs (median alkalinity >20 mg/L $CaCO_3$). Waters were soft (median range 21 mg/L $CaCO_3$ to 35 mg/L $CaCO_3$ hardness) and both alkalinity and water hardness exhibited decreasing trends downstream (Table 13.4-5). In terms of anions, sulphate concentrations were generally low compared to the Harper Creek and North Thompson areas (median range 1.6 to 2.4 mg/L). Chloride and fluoride concentrations were also low but comparable relative to other areas (Table 13.4-5). Temporally, patterns for pH, alkalinity, hardness, and concentrations of anions were similar to those exhibited in the Harper Creek area (concentrations were lowest during freshet high flows). Total alkalinity and water hardness were similar to that of the Harper Creek area but low in comparison to most creek tributaries in the North Thompson area. As in the Harper Creek area, waters in the Barriere area were very clear, with slightly greater turbidity observed during the freshet period. Total suspended solids (TSS) concentrations were often below analytical detection and median turbidity ranged from 0.3 NTU to 07 NTU among Barriere area sites (Table 13.4-5). Concentrations of cyanide species (total, free, and WAD) were low at all sites and generally below detection limits.

During most sampling periods, the sampled creeks in the Barriere area were nutrient poor and ultra-oligotrophic (phosphorus < 0.004 mg/L) but reached mesotrophic to eutrophic status during certain sampling periods. North Barrière Lake was ultra-oligotrophic throughout the sampling years. Nitrate generally made up the greatest concentration of inorganic nitrogen and exhibited a downstream decreasing trend (median of 0.115 mg/L at S1 to 0.0402 mg/L at B1; Table 13.4-5).

Concentrations of anions, cyanide, and organic carbon were lower than the BC and CCME guidelines for the protection of freshwater aquatic life, drinking water and wildlife water supply. Turbidity was greater than Health Canada guidelines for drinking water in all North Barrière Lake samples and in 95% to 100% of samples from each Barriere area stream site. The concentration of total phosphorus was higher than the BC drinking water guideline for total phosphorus in a subset of samples from the three Barrière River sites.

In the Barriere area, metals were generally similar in concentration to that observed in the Harper Creek area and concentrations exhibited similar temporal trends. Total molybdenum and total uranium were two exceptions; concentrations of these parameters were notably higher at upstream site S1 compared to downstream sites and concentrations in the Harper Creek and North Thompson areas.

As in the Harper Creek area, total aluminum, cadmium, and copper concentrations were greater than guidelines for the protection of aquatic life in a subset of samples from all sites. Concentrations of dissolved aluminum, and total chromium, iron, lead, mercury, and zinc were also greater than aquatic life guidelines in select samples from a subset of Barriere area sites. The percentage of samples greater than aquatic life guidelines was generally greatest at downstream site B1. In North Barrière Lake, concentrations of dissolved aluminum, and total cadmium, lead, and zinc were greater than guidelines for the protection of aquatic life in a subset of samples from both shallow and/or deep depths. Concentrations of total aluminum and total iron were higher than BC and Health Canada guidelines for drinking water in a subset of samples from all Barrière River stream sites. Total mercury concentrations were higher than the drinking water and wildlife water supply guidelines in a few samples from Barrière River site S2.

North Thompson River Area

North Thompson area stream temperatures exhibited the expected seasonal patterns, similar to that observed in the Harper Creek and Barriere areas. Peak temperatures were greater in the North Thompson River compared to the four tributary streams and did not exhibit a distinct temperature difference between upstream and downstream locations as observed in most other creeks and rivers.

Dissolved oxygen concentrations were similar among all sites and varied seasonally but were consistently greater than the CCME and BC guideline for the protection of aquatic life (6.5 mg/L).

North Thompson area creek and river waters were neutral to slightly alkaline (median range 7.30 to 8.21) similar to other areas but had widely differing sensitivities to acid inputs (median range 9 mg/L $CaCO_3$ to 130 mg/L $CaCO_3$). Waters ranged from soft to hard (median range 13 mg/L $CaCO_3$ to 132 mg/L $CaCO_3$ hardness). The North Thompson River had soft water (median <60 mg/L $CaCO_3$ hardness) and upstream sites within each tributary tended to have lower hardness (median range 13 mg/L $CaCO_3$ to 81 mg/L $CaCO_3$) than downstream sites (median range 92 mg/L $CaCO_3$ to 132 mg/L $CaCO_3$; Table 13.4-5). Chloride and fluoride concentrations were low but comparable relative to other areas, though peak fluoride concentrations were observed in the North Thompson River (median 0.05 mg/L; Table 13.4-5). Sulphate concentrations were generally greater than concentrations observed in the Barriere area but similar to concentrations observed at upstream Harper Creek area sites and exhibited an increasing trend from upstream to downstream within each North Thompson tributary. Though somewhat different spatially, temporally, patterns for pH, alkalinity, hardness, and concentrations of anions were similar to those exhibited in the Harper Creek and Barriere areas (concentrations were lowest during freshet high flows). Similar to the other sampled areas, cconcentrations of cyanide species (total, free, and WAD) were low at all sites and generally below detection limits.

Tributary creeks in the North Thompson area had very clear water with slight increases in turbidity during freshet, as seen in the Harper Creek and Barriere areas. Water clarity in the North Thompson River was notably poorer during summer months (median turbidity 4.4 NTU and 6.6 NTU at sites NT2 and NT1, respectively). Peak levels of measured parameters were often greatest within the North Thompson area; both Harper Creek and Barriere area stations generally displayed much smaller variability in concentrations. The North Thompson River, being the largest and most energetic waterway, had a greater capacity to carry suspended material and their associated metals, particularly during the freshet period. Thus, in addition to TSS and turbidity, the North Thompson River sites (NT1 and NT2) had considerably higher concentrations of total aluminum, total chromium, total cobalt, total and dissolved iron, total manganese, and total nickel than other sampled creek sites in the study area.

The trophic status of North Thompson area creeks and river sites varied from ultra-oligotrophic to hyper-eutrophic (phosphorus >0.1 mg/L). Typically the trophic status was elevated during freshet (May and June) when phosphorus loads increased due to increased runoff. The trophic status of the North Thompson River was generally elevated for a sustained period each year (May through October). Nitrate generally made up the greatest concentration of inorganic nitrogen, followed by ammonia and nitrite, which were often below or near analytical detection at all sites. Nitrate concentrations tended to be greater at North Thompson River, Avery Creek, and Chuck Creek sites compared to other North Thompson tributaries but were comparable to concentrations observed in the Harper Creek and Barriere areas.

Concentrations of anions, cyanide, and organic carbon were below BC and CCME guidelines for the protection of freshwater aquatic life and wildlife water supply at North Thompson area sites. Few samples (2%) from Jones Creek had pH lower than the guideline for the protection of aquatic life and drinking water guideline (Health Canada and BC) of 6.5. Few samples from Avery and Baker creeks were also greater than the aquatic life guideline for total ammonia. Turbidity and total phosphorus concentrations were greater than Health Canada and BC guidelines for drinking water in a subset of samples from all North Thompson area sites.

For metals, in the North Thompson River, dissolved and total aluminum, and total cadmium, chromium, copper, iron, lead, and zinc concentrations were greater than guidelines for the protection of aquatic life in a subset of samples from both sampling locations (NT2 and NT1). Concentrations of total aluminum were also greater than the aquatic life guideline during some sampling periods at all North Thompson tributaries. Dissolved aluminum, and total arsenic, cadmium, chromium, copper, iron, lead, mercury, silver, and zinc concentrations were also greater than aquatic life guidelines at some sites. The concentration of total aluminum was higher than the Health Canada guideline for drinking water at all North Thompson sites. Concentrations of total arsenic, total iron, total manganese, and total mercury were occasionally higher than drinking water guidelines at select sites.

13.5 Effects Assessment and Mitigation

13.5.1 Screening Project Effects

The purpose of this section is to identify the potential effects that can result from the interaction of the Project components and activities with surface water quality (i.e., the VC selected in Section 13.3.1) within the boundaries selected in Section 13.3.2. The potential effects were identified through professional experience with other mining EA projects in BC and through consultation with the EA Working Group for the Project. A change in surface water quality has the potential to occur through various pathways during the entire life of the Project. Components and activities, which were selected in the scoping process (Table 13.3-2), for each temporal phase are discussed to describe the pathways that can lead to effects on surface water quality (Table 13.5-1).

Table 13.5-1. Risk Ratings of Project Effects on Surface Water Quality Valued Components

Project Component/Activity and Potential Effects	Surface Water Quality
Construction	
Construction of fish habitat offsetting sites	🟢
On-site equipment and vehicle use: heavy machinery and trucks	🟡
Explosives storage and use	🟡
Open pit development - drilling, blasting, hauling and dumping	🟡
Power line and site distribution line construction: vegetation clearing, access, poles, conductors, tie-in	🟡
Plant construction: mill building, mill feed conveyor, truck shop, warehouse, substation and pipelines	🟢
Aggregate sources/ borrow sites: drilling, blasting, extraction, hauling, crushing	🟡
Clearing vegetation, stripping and stockpiling topsoil and overburden, soil salvage handling and storage	🟡

(continued)

Table 13.5-1. Risk Ratings of Project Effects on Surface Water Quality Valued Components (continued)

Project Component/Activity and Potential Effects	Surface Water Quality
Construction ***(cont'd)***	
Rail load-out facility upgrade and site preparation	🟢
New TMF access road construction: widening, clearing, earth moving, culvert installation using non-PAG material	🟡
Road upgrades, maintenance and use: haul and access roads	🟡
Coarse ore stockpile construction	🟡
Non-PAG Waste Rock Stockpile construction	🟡
PAG and Non-PAG Low-grade ore stockpiles foundation construction	🟡
PAG Waste Rock stockpiles foundation construction	🟡
Coffer dam and South TMF embankment construction	🟡
Tailings distribution system construction	🟢
Construction camp construction, operation, and decommissioning	🟡
Traffic delivering equipment, materials and personnel to site	🟢
Waste management: garbage, incinerator and sewage waste facilities	🟢
Water management pond, sediment pond, diversion channels and collection channels construction	🟡
Operations*	
Explosives storage and use	🟡
Fish habitat offsetting site monitoring and maintenance	🟢
Mine site mobile equipment (excluding mining fleet) and vehicle use	🟡
Mine pit operations: blast, shovel and haul	🟡
Ore crushing, milling, conveyance and processing	🟡
Progressive mine reclamation	🟡
Construction of Non-PAG tailings beaches	🟢
Construction of PAG and Non-PAG Low Grade Ore Stockpile	🔴
Non-PAG Waste Rock Stockpiling	🔴
Overburden stockpiling	🟡
Reclaim barge and pumping from TMF to Plant Site	🟢
South TMF embankment construction	🟡
Sub-aqueous deposition of PAG waste rock into TMF	🟢
Tailings transport and storage in TMF	🟢
Treatment and recycling of supernatant TMF water	🟢
Waste management: garbage and sewage waste facilities	🟢
Monitoring and maintenance of mine drainage and seepage	🟢
Low grade ore crushing, milling and processing	🟡
Partial reclamation of Non-PAG waste rock stockpile	🟡
Partial reclamation of TMF tailings beaches and embankments	🟡

(continued)

Table 13.5-1. Risk Ratings of Project Effects on Surface Water Quality Valued Components (continued)

Project Component/Activity and Potential Effects	Surface Water Quality
Operations *(cont'd)*	
Construction of North TMF embankment and beach	🟡
Deposit of low grade ore tailings into open pit	🟢
Closure	
Monitoring and maintenance of mine drainage, seepage, and discharge	🟢
Reclamation monitoring and maintenance	🟢
Filling of open pit with water and storage of water as a pit lake	🟡
Decommissioning of rail concentrate loadout area	🟢
Decommissioning and reclamation of mine site roads	🟢
Decommissioning and removal of plant site, processing plant and mill, substation, conveyor, primary crusher, and ancillary infrastructure (e.g., explosives facility, truck shop)	🟢
Decommissioning of diversion channels and distribution pipelines	🟢
Reclamation of Non-PAG LGO stockpile, overburden stockpile and Non-PAG waste rock stockpile	🟡
Reclamation of TMF embankments and beaches	🟡
Removal of contaminated soil	🟢
Use of topsoil for reclamation	🟡
Storage of waste rock in the non-PAG waste rock stockpile	🟡
Construction and activation of TMF closure spillway	🟡
Maintenance and monitoring of TMF	🟢
Storage of water in the TMF and groundwater seepage	🟡
Sub-aqueous tailing and waste rock storage in TMF	🟢
TMF discharge to T Creek	🔴
Post-Closure	
Environmental monitoring including surface and groundwater monitoring	🟢
Monitoring and maintenance of mine drainage, seepage, and discharge	🟢
Reclamation monitoring and maintenance	🟢
Construction of emergency spillway on open pit	🟢
Storage of water as a pit lake	🟡
Storage of waste rock in the non-PAG waste rock stockpile	🟡
Storage of water in the TMF and groundwater seepage	🟡
Sub-aqueous tailing and waste rock storage	🟢
TMF discharge to T Creek	🔴

Notes:
** Includes Operations 1 and Operations 2 as described in the temporal boundaries.*
🟢 = *Low risk interaction: a negligible to minor adverse effect could occur; no further consideration warranted.*
🟡 = *Moderate risk interaction: a potential moderate adverse effect could occur; warrants further consideration.*
🔴 = *High risk interaction: a key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

In general, the Project has the potential to change surface water quality by:

- erosion and sedimentation through increased TSS and associated water quality parameters (e.g., total metals);
- dust deposition through increased TSS and associated water quality parameters; and
- change in chemical concentrations in the aquatic environment due to metal leaching, seepage, and/or TMF effluent discharge.

High- and moderate-risk interactions with potential major or moderate adverse effects were identified as those that warrant further consideration and assessment (Table 13.5-1). Interactions of Project activities with the potential for negligible or minor expected adverse effects were not further considered in the effects assessment.

13.5.1.1 Construction

During Construction (two years), a change in surface water quality can occur through interactions with Project activities including:

- Moderate risk from erosion and sedimentation:
  - erosion and sedimentation from construction of power line and site distribution line, access road construction (2.5km), road upgrades, and construction activities at the Project Site (including water management) that will involve vegetation clearing, stripping and stockpiling overburden and topsoil, and earth moving;
- Moderate risk from dust deposition:
  - dust deposition from on-site equipment and vehicle use, open pit development and aggregate, and borrow site development;
- High risk from change in chemical concentrations:
  - metal leaching from disturbed surface areas, although likely minimal during Construction; and
  - groundwater seepage, although likely minimal during Construction, from non-PAG waste rock and PAG and non-PAG LGO stockpiles.

13.5.1.2 Operations

During Operations (28 years), a change in surface water quality can occur through interactions with Project activities including:

- Moderate risk from erosion and sedimentation:
  - erosion and sedimentation during progressive mine reclamation and construction of the TMF embankments;
- Moderate risk from dust deposition:
  - dust deposition from mine pit operations, Project Site mobile equipment and vehicle use, ore crushing; and

- High risk from change in chemical concentrations:
  - metal leaching from disturbed surface areas, although likely minimal; and
  - groundwater seepage from the TMF, the non-PAG waste rock stockpile, the PAG LGO stockpile, overburden stockpiles, and water management ponds.

13.5.1.3 Closure

During Closure (seven years), a change in surface water quality can occur through interactions with Project activities including:

- Moderate risk from erosion and sedimentation:
  - erosion and sedimentation during reclamation activities; and
- High risk from change in chemical concentrations:
  - metal leaching from disturbed surface areas;
  - groundwater seepage from the TMF, open pit, and from waste rock, LGO, and overburden stockpiles and water management ponds; and
  - effluent discharge from the TMF to T Creek.

13.5.1.4 Post-Closure

Post-Closure will last until long-term environmental objectives are achieved (currently modelled to 99 years). Surface water and groundwater monitoring will take place during this phase (Chapter 7, Closure and Reclamation, Section 24.6, Fish and Aquatic Effects Monitoring Plan (FAEMP), and Section 24.8, Groundwater Management Plan). A change in surface water quality can occur through interactions with Project activities including:

- High risk from change in chemical concentrations:
  - metal leaching from disturbed surface areas;
  - groundwater seepage from the TMF, open pit, and from waste rock, LGO, and overburden stockpiles and water management ponds; and
  - discharge of excess water from the TMF to T Creek.

13.5.2 Analysis of Potential Surface Water Quality Effects

Potential Project-related effects were assessed by qualitative and quantitative studies and analytical techniques (e.g., predictive modelling results) to evaluate the risk of effects on surface water quality. When data was lacking, scientific knowledge, past experience on other mining projects, and/or professional judgment was used to inform this evaluation.

13.5.2.1 Erosion and Sedimentation

The potential for erosion and sedimentation due to site disturbance as a result of mining is well-documented (Luoma and Rainbow 2008). In the absence of mitigation and management measures, physical disturbance of the terrain has the potential to increase surface runoff and erosion, resulting in increased turbidity, TSS, and sedimentation in the aquatic environment. Changes in site drainage patterns, soil contamination, or alteration of soil attributes such as organic matter content, pH, nutrient availability, and microbial activity can affect the ecological functionality of adjacent aquatic environments. The geographic scope of erosion and sedimentation can range from localized to far-reaching events, depending on the amount and type (e.g., particle size) of particulate and colloidal materials introduced into the aquatic environment.

The potential for Project-related effects due to erosion and sedimentation is dependent on implementation of best management practices (BMPs) and mitigation measures described in Section 13.5.3.1.

13.5.2.2 Dust Deposition

A change in water quality due to dust deposition was assessed through quantitative modelling of fugitive dust. The modelling methods and results are fully described in Section 9.5.2.2 and 9.5.2.3.

Air quality modelling indicated that the maximum 30-day deposition will be 2.5 $mg/dm^2/day$ during Construction and 3.9 $mg/dm^2/day$ during Operations. Background dustfall is 0.6 $mg/dm^2/day$ and the provincial Pollution Control Objective (BC MOE 1979) for 30-day deposition is 1.7 to 2.9 $mg/dm^2/day$.

Dust deposition outside of the Project Site during Construction with the potential to affect surface water quality is primarily limited to Avery Creek. Dust deposition outside of the Project Site during Operations with the potential to affect surface water quality is predicted along Chuck Creek, and in the upper reaches of Baker Creek. Dust deposition is largely predicted to be between 0.9 to 1.1 $mg/dm^2/day$ (less than the provincial objective), with isolated areas of elevated dust deposition. Given these relatively low levels of dust deposition, a change in surface water quality due to dust deposition is not expected and no residual effects were assessed.

Mitigation of dust deposition is further described in Section 13.5.3.2.

13.5.2.3 Change in Chemical Concentrations

A change in water quality due to a change in chemical concentrations was assessed through quantitative modelling. The primary objective of water quality modelling for the Project was to predict the concentrations of total and dissolved metals, nutrients, and anions within the Project Site and in the surrounding aquatic environment that will receive chemical loadings from Project components.

Water quality predictions were developed for the Project using GoldSim by Knight Piesold Ltd. (2014c; Appendix 13-C). A summary of the model approach, assumptions, and sensitivity analyses are provided in the following sections.

The GoldSim water balance and water quality model incorporated water management, Project design, and baseline geochemistry, hydrology, and surface water quality inputs to characterize the potential change in surface water quality due to metal leaching, effluent discharge, and groundwater seepage during all Project phases (Appendix 13-C).

Water quality was predicted at 11 surface water quality assessment nodes (Table 13.5-2; Figure 13.5-1):

- Project Site, including the open pit and TMF;
- Harper Creek area, further subdivided as:
  - upper Harper Creek tributaries, including T Creek and P Creek;
  - upper Harper Creek, defined as mainstem Harper Creek above the waterfall at km 18.5;
  - lower Harper Creek; and
- North Thompson Area, including Baker and Jones creeks.

Potential water quality effects in the outlet of North Barrière Lake and Barrière River were qualitatively assessed based on the predications in lower Harper Creek.

GoldSim Water Quality Model

Approach and Assumptions

The water quality model for the Project was developed using a mass balance calculation approach in GoldSim to model the volume and flow of water and the concentrations and transport of chemical species as a function of time. GoldSim was developed to model complex environmental systems and has been extensively and successfully applied to simulate water resource management, mining operation, contaminant transport, and radioactive waste management (GoldSim 2014). GoldSim is a simulation program that includes Project components as "containers" that are made up of "elements." These containers include the formulas, data, conditions, and/or operation criteria for different Project components.

The primary objective of the water quality modelling for the Project was to predict the concentrations of total and dissolved metals, nutrients, and anions within the Project Site and in the surrounding surface waters that will receive chemical loadings from Project components. Water quality modelling also considered various model sensitivity analyses or model cases that account for uncertainty in the model assumptions (KP 2014c; Table 13.5-3; Appendix 13-C). Results of water quality predictions include management and mitigation measures. These mitigations are further described in Section 13.5.3.3.

The water balance was based on the life-of-mine (LOM) watershed model (KP 2014d; Appendix 12-B) that was designed to simulate the effects of the Project on surface water and groundwater. Additional unrecovered seepage flow paths predicted by groundwater modelling (Appendix 13-C; KP 2014b, 2014a) were considered in a sensitivity scenario.

The expected case water quality model was developed using average climate inputs, expected case geochemical source terms, and seepage pathways predicted by the LOM watershed model (KP 2014c; KP 2014d; Appendices 12-B and 13-C). Sensitivity scenarios assessed uncertainty in geochemical source terms (the upper bound case), variable climate inputs (the low and high precipitation cases), and groundwater seepage flow paths (the seepage case; KP 2014c; Appendix 13-C). A realistic upper limit case was developed to provide a more likely upper limit to uncertainty in geochemical source terms than the upper bound case. Results from this sensitivity analysis are presented in Appendix 13-E.

Table 13.5-2. Surface Water Quality Assessment Nodes within the Study Areas

Area	Sub-area	Surface Water Quality Assessment Node	Hydrology Assessment Node	Equivalent Baseline Surface Water Monitoring Location	Description
Project Site	-	OP	n/a	--	Open pit lake
		TMF	n/a	--	Tailings Management Facility
Harper Creek Area	Upper Harper Creek Tributaries	T Creek	3	H3T	T Creek upstream of Harper Creek confluence
		P Creek	5	H4P[1]	P Creek upstream of Harper Creek confluence
	Upper Harper Creek	HP	8	H4P[1]	Harper Creek below P Creek confluence
		HM	2	H2	Harper Creek between P Creek and T Creek confluences
		HT	9	--	Harper Creek below T Creek confluence
	Lower Harper Creek	HB	10	H1	Harper Creek at Barrière River confluence
North Thompson Area	-	J1	6	J1	Jones Creek above North Thompson River confluence
		BK0	7	BK0	Baker Creek at North Thompson River confluence
	-	BK1	n/a	BK1	Upper Baker Creek

1 Data from baseline surface water monitoring location H4P was used to represent assessment nodes P Creek and HP in the water quality model (Appendix 13-C).

Table 13.5-3. Water Quality Model Cases

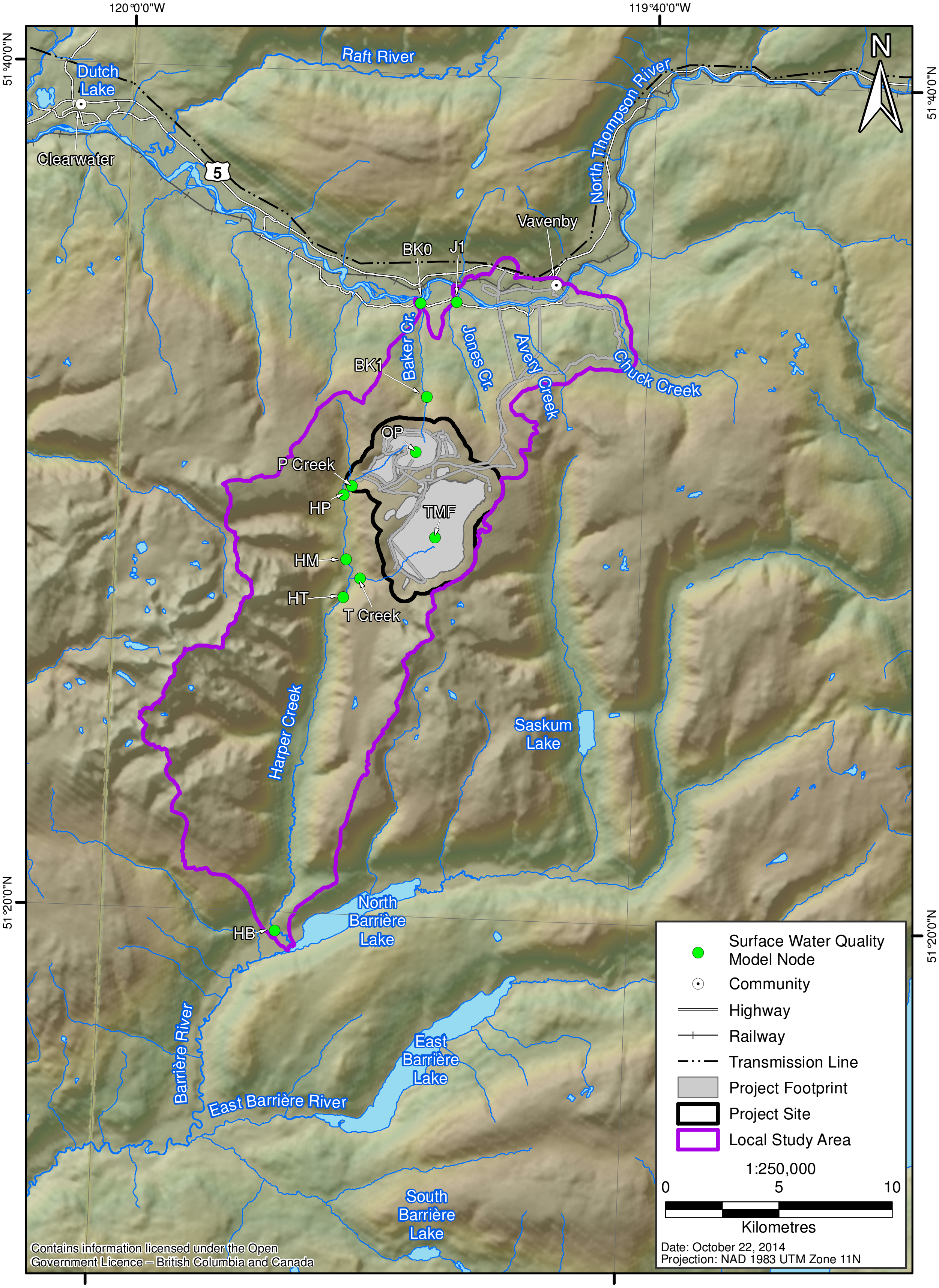
Model Case	Climate Case	Geochemical Source Terms	Seepage Inputs
Expected case	Average Climate Inputs	Expected case source terms	LOM Watershed Model
Sensitivity Analyses			
Upper bound case	Average Climate Inputs	Upper bound case source terms	LOM Watershed Model
Low precipitation case[1]	5th Percentile Precipitation	Expected case source terms	LOM Watershed Model
High precipitation case[1]	95th Percentile Precipitation	Expected case source terms	LOM Watershed Model
Unrecovered seepage sensitivity case[2]	Average Climate Inputs	Expected case source terms	SEEP/W and MODFLOW

[1] *Only model nodes HM, HT, and HB*

[2] *Only model nodes HP, P Creek, and HM*

Figure 13.5-1

Surface Water Quality Effects Assessment Model Nodes



The assessment of Project residual effects on surface water quality is primarily based on the expected case model. The expected case provides the concentrations that are considered most likely to occur (KP 2014c; Appendix 13-C). The overall intent of source term predictions is to err on the side of conservatism. The expected uses typical inputs to the source term calculation that is intended to indicate the expected outcome of the proposed waste and water management approach (Section 6.4.1). In all model cases, the surface water quality model is further considered to be conservative because natural attenuation processes in the aquatic environment are not incorporated in the model (KP 2014c; Appendix 13-C).

Sensitivity cases were further considered where model predictions substantially varied from the expected case (further described in Section 13.5.4), in the determination of likelihood (Section 13.5.4.3), in the significance determination (Section 13.5.5), and in the determination of confidence and uncertainty (Section 13.5.6). The exception is that the effects assessment for P Creek and upper Harper Creek equivalently considered both the expected case and unrecovered seepage sensitivity case model results.

Screening of Contaminants of Potential Concern

A change in surface water quality parameters was assessed through the consideration of locations where there was the potential for interactions between a VC (e.g., sediment quality, aquatic resources, fish, wetlands, wildlife, and human health) and Project-affected water. These locations included the TMF and open pit, and T, P, Jones, Baker, and Harper creeks in all Project phases.

Project-related effects associated with water quality in the TMF and open pit are restricted to potential effects to wildlife. The water quality of the TMF and open pit is presented in Appendix 13-D, Comparison of Predicted Water Quality to Water Quality Guidelines; however, the potential effects to wildlife due to TMF and open pit water quality is assessed in Chapter 16, Wildlife and Wildlife Habitat Effects Assessment.

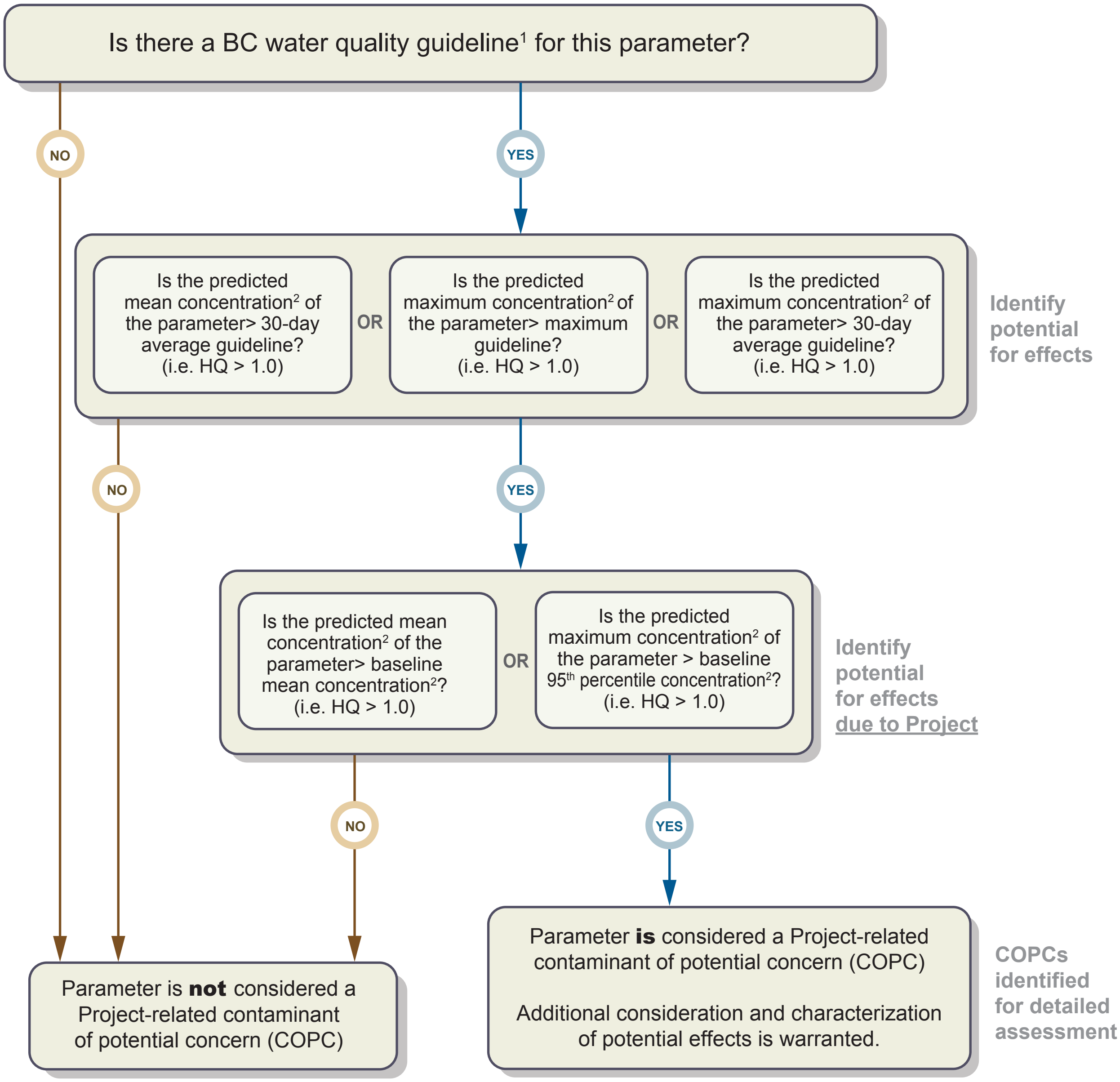
Key changes in surface water quality were identified through the calculation of hazard quotients (HQs) for modelled water quality parameters. In environmental effects assessments, the calculation of HQs can be a useful screening tool for determining the potential for a chemical to cause toxicity in receptors, such as aquatic resources (primary producers, secondary producers, and sediment quality), fish, wildlife species, or human health (Environment Canada 2012a). HQs are most often calculated as a ratio of the concentration of a chemical (either a measured or predicted concentration) compared to the relevant guideline value. A HQ greater than 1.0 may indicate a potential for effects in receptors, while a HQ less than 1.0 is considered to not carry additional risk of toxicity to receptors.

The screening process used for surface waters is illustrated in Figure 13.5-2. Monthly water quality predictions for different Project phases were assessed. The screening method considered both maximum and mean predicted values.

The scope of the water quality effects assessment is restricted to parameters with an approved or working BC water quality guideline for the protection of freshwater aquatic life, wildlife, drinking water, and livestock watering. The exception is dissolved cadmium, which was screened against the draft freshwater aquatic life guideline released for review in June 2014 (BC MOE 2014).

Figure 13.5-2

Screening Process for Selection of Contaminants of Potential Concern (COPC) for Surface Water Quality Assessment, Harper Creek Project



Notes: COPC = contaminant of potential concern.
HQ = hazard quotient.
[1] Approved and working BC water quality guidelines.
[2] Concentrations (predicted and baseline) were assessed on a monthly basis.

In the first screening step, HQs were calculated by dividing the predicted monthly mean and maximum concentration of water quality parameters by the appropriate 30-day average or maximum guideline. Water quality parameters with a HQ less than or equal to 1.0 were screened out of the assessment for residual effects, because the guidelines are determined by the BC Ministry of Environment (MOE) to be protective of the relevant receptors; therefore, there is no potential for adverse effects as a result of a change to water quality. Water quality parameters with a HQ greater than 1.0 relative to the guideline limit were retained for a second screening step. The results of the first screening step for the expected case are presented in Appendix 13-D, Comparison of Predicted Water Quality to Water Quality Guidelines.

In the second screening step, predicted monthly mean and maximum water quality parameters for each Project phase were compared to the monthly mean and 95th percentile baseline concentrations (Figure 13.5-2). Predicted mean values were compared to baseline mean values because baseline mean values were used as the model source term for existing surface water conditions (Appendix 13-D, Comparison of Predicted Water Quality to Water Quality Guidelines). The comparison of predicted concentrations to baseline concentrations provides a good indicator of the potential for incremental change due to Project-related activities. This step screens out those contaminants where concentrations are at or above guidelines under baseline conditions; naturally elevated concentrations above guideline are not a Project-related effect. If the HQ calculated during this screening step was greater than 1.0, the parameter was considered a possible Project-related contaminant of potential concern (COPC) and retained for further assessment. If the final HQ was equal to or less than 1.0, the parameter was not considered a Project-related COPC and was not assessed further.

The TMF and open pit water quality screening process was restricted to BC water quality guidelines (WQG) for the protection of wildlife as there is only the potential for interaction between wildlife VCs and TMF and open pit water quality, and there are no relevant baseline data. Identified COPCs for the TMF and open pit are presented in Appendix 13-D. The TMF and open pit water quality were carried forward to the assessment of effects on wildlife (Chapter 16).

Those water quality parameters determined to be Project-related COPCs for the expected case model are carried forward to the effects assessments for the following linked VCs:

- aquatic environment (aquatic resources and fish)– Chapter 14;
- wildlife (multiple VCs) – Chapter 16;
- commercial interests (livestock) – Chapter 18;
- human health (drinking water and country foods) – Chapter 21.

Identified aquatic life COPCs in the aquatic environment were used to assess the effect on the surface water quality VC. By following the COPC screening procedure as outlined above, the assessment of residual effects on surface water quality due to a change in water quality incorporates water quality parameters that are predicted to increase in concentration above WQG and above the range of natural variability. The screening procedure thus focuses the residual effects assessment on those parameters with the potential for a Project-related effect. The significance determination on residual effects considers, but is not limited to, factors, such as the sensitivity of potential receptors, uncertainty in guideline limits (e.g., due to safety factors or the underlying studies used to derive the guidelines), or other Project-specific information (e.g., uncertainty in the predicted concentrations or other factors that may affect the metal concentration or toxicity).

13.5.3 Mitigation Measures

The proposed mitigation and management measures are actions to prevent, avoid, minimize, or restore effects to surface water quality within the spatial and temporal boundaries of the Project. Mitigation and management measures to eliminate or reduce Project effects include design and planning, engineered structures, the application of control technologies, BMPs, regulatory requirements, and monitoring and adaptive management. The Project will employ design and alternatives analyses to minimize/eliminate potential effects and will use relevant management practices to further mitigate or eliminate residual effects on surface water quality. Many of the mitigation and management measures are designed to avoid or minimize effects on the interaction pathways, such as changes in surface water quantity and groundwater quality and quantity and thus are applicable to surface water quality VC. Mitigation and management measures will be applied throughout the life of the Project.

Details of mitigation and management strategies relevant to the surface water quality VC are available in the following Application/EIS chapters:

- Chapter 9, Air Quality;
- Chapter 11, Groundwater;
- Chapter 12, Hydrology;
- Chapter 14, Fish and Aquatic Resources; and
- Chapter 15, Terrestrial Ecology.

The following environmental management plans and reporting are central to the planned mitigation and management measures for Project effects on surface water quality:

- Air Quality Management Plan (Section 24.2);
- Explosives Handling Plan (Section 24.5);
- Fish and Aquatics Effects Monitoring and Management Plan (Section 24.6);
- Groundwater Management Plan (Section 24.8);
- Mine Waste and ML/ARD Management Plan (Section 24.9);
- Sediment and Erosion Control Plan (Section 24.11);
- Selenium Management Plan (Section 24.12);
- Site Water Management Plan (Section 24.13);
- Soil Salvage and Storage Plan (Section 24.14); and
- Spill Prevention and Response Plan (Section 24.15).

13.5.3.1 Erosion and Sedimentation

The Sediment and Erosion Control Plan (Section 24.11), Soil Salvage and Storage Plan (Section 24.14), and Site Water Management Plan (Section 24.13) describe the practices that Harper Creek Mining Corporation (HCMC) will undertake in order to minimize the degradation and loss of soils due to erosion throughout the Project's life, and to prevent damage to other ecological values as a consequence of soil erosion. Sediment and erosion control strategies will include establishing diversion and runoff collection ditches, constructing sediment control ponds, and stabilizing disturbed land surfaces to minimize erosion.

The following performance objectives are implicit in achieving the plan's purpose:

- conserving soil quantity and quality in areas that are subject to erosion (i.e., areas with fine textured soil, cleared areas, disturbed areas located on slopes, stockpiles);
- minimizing natural drainage disruption along access roads and around mine infrastructure;
- protecting disturbed, erodible materials in a timely manner; and
- reducing or controlling the potential for accelerated sediment delivery into watercourses.

Effluent discharge will be required to meet permit limits under the *Environmental Management Act* (2003), which are expected to include a limit for TSS that is protective of water quality and freshwater aquatic life. The effectiveness of the mitigation and management measures for erosion and sedimentation is assessed to be **high** (Table 13.5-4). Given implementation of the relevant management plans and expected permit limits for effluent discharges, the likelihood of an adverse effect on surface water due to erosion and sedimentation is considered to be low. The effect of change in water quality due to erosion and sedimentation was therefore not considered further.

Table 13.5-4. Proposed Mitigation Measures and their Effectiveness

Surface Water Quality			
Potential Effect	Proposed Mitigation Measure	Mitigation Effectiveness *(Low/Moderate/ High/Unknown)*	Residual Effect *(Y/N)*
Change in water quality due to sediment and erosion	Sediment and Erosion Control Plan (Section 24.11); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.14)	High	N
Change in water quality due to dust deposition	Air Quality and Dust Management Plan (Section 24.2)	High	N
Change in water quality due change in chemical concentrations	Explosives Handling Plan (Section 24.5); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Selenium Management Plan (Section 24.12)	Moderate	Y

13.5.3.2 Dust Deposition

The Air Quality Management Plan (Section 24.2) describes the practices that HCMC will undertake in order to minimize emissions and fugitive dust during the life of the Project. Mitigation measures will be in place during all phases of the Project in order to minimize fugitive dust emissions. The following sources of fugitive dust have been identified:

- fugitive dust on unpaved roads from vehicles travelling on site roads; and
- fugitive dust emissions from mining activities such as bulldozing, grading, stockpiling, drilling, and blasting.

The effectiveness of the mitigation and management measures for dust deposition is assessed to be **high** (Table 13.5-4). Dust deposition is largely predicted to be between 0.9 to 1.1 $mg/dm^2/day$ (less than the provincial objective), with isolated areas of elevated dust deposition. Given these relatively low levels of dust deposition, a change in surface water quality due to dust deposition is not expected and no residual effects were assessed for Chuck Creek.

13.5.3.3 Change in Chemical Concentrations

The following mitigation and management measures are proposed for effects to water quality due to a change in chemical concentrations. Specifically, mitigation measures that target water management, nutrient loading, groundwater seepage, and ML/ARD are described. Monitoring through the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and Selenium Management Plan (Section 24.12) will validate the water quality predictions used for effects assessment and identify the need for further mitigation and adaptive management.

Overall, the effectiveness of the mitigation and management measures for change in chemical concentrations is assessed to be **moderate** (Table 13.5-4). Some water quality parameters are predicted to be higher than BC WQG and background conditions with the implementation of the following mitigation measures. These effects are further described in Section 13.5.4.

<u>Site Water Management Plan</u>

The Site Water Management Plan (Section 24.13) describes a range of mitigation measures to reduce or eliminate the potential effects of the Project on surface water quality.

The aim of the Site Water Management Plan is to use water efficiently within the Project Site to support the milling of ore and to divert non-contact water to the maximum extent practical. The Site Water Management Plan involves collecting and managing site runoff from disturbed areas and maximizing the recycle of process water. Surplus water will be stored on site within the TMF and used as process water through the first 24 years of Operations. Process water for the final four years of Operations will primarily be derived from the open pit.

Sediment and erosion control strategies will include establishing diversion and runoff collection ditches, constructing sediment control ponds, and stabilizing disturbed land surfaces to minimize erosion.

Nutrient Loading

Residues from blasting will contain nitrogen compounds that will remain on the surface of newly exposed rock, waste rock, tailings, and other mine components, and be available to be flushed. The accumulation of these highly soluble residues (nitrate, nitrite, and ammonia) on disturbed rock material and the corresponding nitrogen load to the aquatic environment will depend on the volume and type of explosives used. Most nitrogen loading from this source will occur from runoff, although a minor source may be from dust/atmospheric loading.

Total baseline nitrogen concentrations were generally low within watercourses within the study area (see Section 13.4 and Appendix 13-A). Nitrogen loading may thus increase the potential for eutrophication in nitrogen-limited aquatic systems if there is sufficient phosphorus and other micronutrients for primary production.

Potential residual effects on surface water quality, inclusive of active mitigation and management measures, due to nitrogen loading within the Project Site and downstream surface waters were quantitatively assessed using water predictive water quality modelling (Section 13.5.2.3). The effects of nutrient loading from blasting residues on aquatic resources (primary producers, secondary producers, and sediment quality) are detailed in Chapter 14, Fish and Aquatic Resources Effects Assessment.

The Explosives Handling Plan (Section 24.5) describes the practices that HCMC will undertake in order to minimize nutrient loading from the transportation, storage, and use of explosives required for the Project. A qualified and experienced explosives contracting company, with good performance history, will be used.

The effectiveness of the mitigation and management measures for nutrient loading is assessed to be **moderate** (Table 13.5-4). Once mitigation and management measures are taken into consideration, water quality modelling predicts that nitrogen compounds will be present in surface waters at concentrations greater than baseline levels (see Section 13.5.4).

Groundwater Seepage

Project alternative optimization, design features, and BMPs have served to minimize effects to groundwater quantity and quality, and to surface waters. The functions served by these mitigation measures are described in greater details in Section 11.5.2, and include the following:

- project alternatives, including collecting and conveying the pit dewatering water and the pit lake surplus water to the TMF for storage, and siting PAG waste rock and non-PAG LGO stockpiles in the TMF catchment basin and sub-aqueous disposal of PAG materials;
- project design features, including:
  - low-permeability cores, seepage collection drains and water management ponds, and drainage channels incorporated into the TMF embankments;
  - water management pond and drainage channels incorporated into the non-PAG waste rock stockpile, and transferring the collected water in the water management pond to the TMF for storage;

  - non-contact surface water diversions surrounding a number of Project components; and
  - reclamation of the waste rock stockpiles, overburden stockpile, as well as the TMF during the Operations and Closure phases of the Project.
- BMPs, including:
  - characterization of ML/ARD potential and segregation of PAG and non-PAG materials in accordance with the Mine Waste and ML/ARD Management Plan (Section 24.9); and
  - inspection of stockpile integrity (drainage and erosion) in accordance with the Mine Waste and ML/ARD Management Plan.

Implementation of an adaptive management approach will serve to further reduce effects to potential receptors of discharging contact groundwater (see Section 11.5.3 in Chapter 11 for predicted residual effects on groundwater quantity and quality).

<u>ML/ARD</u>

The Mine Waste and ML/ARD Management Plan (Section 24.9) is designed to minimize chemical loadings to surface waters from:

- non-PAG and PAG waste rock, including overburden, quarry material, material excavated or exposed during construction of the open pit, and any surface infrastructure;
- ore stockpiles;
- cleaner and rougher tailings; and
- exposed open pit walls.

The objectives of the Mine Waste and ML/ARD Management Plan are to:

- minimize the water quality effects of mine waste deposition, by ensuring that PAG waste rock and tailings are stored at an adequate depth below the surface of the TMF pond in a timely and controlled manner;
- minimize the physical effects of waste rock and overburden storage facilities, and topsoil and LGO stockpiles, by ensuring that dust, erosion, suspended solids, and potential contaminants resulting from aeolian and fluvial processes are managed in a timely and controlled manner (see also Section 24.2, Air Quality Management Plan, Section 24.11, Sediment and Erosion Control Plan, and Section 24.13, Site Waste Management Plan); and
- monitor water quality of the affected catchment, per the technical indicators contained in Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), as well as the Groundwater Management Plan (Section 24.8) and the Site Water Management Plan (Section 24.13), such that anomalies in these indicators can be responded to by applying appropriate mitigation.

The quality and quantity of effluent and surface and seepage water quality from the waste rock piles, TMF, open pit, and other infrastructure during Operations, Closure, and Post-Closure will be monitored to verify prediction of the water quality modelling.

Monitoring

Fish and Aquatic Effects Monitoring and Management Plan

The goal of the Fish and Aquatic Effects Monitoring and Management Plan (FAEMMP; Section 24.6) is to avoid, minimize, or control adverse effects on the aquatic environment. This goal will be achieved by meeting the following objectives:

- Implementing a monitoring program that meets federal Metal Mining Effluent Regulations (MMER; SOR/2002-222) – Environmental Effects Monitoring (EEM) program requirements and BC *Environmental Management Act* (2003) effluent permit discharge requirements, and that follows the standards contained in the guideline documents below to ensure proper study design, sampling methods, analyses, and QA/QC procedures are carried out:
  - *British Columbia Field Sampling Manual* (Clark 2003);
  - *Water and Air Baseline Monitoring Guidance Document for Mine Proponents* (BC MOE 2012b);
  - *Metal Mining Technical Guidance for Environmental Effects Monitoring* (Environment Canada 2012b);
  - *Fish Collection Methods and Standards* (RIC 1997);
  - *Environmental Code of Practice for Metal Mines* (Environment Canada 2012b);
  - *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* (Price and Errington 1998); and
  - *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials* (Price 2009);
- designing a monitoring program that will confirm the conclusions of the effects assessment, including the anticipated effectiveness of mitigation measures;
- monitoring the response of the target VCs along pathways of interaction between the Project and the aquatic environment, which will allow for early detection of any emerging issues; and
- using the results of the monitoring program to adaptively manage adverse effects on the aquatic environment as needed.

Selenium Management Plan

The framework of the Selenium Management Plan (SeMP; Section 24.12) is designed to meet best practices for environmental and technical performance objectives for the Project, in addition to ensuring statutory requirements are considered and addressed. The framework of the SeMP is supported by four aspects: prediction, prevention, mitigation, and monitoring, that together form an effective strategy to achieve environmental protection. Once Project-specific data and bioaccumulation models are available (see Section 24.12.8) a science-based environmental benchmark (SBEB) for selenium will be formally developed for the Project. The SBEB will be developed based on guidance provided by the BC MOE (BC MOE 2013), with additional guidance currently under development.

Potential risks due to elevated selenium will be adaptively managed based on the results of the proposed monitoring plan to ensure that risks are mitigated before adverse surface water quality effects occur.

13.5.4 Predicted Residual Effects and Characterization

13.5.4.1 Residual Effects on Surface Water Quality

Change in Surface Water Quality due to a Change in Chemical Concentrations

Based on the results of the water quality model (KP 2014c; Appendix 13-C, Water Quality Predictions) and the COPC screening methodology described in Section 13.5.2.3, there is potential for a Project-related change to surface water quality after the implementation of mitigation measures described in Section 13.5.3. The results of the screening-level assessment are presented in Appendix 13-D, Comparison of Predicted Water Quality to Water Quality Guidelines.

A water quality assessment is presented in the following sections for the Harper Creek, Barriere, and North Thompson areas. COPC for the Expected Case and four sensitivity scenarios are presented in Table 13.5-5 for the following assessment nodes and discussed in the following sections:

- Harper Creek area – T Creek, P Creek, and Harper Creek (HP, HT, HM, and HB); and
- North Thompson area – Baker Creek (BK0).

A qualitative assessment was completed for the outlet of North Barrière Lake and the Barrière River downstream of Harper Creek and the North Thompson River downstream of Jones, Baker, and Chuck creeks.

No Project-related COPC were identified for Jones Creek for any of the model sensitivity analyses following the screening-level assessment. Water quality predictions indicate that no change to water quality is expected as a result of Project-related activities; therefore, no residual effect on Jones Creek was determined and effects on surface water due to a change in water quality in Jones Creek will not be considered further in the assessment.

Residual effects were primarily determined based on the results of the expected case. The expected case water quality model is considered to predict the conditions that are most likely to occur and that these results are conservative based on the methods of source term development and modelling (KP 2014c; Appendix 13-C, Water Quality Predictions). Uncertainty in the expected case was assessed through the additional COPCs and/or increased concentrations predicted in the sensitivity scenarios. Project-related COPCs with residual effects are presented in Table 13.5-6.

In general, the upper bound case provided the highest predicted concentrations, indicating that water quality is more sensitive to chemical loading from Project components than changes in climate. The upper bound case utilizes the upper bound geochemistry source terms, which represent the upper limit of uncertainty in the water quality predictions. It is extremely unlikely that concentrations will exceed the upper bound case (KP 2014c; Appendix 13-C, Water Quality Predictions).

Table 13.5-5. Contaminants of Potential Concern (COPC) Identified by Screening-level Assessment, Harper Creek Project

				P Creek				T Creek				Upper Harper Creek (HP, HM, and HT)			
Model Case	Climate Case	Groundwater Seepage	Geochemistry Source Terms	Construction	Operations	Closure	Post-Closure	Construction	Operations	Closure	Post-Closure	Construction	Operations	Closure	Post-Closure
Expected Case	average	LOM Watershed Model	expected case							cadmium, copper, selenium, sulphate	cadmium, copper, selenium, sulphate, zinc	copper	copper, selenium	cadmium, copper, selenium	cadmium, copper, selenium
Unrecovered Seepage Sensitivity[1]	average	SEEP/W and MODFLOW	expected case	copper, nitrite	ammonia, copper, nitrite, selenium	copper	copper					copper	copper, nitrite, selenium	copper	copper
Upper Bound Case	average	LOM Watershed Model	upper bound case					cadmium	cadmium	aluminum, cadmium, chromium, cobalt, copper, manganese, mercury, selenium, silver, sulphate, zinc	aluminum, cadmium, chromium, cobalt, copper, manganese, mercury, selenium, silver, sulphate, zinc	copper	cobalt, copper, selenium	cadmium, cobalt, copper, mercury, selenium	cadmium, cobalt, copper, mercury, selenium, zinc
5th Percentile Precipitation[2]	5th percentile precipitation	LOM Watershed Model	expected case										copper, selenium	copper, selenium	cadmium, copper, selenium
95th Percentile Precipitation[2]	95th percentile precipitation	LOM Watershed Model	expected case										cadmium, copper, nitrite, selenium	cadmium, copper, selenium	cadmium, copper, selenium

				Lower Harper Creek (HB)				Baker Creek (BK0)			
Model Case	Climate Case	Groundwater Seepage	Geochemistry Source Terms	Construction	Operations	Closure	Post-Closure	Construction	Operations	Closure	Post-Closure
Expected Case	average	LOM Watershed Model	expected case			cadmium, copper, selenium	cadmium, copper, selenium		chromium	chromium	chromium
Unrecovered Seepage Sensitivity[1]	average	SEEP/W and MODFLOW	expected case								
Upper Bound Case	average	LOM Watershed Model	upper bound case		copper	cadmium, copper, selenium	cadmium, cobalt, copper, mercury, selenium		chromium	chromium	chromium
5th Percentile Precipitation[2]	5th percentile precipitation	LOM Watershed Model	expected case				cadmium, copper, [illegible]				
95th Percentile Precipitation[2]	95th percentile precipitation	LOM Watershed Model	expected case		cadmium, copper, selenium	cadmium, copper, selenium	cadmium, copper, selenium				

Note: Aluminum and cadmium are dissolved parameters

[1] *Only P Creek, HP, and HM assessed in this case*

[2] *Only HM, HT, and HB assessed in this case*

Table 13.5-6. Contaminants of Potential Concern (COPC) Identified as Residual Effects, Harper Creek Project

				P Creek				T Creek				Upper Harper Creek (HP, HM, and HT)			
Model Case	Climate Case	Groundwater Seepage	Geochemistry Source Terms	Construction	Operations	Closure	Post-Closure	Construction	Operations	Closure	Post-Closure	Construction	Operations	Closure	Post-Closure
Expected Case	average	LOM Watershed Model	expected case							cadmium, copper, selenium, sulphate	cadmium, copper, selenium, sulphate, zinc	copper	copper, selenium	cadmium, copper, selenium	cadmium, copper, selenium
Unrecovered Seepage Sensitivity	average	SEEP/W and MODFLOW	expected case		selenium							copper	copper, nitrite, selenium	copper	copper

				Lower Harper Creek (HP, HM, and HT)			
Model Case	Climate Case	Groundwater Seepage	Geochemistry Source Terms	Construction	Operations	Closure	Post-Closure
Expected Case	average	LOM Watershed Model	expected case			cadmium, copper, selenium	cadmium, copper, selenium
Unrecovered Seepage Sensitivity	average	SEEP/W and MODFLOW	expected case				

Note: Aluminum and cadmium are dissolved parameters

[1] Only P Creek, HP, and HM assessed in this case

Harper Creek Area

P Creek

The P Creek assessment node is located down-gradient of the non-PAG waste rock, PAG LGO stockpile, and associated water management ponds. SEEP/W and MODFLOW groundwater modelling (Appendix 13-C; KP 2014c, 2014d, 2014b, 2014a) indicates that unrecovered seepage pathways may report to P Creek.

No Project-related loads report to P Creek in the expected case model; therefore the unrecovered seepage sensitivity case was used to assess potential residual effects at the P Creek assessment node.

COPCs for all sensitivity analyses are presented in Table 13.5-5. COPCs with a residual effect on surface water quality are presented in Table 13.5-6.

Ammonia

Ammonia concentrations are predicted to be greater than 30-day BC WQG and 0.6% greater than background concentrations in August of Operations 1 phase. It is unlikely that a 0.6% change in ammonia concentrations would be measureable in a water quality monitoring program. For water quality assessments, BC MOE has defined no change as a difference of not greater than 20% (BC MOE 2013). This definition considers that the precision of laboratory measurements is typically not better than 20% and natural variability is often greater than 20% (BC MOE 2013). Based on this assessment, no detectable change in ammonia concentrations at the P Creek assessment node is expected; therefore, a change in water quality due to increased ammonia concentrations in P Creek will not be considered further and no residual effect is identified.

Copper

Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L, based on hardness) by 1.8 or 1.9 fold in June in all years from Year 1 (Construction) to Year 99 (Post-Closure). However, the predicted concentrations are between 0.9 and 6.8% higher than baseline concentrations of copper at this site.

It is unlikely that a 0.9 and 6.8% change in copper concentrations would be measureable in a water quality monitoring program given inter-annual variation and uncertainty in field sampling and laboratory methods (BC MOE 2013). Based on the assessment, no change in copper concentrations at the P Creek assessment node is predicted; therefore, a change in water quality due to increased copper concentrations in P Creek will not be considered further and no residual effect is identified.

Nitrite

Nitrite concentrations in water are predicted to be greater than the BC WQG and greater than background concentrations in:

- October of Year -1 (Construction phase, by 1.2 fold); and
- August of Year 2 and 3 (Operations 1 phase, by 1.3 and 1.4 fold, respectively).

Nitrite is predicted to be below the BC WQG during all other months and phases.

Nitrite is an intermediate nitrogen species that occurs in the oxidation of ammonia to nitrate. Concentrations are likely overestimated since nitrite is rapidly converted to nitrate under the oxygenated conditions that would be expected in P Creek (Mortonson and Brooks 1980; Wetzel 2001). Since the predicted concentrations are only marginally higher than guidelines, occur for only three months out of the entire modelled period and are likely overestimated, a change in water quality due to increased nitrite concentrations in P Creek will not be considered further and no residual effect is identified.

Selenium

Selenium concentrations in water are predicted to be greater than the BC WQG (0.002 mg/L or 2 μg/L) and greater than background concentrations in August of Years 3 to 28 (Operations 1 and Operations 2 phases). The concentration in August is predicted to increase slowly over time, peaking in August of Year 28 at 6.2 μg/L. The concentration of selenium is predicted to be below BC WQGs during all other months and phases.

Since the predicted concentration of selenium is greater than guidelines and greater than background concentrations sporadically during Operations 1 and 2, a change in water quality due to increased selenium concentrations in P Creek is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sensitivity Analyses

Project-related loads do not report to P Creek in the expected case and upper bound case; therefore no additional COPCs were identified. Predictions for the two variable climate cases did not include P Creek; therefore, no additional COPCs were identified.

Harper Creek Downstream of P Creek (HP)

The HP assessment node is located in Harper Creek downstream of P Creek. Bull Trout are the only species of fish that may be found in this area of Harper Creek (see Section 14.4.2.1 for further discussion of fish baseline studies).

No Project-related loads report to HP in the expected case model; therefore the unrecovered seepage sensitivity case was used to assess potential residual effects at the HP assessment node.

COPCs for all sensitivity analyses are presented in Table 13.5-4. COPCs with a residual effect are presented in Table 13.5-5.

Copper

The potential for toxicity due to total copper is dependent on hardness, which is reflected in the hardness-dependent formula for determining the appropriate guideline concentration. Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L, based on hardness) by 1.8 fold in June in all years from Year 1 (Construction) to Year 99 (Post-Closure). However, the predicted concentrations are between 0.6% and 2.8% higher than baseline concentrations of copper at this site.

It is unlikely that a 0.6% and 2.8% change in copper concentrations would be measureable in a water quality monitoring program given inter-annual variation and uncertainty in field sampling and laboratory methods (BC MOE 2013). Based on the assessment, no change in copper concentrations at the HP assessment node is predicted; therefore a change in water quality due to increased copper concentrations in P Creek will not be considered further and no residual effect is identified.

Nitrite

Nitrite concentrations in water are predicted to be greater than the BC WQG by up to 1.6 fold and greater than background concentrations in:

- February and March of Year -1 (Construction phase), Year 3 (Operations 1 phase), and Year 15 (Operations 1 phase); and
- January to March of Year 2 (Operations 1 phase).

Nitrite is predicted to be below the BC WQG during all other months and phases.

Nitrite is an intermediate nitrogen species that occurs in the oxidation of ammonia to nitrate. Concentrations are likely overestimated since nitrite is rapidly converted to nitrate under the oxygenated conditions that would be expected in Harper Creek (Mortonson and Brooks 1980; Wetzel 2001). Since the predicted concentrations are only marginally higher than guidelines, occur for only nine months out of the entire modelled period, and are likely overestimated, a change in water quality due to increased nitrite concentrations in Harper Creek at assessment node HP will not be considered further and no residual effect is identified.

Selenium

Selenium concentrations in water are predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) by up to 3.0 fold (0.006 mg/L or 6 µg/L) and greater than background concentrations in:

- February and March of Years 3 and 4 (Operations 1 phase);
- January to March of Years 5 to 7 (Operations 1 phase);
- January to March and December of Years 8 and 9 (Operations 1 phase);
- January to March, September, and December of Years 10 to 12 (Operations 1 phase);
- January to March, September, November, and December in Year 13 (Operations 1 phase);
- January to March and September to December in Years 14 to 17 (Operations 1 phase);
- January to March and August to December in Years 18 to 23 (Operations phase 1);
- January to March and September to December in Years 24 and 25 (Operations 2 phase); and
- January to March and August to December in Years 26 to 28 (Operations phase 2).

Selenium is predicted to be below BC WQGs in all months and years after January of Year 29. The concentration of selenium is predicted to increase throughout Operations 1 phase to a maximum of 6.0 µg/L in March of Year 27 of Operations 2 phase.

Since the predicted concentration of selenium is greater than guidelines and greater than background concentrations sporadically during Operations 1 and 2, a change in water quality due to increased selenium concentrations in Harper Creek at assessment node HP is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sensitivity Analyses

Project-related loads do not report to Harper Creek at assessment node HP in the expected case and upper bound case; therefore, no additional COPCs were identified. Predictions for the two variable climate cases did not include assessment node HP; therefore, no additional COPCs were identified.

Harper Creek between P and T creeks (HM)

The assessment node HM is located downstream from the confluence with P creek and upstream of the confluence with T Creek. HM represents the point in Harper Creek where seepage losses from the temporary non-PAG LGO Stockpile (only on the surface for 5 years), PAG LGO, and the non-PAG waste rock stockpile, and associated water management ponds are expected to intercept with Harper Creek. The majority of mine-related loading at HM is attributed to the non-PAG and PAG LGO stockpiles. The non-PAG LGO materials are stored on the surface in the P Creek catchment for the first 5 years of Operations 1. The PAG LGO is stockpiled until it is processed by the end of Operations 2. Mine-related loadings that report to model node HM decrease as the LGO materials are removed for processing by the end of Operations 2. A nominal amount of seepage from the TMF West Saddle dam also reports to HM (KP 2014c; Appendix 13-C).

Selenium

Selenium is predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) by up to 1.4 fold and greater than background concentrations during:

- March of Years 19 to 21 and Year 25 of the Operations 1 and 2 phases; and
- February and March in Years 22 to 24, 26, and 27 of the Operations 1 and 2 phases.

The maximum concentration predicted during these years is 2.8 µg/L. Selenium is predicted to be below the BC WQG in all other months and in all other phases.

Since the predicted concentration of selenium is greater than guidelines and greater than background concentrations sporadically during Operations 1 and 2, a change in water quality due to increased selenium concentrations in Harper Creek at assessment node HM is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sensitivity Analyses

Additional COPCs

The upper bound case identified the potential for total cobalt as an additional COPC during Operations 1 and Operations 2.

The unrecovered seepage sensitivity case identified the potential for total copper and nitrite. Elevated concentrations of these parameters are the result of upstream chemical loading from

P Creek. Since no residual effect was assessed at the upstream assessment nodes for these parameters, a change in water quality due to increased copper or nitrite concentrations in Harper Creek at assessment node HM is unlikely.

Summary

The results of the upper bound case establish the degree of uncertainty that exists with respect to the predicted change in water quality in upper Harper Creek. Water quality monitoring through the Fish and Aquatic Effects Monitoring and Management Plan (FAEMMP; Section 24.6) and Selenium Management Plan (SeMP; Section 24.12) will identify any changes in water quality above those predicted in the expected case and allow for adaptive management as described in Section 13.5.3.3.

T Creek

T Creek receives chemical loading from unrecovered seepage from the TMF during Operations and discharge of excess water from the TMF during Closure and Post-Closure.

Cadmium

Predicted water concentrations of dissolved cadmium are greater than the 30-day average draft BC WQG (BC MOE 2014) by up to 8.7 fold and greater than baseline concentrations throughout all months of the Closure and Post-Closure phases.

Dissolved cadmium is also greater than the maximum draft BC WQG by up to 3.8 fold and greater than baseline concentrations in:

- June and November of Years 31 to 35 (Closure phase);
- June, October, and November of Year 36 (Post-Closure phase);
- May to July, October, and November of Year 37 (Post-Closure phase);
- May to December of Year 38 (Post-Closure phase);
- January and May to December of Year 39 (Post-Closure phase);
- all months in Years 40 to 78 (Post-Closure phase); and
- decreasing frequency of dissolved cadmium concentrations above the maximum BC WQG between Years 79 and 100 (Post-Closure phase).

Since the predicted concentration of dissolved cadmium is greater than BC WQGs and greater than background concentrations during much of the Closure and Post-Closure phases, a change in water quality due to increased cadmium concentrations in T Creek is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Copper

Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L) by up to 2.6 fold and greater than baseline concentrations throughout all months of the Closure and Post-Closure phases.

Total copper is also greater than the maximum draft BC WQG by up to 1.4 fold and greater than baseline concentrations in:

- all months between June of Year 31 and December of Year 32 (Closure phase);
- all months except July and August of Years 33 to 35 (Closure phase);
- all months in Years 36 to 59 (Post-Closure phase);
- all months except July of Years 60 and 61 (Post-Closure phase);
- all months except July and August of Years 62 to 66 (Post-Closure phase);
- decreasing frequency of copper concentrations above BC WQGs between Years 67 and 87 (Post-Closure phase).

The predicted concentration of total copper is below the maximum guideline in all months starting in January of Year 88 of the Post-Closure phase.

Since the predicted concentration of copper is greater than guidelines and greater than background concentrations during much of the Closure and Post-Closure phases, a change in water quality due to increased copper concentrations in T Creek is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Selenium

Starting in June of Year 31, selenium concentrations in T Creek are predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) during all months throughout the Closure and Post-Closure phases. The concentration of selenium is predicted to be highest in the third and fourth years of the Closure phase (October to December of Year 31 and January to March of Year 32, 12.1 µg/L), with concentrations decreasing annually with time. The minimum predicted concentration throughout the Closure and Post-Closure phases is 4.5 µg/L in May of Years 94 to 99. Concentrations of selenium are generally predicted to be higher during periods of lower flow (September through April) and lower during higher flow periods (May to August).

Since the predicted concentration of selenium is greater than guidelines and greater than background concentrations during much of the Closure and Post-Closure phases, a change in water quality due to increased selenium concentrations in T Creek is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sulphate

Predicted water concentrations of sulphate in T Creek are greater than the 30-day average BC WQG (128 mg/L) by up to 1.8 fold and greater than baseline concentrations in:

- all months between June of Year 31 and December of Year 74 (Closure and Post-Closure phases);
- all months except May of Years 75 to 83 (Post-Closure phases);
- all months except May and June of Years 84 to 91 (Post-Closure phase); and
- all months except May to July of Years 92 to 100 (Post-Closure phase).

Since the predicted concentration of sulphate is greater than BC WQGs and greater than background concentrations during much of the Closure and Post-Closure phases, a change in water quality due to increased sulphate concentrations in T Creek is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Zinc

Predicted water concentrations of total zinc in T Creek are greater than the 30-day average BC WQG (0.004 mg/L) by up to 1.6 fold and greater than baseline concentrations in the Post-Closure phase only during:

- September to December in Year 39;
- January to March and September to December in Year 40;
- January to April and August to December in Year 41 and 42;
- all months except July in Year 43;
- all months in Years 44 to 65; and
- decreasing frequency of zinc concentrations above BC WQGs between Years 66 and 79.

The predicted concentration of total zinc is below the BC WQG throughout the remainder of the Post-Closure phases (after March of Year 79).

Since the predicted concentration of total zinc is greater than guidelines and greater than background concentrations occasionally during the Post-Closure phase, a change in water quality due to increased zinc concentrations in T Creek is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sensitivity Analyses - Comparison with the Upper Bound Case

Uncertainty in the Predictions

Predicted maximum cadmium concentrations in the upper bound case are approximately three times greater than in the expected case, indicating a moderate level of uncertainty in cadmium predictions. Cadmium concentrations are also identified as a COPC during November of Construction and October and November of Operations 1.

Predicted maximum copper concentrations are predicted to be approximately 19 times greater than in the expected case, indicating a high level of uncertainty in copper predictions.

Predicted maximum selenium concentrations are predicted to be approximately five times greater than in the expected case, indicating a moderate level of uncertainty in selenium predictions.

Predicted maximum sulphate concentrations are predicted to be approximately 1.5 times greater than in the expected case, indicating a low level of uncertainty in sulphate predictions.

Predicted maximum zinc concentrations are predicted to be approximately 1.5 times greater than in the expected case, indicating a low level of uncertainty in zinc predictions.

Additional COPCs

The upper bound case identified the potential for additional COPCs during the Closure and Post-Closure phases including dissolved aluminum, total chromium, total cobalt, total manganese, total mercury, and total silver.

Summary

The results of the upper bound case indicate that uncertainty exists with respect to the predicted change in water quality in T Creek. Water quality monitoring through the Fish and Aquatic Effects Monitoring and Management Plan (FAEMMP; Section 24.6) and Selenium Management Plan (SeMP; Section 24.12) will identify changes in water quality above those predicted in the expected case predictions and allow for adaptive management as described in Section 13.5.3.3.

Harper Creek downstream of T Creek (HT)

The HT assessment node is located in Harper Creek downstream of T Creek. Bull Trout are the only species of fish that may be found in this area of Harper Creek (see Section 14.4.2.1 for further discussion of fish baseline studies).

Project-related loadings in Harper Creek at assessment node HT originate from unrecovered seepage reporting upstream in Harper Creek and from Closure and Post-Closure discharge of excess water from the TMF to T Creek.

Cadmium

Predicted water concentrations of dissolved cadmium are greater than the 30-day average draft BC WQG by up to 2.3 fold and greater than baseline concentrations in:

- June of Years 31 to 36, and May and June of Year 37 (Closure and Post-Closure phases);
- March, May, and June of Years 38 and 39 (Post-Closure phase);
- February, March, and May to July of Year 40 to 42 (Post-Closure phase);
- February to July of Years 43 to 46 (Post-Closure phase);
- February to July and October of Years 47 to 56 (Post-Closure phase);
- February to July of Years 57 to 66 (Post Closure phase);
- February, March, and May to July of Years 67 to 77 (Post-Closure phase);
- March, May and June of Years 78 to 88 (Post-Closure phase); and
- May and June of Years 89 to 100 (Post-Closure).

Dissolved cadmium is predicted to be lower than the draft maximum BC WQG throughout the various phases of the Project.

Since the predicted concentration of dissolved cadmium is greater than guidelines and greater than background concentrations regularly throughout the Closure and Post-Closure phases, a change in water quality due to increased cadmium concentrations in Harper Creek at assessment node HT is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Copper

Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L) by up to 1.6 fold and greater than baseline concentrations in:

- May and June of Years 1 to 30 (Construction, Operations 1 and 2, and Closure phases);
- May, June, and October of Year 31 (Closure phase);
- March to June and October of Year 32 (Closure phase);
- April to June and October of Year 34 (Closure phase);
- April to June of Years 34 and 35 (Closure phase);
- February to June of Years 36 to 70 (Post-Closure phase);
- March to June of Years 71 to 78 (Post-Closure phase); and
- March, May, June, and October of Years 79 to 99 (Post-Closure).

Total copper is predicted to be lower than the maximum BC WQG throughout the various phases of the Project.

Since the predicted concentration of total copper is greater than guidelines and greater than background concentrations regularly throughout the Construction, Operations, Closure, and Post-Closure phases, a change in water quality due to increased copper concentrations in Harper Creek at assessment node HT is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Selenium

Selenium concentrations in water are predicted to be greater than the BC WQG (0.002 mg/L) and greater than background concentrations in:

- March of Years 19 to 21 (Operations 1 phase);
- February and March of Years 22 to 28 (Operations 1 and 2 phases);
- June, July and September to December of Year 31 (Closure phase);
- all months except August of Years 32 to 42 (Closure and Post-Closure phases);
- all months except August and November of Years 43 to 46 (Post-Closure phase);
- six to nine months per year in Years 47 to 65 (Post-Closure); and
- February to April, June, and October during in Years 66 to 99 (Post-Closure phase).

The concentration of selenium is predicted to peak in March of Year 36 (5.9 µg/L), with concentrations decreasing annually thereafter with time. Concentrations of selenium are generally predicted to be higher during periods of lower flow (September through April) and lower during higher flow periods (May to August).

Since the predicted concentration of selenium is greater than BC WQGs and greater than background concentrations regularly during the Operations, Closure, and Post-Closure phases, a change in water quality due to increased selenium concentrations in Harper Creek at assessment node HT is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sensitivity Analyses - Comparison with the Upper Bound Case

Uncertainty in the Predictions

Predicted maximum cadmium concentrations in the upper bound case are predicted to be approximately three times greater than in the expected case, indicating a moderate level of uncertainty in cadmium predictions.

Predicted maximum copper concentrations are predicted to be approximately 14 times greater than in the expected case, indicating a high level of uncertainty in copper predictions.

Predicted maximum selenium concentrations are predicted to be approximately three times greater than in the expected case, indicating a moderate level of uncertainty in selenium predictions.

Additional COPCs

The upper bound case identified the potential for additional COPCs during the Closure and Post-Closure phases including total cobalt and total mercury.

Summary

The results of the upper bound case establish the degree of uncertainty that exists with respect to the predicted change in water quality in Harper Creek at assessment node HT. Water quality monitoring through the Fish and Aquatic Effects Monitoring and Management Plan (FAEMMP; Section 24.6) and Selenium Management Plan (SeMP; Section 24.12) will identify any changes in water quality above those predicted in the expected case predictions and allow for adaptive management as described in Section 13.5.3.3.

Lower Harper Creek (HB)

The HB assessment node is located in Harper Creek just upstream from North Barrière Lake at the edge of the LSA.

Cadmium

Predicted water concentrations of dissolved cadmium are greater than the 30-day average draft BC WQG by up to 1.7 fold and greater than baseline concentrations in:

- June of Years 31 to 37 (Closure and Post-Closure phases);
- May and June of Year 38 (Post-Closure phase);
- March, May, and June of Year 39 (Post-Closure phase);
- March and May to July of Years 40 to 72 (Post-Closure phase);
- March, May and June of Years 73 to 79 (Post-Closure phase);
- May and June of Years 80 to 88 (Post-Closure phase); and
- June of Years 89 to 99 (Post-Closure phase).

Dissolved cadmium is predicted to be lower than the maximum draft BC WQG throughout the various phases of the Project.

Since the predicted concentration of dissolved cadmium is greater than guidelines and greater than background concentrations regularly throughout the Closure and Post-Closure phases, a change in water quality due to increased cadmium concentrations in Harper Creek at assessment node HB is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Copper

Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L, based on hardness) by up to 1.4 fold and greater than baseline concentrations in:

- June of Years 31 to 71 (Closure and Post-Closure phases).

Total copper is predicted to be lower than the maximum BC WQG throughout the various phases of the Project and lower than the 30-day average BC WQG in all months after June of Year 71.

Since the predicted concentration of total copper is greater than guidelines and greater than background concentrations sporadically throughout the Closure and Post-Closure phases, a change in water quality due to increased copper concentrations in Harper Creek at assessment node HB is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Selenium

Selenium concentrations in water are predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) and greater than background concentrations in:

- March of Year 32 (Closure phase, 2.03 µg/L);
- February and March of Years 36 to 41 (Post-Closure phase); and
- March of Years 42 to 72 (Post-Closure phase).

The concentration of selenium is predicted to be highest in the first year of the Post-Closure phase (March of Year 36, 3.2 µg/L), with concentrations decreasing annually with time. Concentrations of selenium in water are predicted to be below the 30-day average BC WQG (2 µg/L) in all months after March of Year 72. Concentrations of selenium are predicted to be higher during periods of lower flow (September through April) and lower during higher flow periods (May to August).

Since the predicted concentration of selenium is greater than guidelines and greater than background concentrations sporadically during the Closure and Post-Closure phases, a change in water quality due to increased selenium concentrations in Harper Creek at assessment node HB is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

Sensitivity Analyses - Comparison with the Upper Bound Case

Uncertainty in the Predictions

Predicted maximum cadmium concentrations in the upper bound case are approximately three times greater than in the expected case, indicating a moderate level of uncertainty in cadmium predictions.

Predicted maximum copper concentrations are predicted to be approximately 10 times greater than in the expected case, indicating a high level of uncertainty in copper predictions.

Predicted maximum selenium concentrations are predicted to be approximately three times greater than in the expected case, indicating a moderate level of uncertainty in selenium predictions.

Additional COPCs

The upper bound case identified the potential for additional COPCs during the Post-Closure phase including total cobalt and total mercury.

Summary

The results of the upper bound case establish the degree of uncertainty that exists with respect to the predicted change in water quality in Harper Creek at assessment node HB. Water quality monitoring through Fish and Aquatic Effects Monitoring and Management Plan (FAEMMP; Section 24.6) and Selenium Management Plan (SeMP; Section 24.12) will identify changes in water quality above those predicted in the expected case predictions and allow for adaptive management as described in Section 13.5.3.3.

Barriere Area

The water quality predictions in Harper Creek before the confluence with the outlet of North Barrière Lake at assessment node HB indicate concentrations of dissolved cadmium, total copper, and total selenium above BC WQG and background conditions. Therefore, there is some limited potential for a change in water quality in the outlet of North Barrière Lake and the Barrière River, until dilution is sufficient to reduce concentrations below BC WQG or background conditions. A change in water quality due to increased cadmium, copper, and selenium concentrations in Barrière River is identified as a residual effect. Further characterization is presented in Section 13.5.4.2.

North Thompson Area

Baker Creek

Baker Creek is located down-gradient from the open pit and Project-related chemical loadings originate from runoff from topsoil stockpiles and seepage from the open pit.

Chromium

Chromium is predicted to be greater than the maximum BC WQG by up to 0.6% and greater than baseline concentrations (by up to 1.5 fold) in May of each year from Year 1 to 99. Given the marginal predicted increase above BC WQG, a change in water quality due to increased chromium concentrations in Baker Creek will not be considered further and no residual effect is identified.

Sensitivity Analyses

No additional COPCs were identified in the sensitivity analyses.

Table 13.5-7. Definitions of Specific Characterization Criteria for Surface Water Quality

Timing*	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Resiliency
When will the effect begin?	*How severe will the effect be?*	*How far will the effect reach?*	*How long will the effect last?*	*How often will the effect occur?*	*To what degree is the effect reversible?*	*How resilient is the receiving environment or population? Will it be able to adapt to or absorb the change?*
Construction Phase	**Negligible:** the predicted change is likely undetectable relative to natural variation, or is below an applicable guideline.	**Discrete:** effect is limited to the Project Site.	**Short-term:** effect lasts less than 2 years (e.g., during the Construction phase of the Project).	**One Time:** effect is confined to one discrete event.	**Reversible:** effect can be reversed.	**High:** the receiving environment or population has a high natural resilience to imposed stresses, and can respond and adapt to the effect.
Operations Phases (Stages 1 and 2)	**Low:** the predicted change is likely detectable and within the range of natural variation, or is within two times the applicable guideline.	**Local:** effect is limited to the LSA.	**Medium-term:** effect lasts from 2 to 30 years (e.g., during the Operations phases of the Project).	**Sporadic:** effect occurs rarely and at sporadic intervals.	**Partially Reversible:** effect can be partially reversed.	**Neutral:** the receiving environment or population has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.
Closure Phase	**Medium:** the predicted change is beyond the range of natural variation and is within five times the applicable guideline.	**Regional:** effect occurs throughout the RSA.	**Long-term:** effect lasts from 30 to 37 years (e.g., during the Closure phase of the Project).	**Regular:** effect occurs on a regular basis.	**Irreversible:** effect cannot be reversed, is of permanent duration.	**Low:** the receiving environment or population has a low resilience to imposed stresses, and will not easily adapt to the effect.
Post-Closure Phase	**High:** the predicted change is beyond the range of natural variation and is greater than five times the applicable guideline.	**Beyond regional:** effect extends beyond the RSA.	**Far-future:** effect lasts more than 37 years (e.g., during the Post-Closure phase and beyond).	**Continuous:** effect occurs constantly.		

**Timing has been included for information purposes but is not an attribute of the residual effects characterization criteria.*

North Thompson River

As no change in water quality was determined for Chuck, Jones, or Baker creeks, no effects downstream in North Thompson River are expected. Change in water quality in North Thompson River will not be considered further and no residual effect is identified.

13.5.4.2 Characterization of Residual Effects on Surface Water Quality

Residual effects are characterized using standard criteria (i.e., the timing, magnitude, duration, frequency, geographic extent, reversibility, and resiliency). Standard ratings for these characterization criteria are provided in Chapter 8, Assessment Methodology; Table 13.5-7 provides a summary of definitions for each characterization criterion, specific to the surface water quality VC. The assessment considered results of baseline studies, predictive modelling, and feedback received during the pre-Application stage from review participants, relevant legislation/standards, scientific literature, and professional experience and judgement.

<u>Change in Surface Water Quality: P Creek</u>

- **Timing:** Change in surface water quality is predicted to occur in the Operations phase of the Project.
- **Magnitude**: Increased selenium concentrations in P Creek are predicted to be beyond the range of natural variation, but are within five times the applicable guideline. Therefore, the magnitude was assessed as **medium.**
- **Geographic Extent**: The change in water quality in P Creek is outside the Project Site but within the LSA; therefore, the geographic extent is **local**.
- **Duration**: The effect encompasses both stages of the Operations phase; therefore, the duration of the effect is considered **medium-term.**
- **Frequency**: Increased metal concentrations occur in August annually; therefore, the frequency of the effect is **regular.**
- **Reversibility**: Surface water quality effects are **partially reversible** as chemical loading is expected to decrease over time due to reclamation activities.
- **Resiliency:** Bull Trout are found in the lower 469 m of P Creek, upstream of the confluence with Harper Creek, during baseline studies. P Creek flows are expected to be substantially reduced due to Project development limiting the available natural assimilative capacity. Therefore, the resiliency was assessed as **low.**

<u>Change in Surface Water Quality: T Creek</u>

- **Timing:** Change in surface water quality is predicted to occur in the Closure and Post-Closure phases of the Project.
- **Magnitude**: Increased concentrations of selenium in T Creek are predicted to be beyond the range of natural variation, and greater than five times the applicable guideline. Increased concentrations of cadmium, copper, sulphate, and zinc are predicted to be beyond the range

of natural variation, and above water quality guidelines. Therefore, the magnitude was assessed as **high.**

- **Geographic Extent**: The change in water quality in T Creek is outside the Project Site but within the LSA; therefore, the geographic extent is **local**.
- **Duration**: Residual effects on water quality are predicted to begin in Closure and extend into Post-Closure; therefore, the duration of the effect is considered **far-future.**
- **Frequency**: Increased selenium concentrations occur in all months in the Closure and Post-Closure phases; therefore, the frequency of the effect is **continuous.**
- **Reversibility**: Surface water quality effects are **partially reversible** as the quality of effluent discharge from the TMF improves over time due to dilution of the supernatant water.
- **Resiliency**: Flows in T Creek are reduced by construction of the TMF and effluent discharge makes up 66% to 94% of T Creek flows in Closure limiting the available natural assimilative capacity. Bull Trout are found in the lower 336 m of T Creek, upstream of the confluence with Harper Creek, during baseline studies. Therefore, the resiliency was assessed as **low.**

<u>Change in Surface Water Quality: Upper Harper Creek</u>

- **Timing:** Change in surface water quality is predicted to occur in the Construction, Operation, Closure, and Post-Closure phases of the Project.
- **Magnitude**: The change in water quality is predicted to be beyond the range of natural variability, but within five times the applicable guidelines; therefore, the magnitude of the effect was assessed as **medium**.
- **Geographic Extent**: The change in water quality in Harper Creek is within the LSA; therefore, the geographic extent is **local.**
- **Duration**: Residual effects on water quality are predicted to begin in Closure and extend into Post-Closure; therefore, the duration of the effect is considered **far-future.**
- **Frequency**: Water quality effects are predicted in most months; therefore, the frequency of the effect is **continuous.**
- **Reversibility**: Surface water quality effects are **partially reversible** as the quality of effluent discharge from the TMF improves over time due to dilution of the supernatant water.
- **Resiliency:** Bull Trout are found in this area of Harper Creek; therefore the resiliency was assessed as **low.**

<u>Change in Surface Water Quality: Lower Harper Creek</u>

- **Timing:** Change in surface water quality is predicted to occur in the Closure and Post-Closure phases of the Project.
- **Magnitude**: The change in water quality is predicted to be beyond the range of natural variability, but within two times the applicable guidelines; therefore, the magnitude of the effect was assessed as **low**.

- **Geographic Extent**: The change in water quality in Harper Creek is within the LSA; therefore, the geographic extent is **local.**
- **Duration**: Residual effects on water quality are predicted to begin in Closure and extend into Post-Closure; therefore, the duration of the effect is considered **far-future.**
- **Frequency**: Water quality effects are predicted in February and March; therefore, the frequency of the effect is **regular.**
- **Reversibility**: Surface water quality effects are **partially reversible** as the quality of effluent discharge from the TMF improves over time due to dilution of the supernatant water.
- **Resiliency:** Bull Trout are found in this area of Harper Creek; therefore the resiliency was assessed as **low.**

<u>Change in Surface Water Quality: North Barrière Lake and Barrière River</u>

- **Timing:** Change in surface water quality may occur in the Closure and Post-Closure phases of the Project.
- **Magnitude**: The change in water quality is predicted to be beyond the range of natural variability, but within two times the applicable guidelines; therefore, the magnitude of the effect was assessed as **low**.
- **Geographic Extent**: The change in water quality in the outlet of North Barrière Lake and the Barrière River is within the RSA; therefore, the geographic extent is **regional.**
- **Duration**: Residual effects on water quality are likely to begin in Closure and extend into Post-Closure; therefore, the duration of the effect is considered **far-future.**
- **Frequency**: Water quality effects are likely to occur in February and March; therefore, the frequency of the effect is **regular.**
- **Reversibility**: Surface water quality effects are **partially reversible** as the quality of effluent discharge from the TMF improves over time due to dilution of the supernatant water.
- **Resiliency**: Bull Trout are likely found in the outlet of North Barrière Lake and the Barrière River; therefore the resiliency was assessed as **low**.

13.5.4.3 Likelihood of Residual Effects on Surface Water Quality

Likelihood refers to the probability of the predicted residual effect occurring and is determined according to the attributes identified in Table 13.5-8.

Table 13.5-8. Attributes of Likelihood of Effects

Probability Rating	Quantitative Threshold
High	> P80 (effect has > 80% chance of effect occurring)
Moderate	P40 - P80 (effect has 40 - 80% chance of effect occurring)
Low	< P40 (effect has < 40% chance of effect occurring)

Change in Surface Water Quality due to a Change in Chemical Concentrations

- **Probability in P Creek**: Based on two different model outcomes of seepage pathways (Appendix 13-C; KP 2014c, 2014d, 2014b, 2014a) used to understand the cause-effect relationship between the Project components and activities that can change chemical concentrations in surface water, the probability of an effect occurring is **moderate.**
- **Probability in upper Harper Creek, T Creek, lower Harper Creek, North Barrière Lake, and Barrière River**: Based on the understanding of the cause-effect relationship between the various Project components and activities that can change chemical concentrations in surface water, the probability of an effect occurring is **high.**

13.5.4.4 Summary of Residual Effects on Surface Water Quality

The residual effects determined for surface water quality are presented in Table 13.5-9.

Table 13.5-9. Summary of Residual Effects on Surface Water Quality

Project Phase (Timing of Effect)	Cause-Effect [1]	Mitigation Measure(s)	Residual Effect
Surface Water Quality			
Construction, Operations, Closure, Post-Closure	Change in surface water quality due to change in chemical concentrations from groundwater seepage and effluent discharge	Air Quality and Dust Management Plan (Section 24.2); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Sediment and Erosion Control Plan (Section 24.11); Selenium Management Plan (Section 24.12); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.14)	Change in surface water quality in P, T, and Harper creeks, the outlet of North Barrière Lake, Barrière River

13.5.5 Significance of Residual Effects

The CEA Agency's (1994) *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects* was used as guidance in evaluating the significance of the adverse residual effects for the Project. The significance of residual effects of the Project is founded on a comparison of the baseline surface water quality if the Project does not proceed with the predicted surface water quality if the Project proceeds, after mitigation measures described in Section 13.5.3 are applied.

The significance determination follows a two-step process (see Chapter 8, Effects Assessment Methodology); first the severity of residual effects is ranked according to a minor, moderate, and major scale. Then, a consideration of whether minor, moderate, or major effects are significant is made, following the definitions below:

- **Not significant (minor or moderate scale)**: Residual effects have low or moderate magnitude; local to regional geographic extent; short- or medium-term duration; could occur at any frequency, and are reversible or partially reversible in either the short- or long-term. The effects on the VC (e.g., at a species or local population level) are either indistinguishable from background conditions (i.e., occur within the range of natural variation as influenced by physical, chemical, and biological processes), or distinguishable at the individual level. Land and resource management plan objectives will likely be met, but some management objectives may be impaired.

- **Significant (major scale)**: Residual effects have high magnitude; regional or beyond regional geographic extent; duration is long-term or far-future; and occur at all frequencies. Residual effects on VCs are consequential (i.e., structural and functional changes in populations, communities, and ecosystems are predicted) and are irreversible. The ability to meet land and resource management plan objectives is impaired.

Residual effects on T Creek have high magnitude, local geographic extent, far-future duration, and continuous frequency. Residual effects are partially reversible and affect a waterbody with low resiliency. Therefore, the significance of the effect was assessed as **significant (major)**. Additional water management options to reduce concentrations of water quality parameters and mitigate water quality effects in T Creek continue to be investigated by HCMC through iterative technical and predictive studies. The results of these studies and details of additional mitigation measures will be made available to the Working Group as feasible options are identified.

Residual effects on P and Harper creeks, the outlet of North Barrière Lake, and Barrière River have low to medium magnitude, local to regional geographic extent, far-future duration, and regular or continuous frequency. Residual effects are partially reversible and affect waterbodies with low resiliency. Therefore, the significance of the effect in these areas was assessed as **not significant (moderate)**.

It is expected that SBEBs will be developed at appropriate locations during the *Environmental Management Act* process for selenium and other water quality parameters with baseline concentrations above BC WQG. Development of SBEBs will be consistent with guidance provided in BC MOE (2013). Establishment of SBEBs will likely reduce the magnitude of residual effects on water quality; however, since the screening process (see Section 13.5.2.3) considered background conditions, residual effects are still anticipated.

13.5.6 Confidence and Uncertainty in Determination of Significance

Confidence, which can also be understood as the level of uncertainty associated with the assessment, is a measure of how well residual effects are understood and the confidence associated with the baseline data, modelling techniques used, assumptions made, effectiveness of mitigation, and resulting predictions.

- **Confidence Level**: Sensitivity analysis indicates that there is some uncertainty as to the timing, magnitude, and duration of effects. However, water quality modelling followed industry-standard techniques, incorporated reasonable conservatisms, and was developed using site-specific baseline and technical studies.
- The confidence in the significance prediction and mitigation measures being followed was rated as **medium** for the residual effect of the Project on surface water quality.

13.5.6.1 Summary of the Assessment of Residual Effects for Surface Water Quality

Table 13.5-10 provides a summary of key residual effects, likelihood, significance, and confidence for the surface water quality VC. Identified residual effects were carried forward to the cumulative effects assessment (CEA) in Section 13.6.

13.6 CUMULATIVE EFFECTS ASSESSMENT

13.6.1 Scoping Cumulative Effects

Cumulative effects are the result of a Project-related effect interacting with the effects of other human actions (i.e., anthropogenic developments, projects, or activities) to produce a combined effect. Cumulative effects are assessed in each of the assessment chapters, as required by the BC EAO (2013).

13.6.1.1 Valued Components and Project-related Residual Effects

The residual effects on surface water quality identified in Section 13.5 (Table 13.5-10) were carried forward and considered for the CEA.

13.6.1.2 Defining Assessment Boundaries

Similar to the Project-related effects, assessment boundaries define the maximum limit within which the cumulative effects assessment is conducted. Boundaries relevant to surface water quality are described below.

The temporal boundaries for the identification of physical projects and activities have been categorized into past, present and reasonably foreseeable projects and are defined as follows:

- **Past**: no longer operational projects and activities that were implemented in the past 50 years. This temporal boundary enables any far-future effects from past projects and activities[1] to be taken into account;
- **Present**: active and inactive projects and activities; and
- **Future:** certain projects and activities that will proceed, and reasonably foreseeable projects and activities that are likely to occur. These projects are restricted to those that 1) have been publicly announced with a defined project execution period and with sufficient project details for assessment; and/or 2) are currently undergoing an environmental assessment, and/or 3) are in a permitting process.

[1] Far-future effects are defined as effects that last more than 37 years, as per Table 8.6-2: Attributes for Characterization of Residual Effects.

Table 13.5-10. Summary of Key Effects, Mitigation, Residual Effects Characterization Criteria, Likelihood, Significance, and Confidence

Key Effect	Mitigation Measures	Summary of Residual Effects Characterization Criteria *(Magnitude, Geographic Extent, Duration, Frequency, Reversibility, Resiliency)*	Likelihood *(High, Moderate, Low)*	Significance of Adverse Residual Effects: Scale *(Minor, Moderate, Major)*	Significance of Adverse Residual Effects: Rating *(Not Significant; Significant)*	Confidence *(High, Moderate, Low)*
Change in surface water quality in P Creek	Fish and Aquatic Effects Monitoring and Management Plan; Groundwater Management Plan; Mine Waste and ML/ARD Management Plan; Selenium Management Plan; Site Water Management Plan	Medium, local, medium-term, regular, partially reversible, low	High	Moderate	Not Significant	Medium
Change in surface water quality in T Creek	Fish and Aquatic Effects Monitoring and Management Plan; Groundwater Management Plan; Mine Waste and ML/ARD Management Plan; Selenium Management Plan; Site Water Management Plan	High, local, far-future, continuous, partially reversible, low	High	Major	Significant	Medium
Change in surface water quality in upper Harper Creek	Fish and Aquatic Effects Monitoring and Management Plan; Groundwater Management Plan; Mine Waste and ML/ARD Management Plan; Selenium Management Plan; Site Water Management Plan	Medium, local, far-future, continuous, partially reversible, low	High	Moderate	Not Significant	Medium

(continued)

Table 13.5-10. Summary of Key Effects, Mitigation, Residual Effects Characterization Criteria, Likelihood, Significance, and Confidence (completed)

Key Effect	Mitigation Measures	Summary of Residual Effects Characterization Criteria *(Magnitude, Geographic Extent, Duration, Frequency, Reversibility, Resiliency)*	Likelihood *(High, Moderate, Low)*	Significance of Adverse Residual Effects: Scale (*Minor, Moderate, Major*)	Significance of Adverse Residual Effects: Rating *(Not Significant; Significant)*	Confidence *(High, Moderate, Low)*
Change in surface water quality in lower Harper Creek	Fish and Aquatic Effects Monitoring and Management Plan; Groundwater Management Plan; Mine Waste and ML/ARD Management Plan; Selenium Management Plan; Site Water Management Plan	Low, local, far-future, regular, partially reversible, low	High	Moderate	Not Significant	Medium
Change in surface water quality at the outlet of North Barrière Lake and in Barrière River	Fish and Aquatic Effects Monitoring and Management Plan; Groundwater Management Plan; Mine Waste and ML/ARD Management Plan; Selenium Management Plan; Site Water Management Plan	Low, regional, far-future, regular, partially reversible, low	High	Moderate	Not Significant	Medium

The spatial boundaries for the identification of other physical projects and activities for the assessment of cumulative effects have been identified in the AIR as the Kamloops LRMP boundary, and are illustrated in Figure 8.7-1. These boundaries are referred to as the CEA area[2]. The spatial boundaries for the identification of other physical projects and activities for the assessment of cumulative effects for surface water quality was further refined to the RSA (Figure 13.6-1). Figure 13.6-1 shows the location of past, present, and reasonably foreseeable future projects, and the location of land-use activities are presented in Figures 13.6-2 to 13.6-5.

Project-related residual effects on surface water quality due to a change in water quality were assessed in P, T, and Harper creeks, the outlet of North Barrière Lake, and Barrière River. Therefore, the potential for interaction with surface water quality effects from other human actions was only considered for those waterbodies.

13.6.1.3 Projects and Activities Considered

Past, present, and reasonably foreseeable future projects and activities within the boundaries described above were considered in the CEA. The project list was developed from a wide variety of information sources, including municipal, regional, provincial, and federal government agencies; other stakeholders; and companies' and businesses' websites. The projects and activities considered in the CEA are presented in Chapter 8 in Tables 8.7-1 and 8.7-2, respectively. The methodology used in the CEA is provided in Chapter 8, Section 8.7.

13.6.2 Screening and Analyzing Cumulative Effects

No potential spatial interactions with past, present, and reasonably foreseeable future projects and activities were identified for Project residual effects due to the change in water quality in P, T, or Harper creeks, the outlet of North Barrière Lake, or Barrière River; therefore, no potential cumulative effects were identified.

13.7 CONCLUSIONS FOR SURFACE WATER QUALITY

Table 13.7-1 provides a summary of key Project-related and cumulative residual effects, mitigation measures, and significance.

[2] Note that the CEA area only refers to the spatial boundaries for the identification of other physical projects and activities, i.e., the Kamloops LRMP boundary. Each assessment chapter will define its own spatial and temporal boundaries.

Figure 13.6-1

Location of Past, Present, and Reasonably Foreseeable Future Projects for the Cumulative Effects Assessment

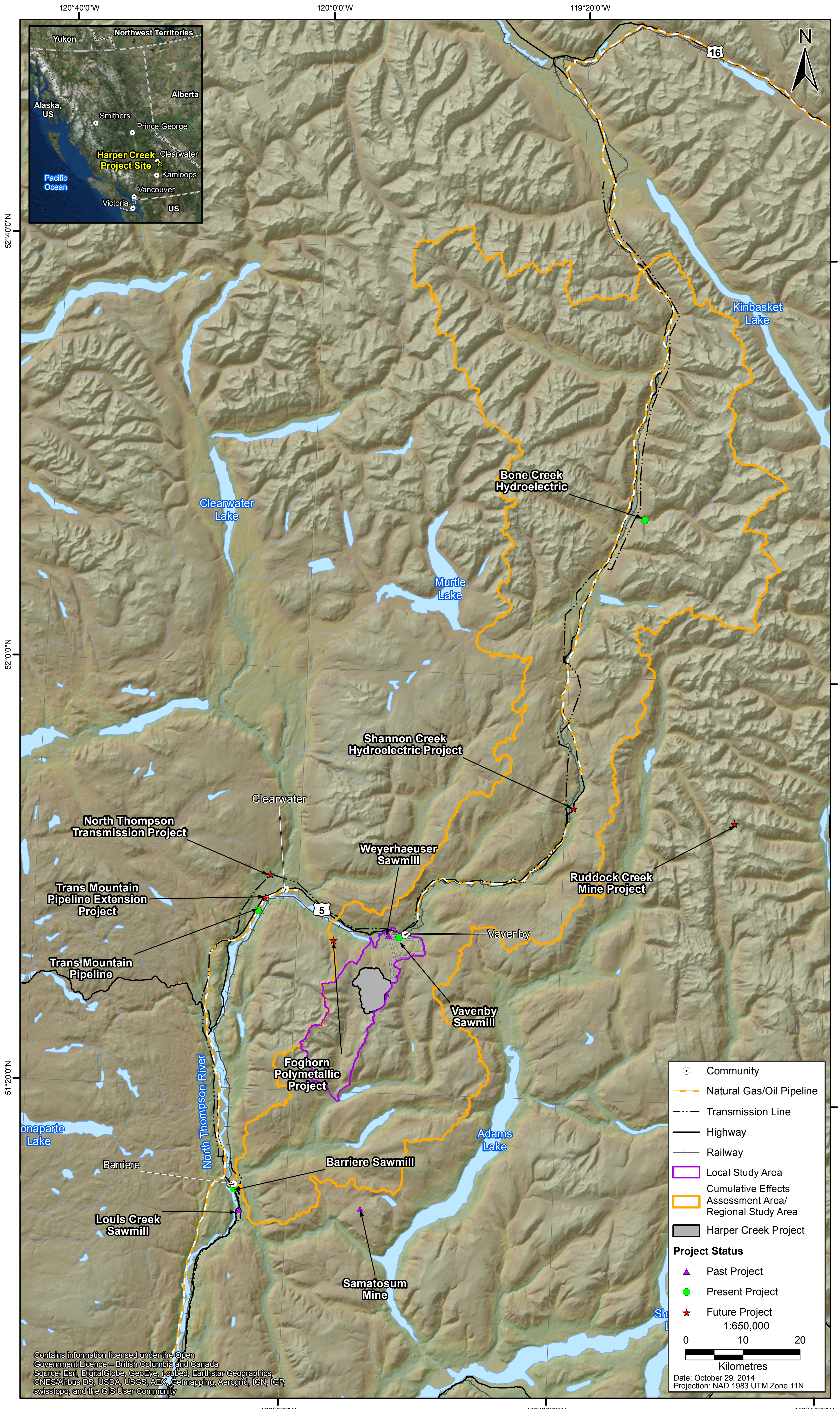


Figure 13.6-2

Forestry in the Cumulative Effects Assessment Area

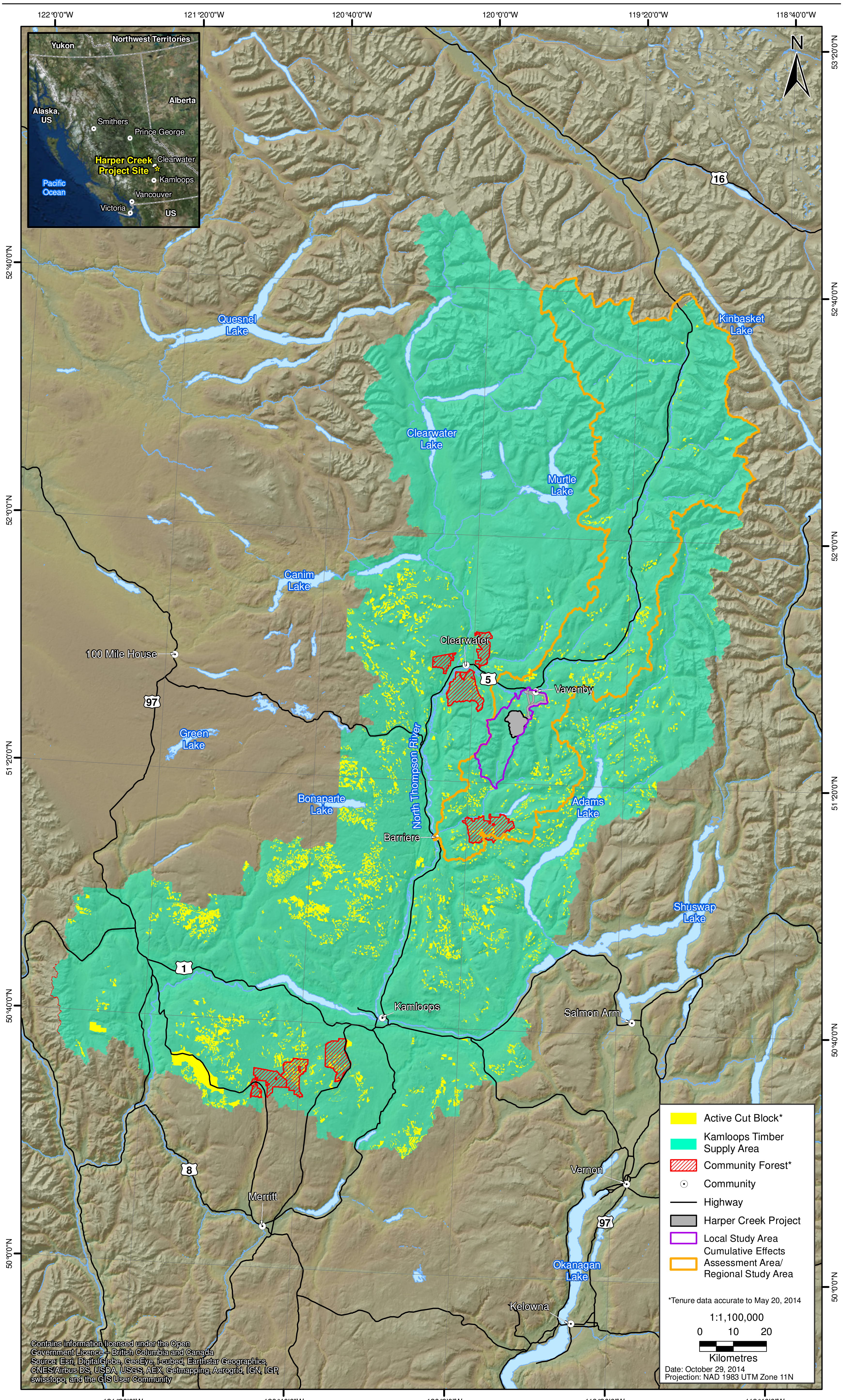


Figure 13.6-3

Commercial Recreation Tenures in the Cumulative Effects Assessment Area

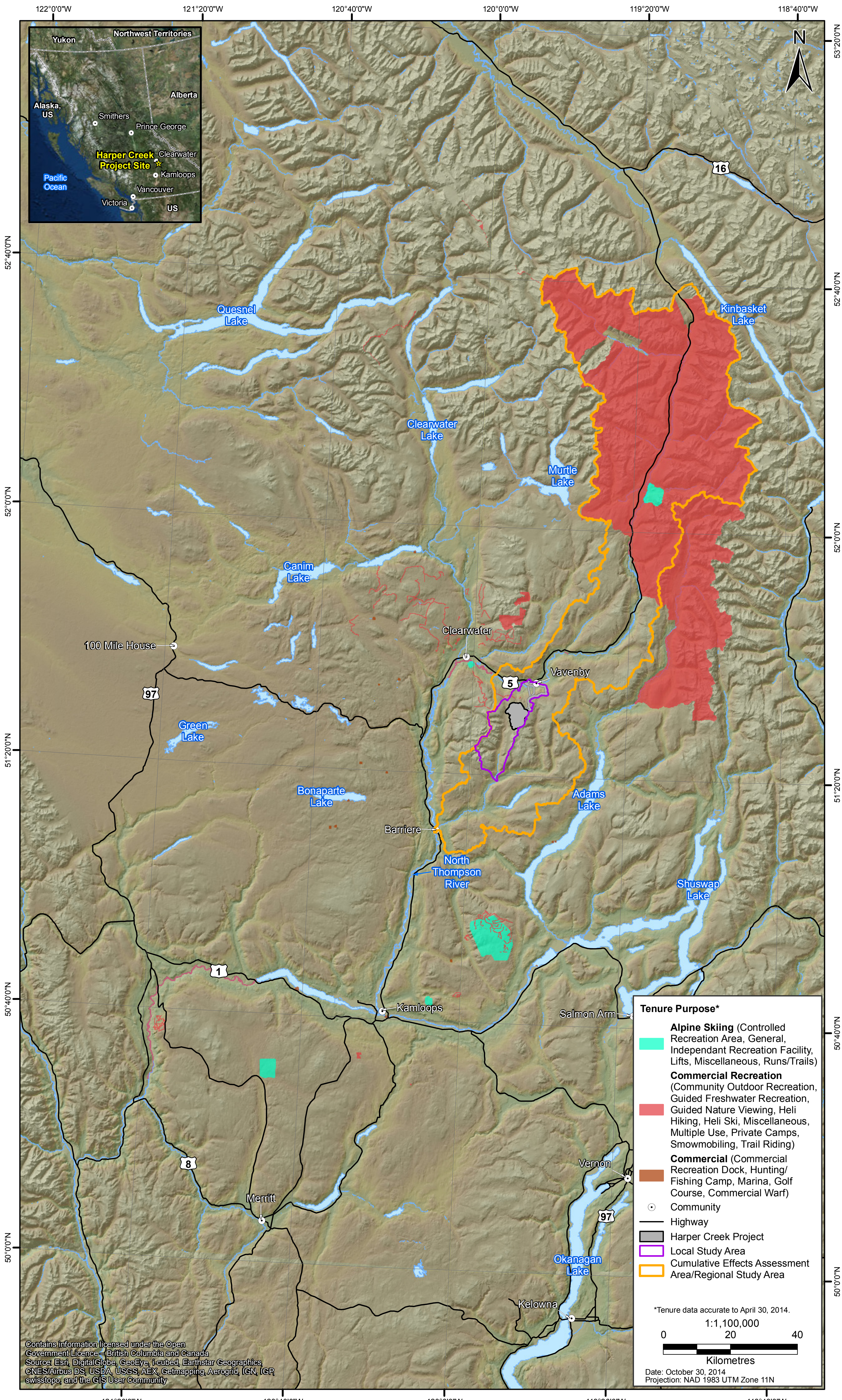


Figure 13.6-4

Water Licences and Range Tenures in the Cumulative Effects Assessment Area

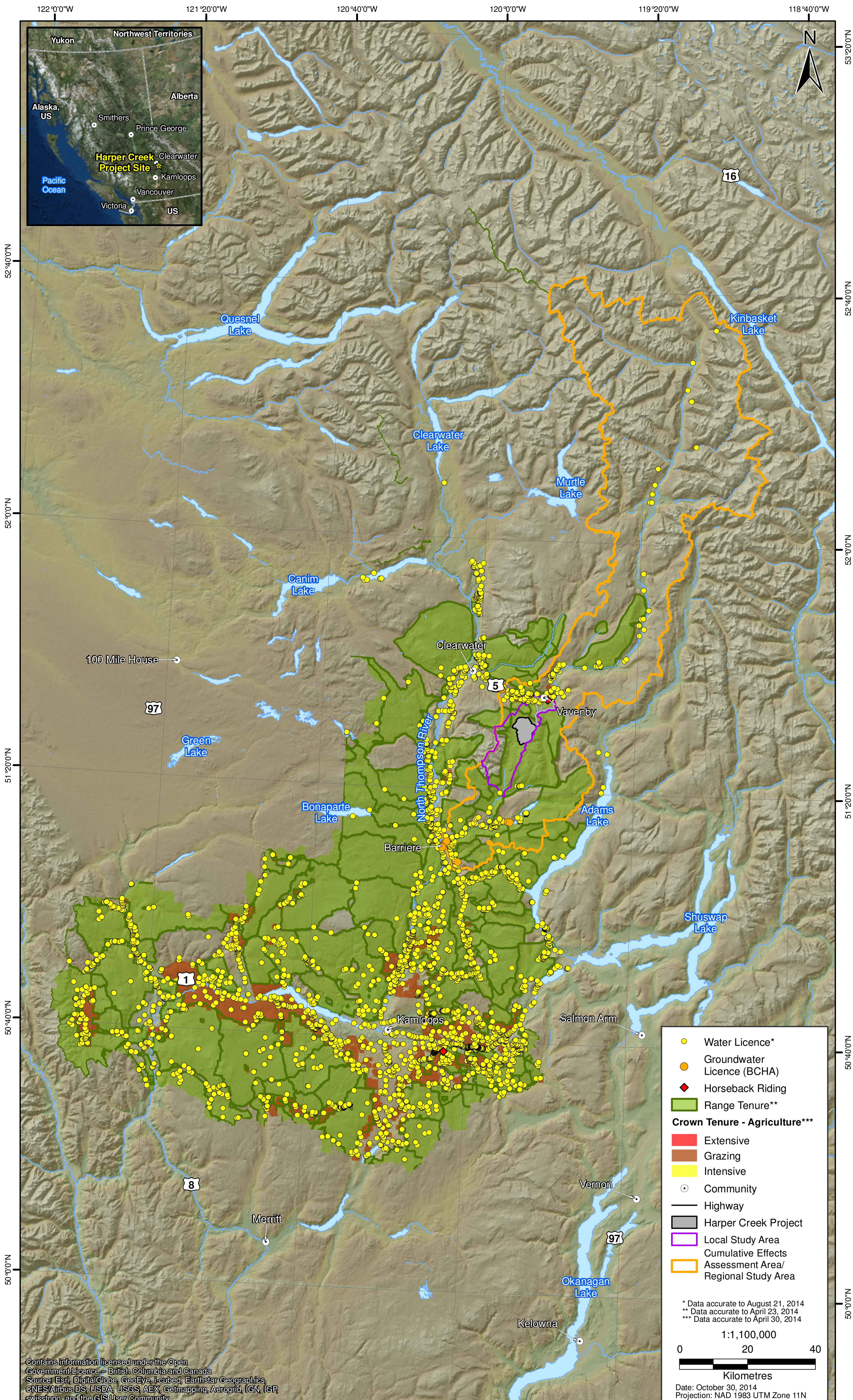


Figure 13.6-5

BC Recreation Sites, Trails, and Private Campgrounds in the Cumulative Effects Assessment Area

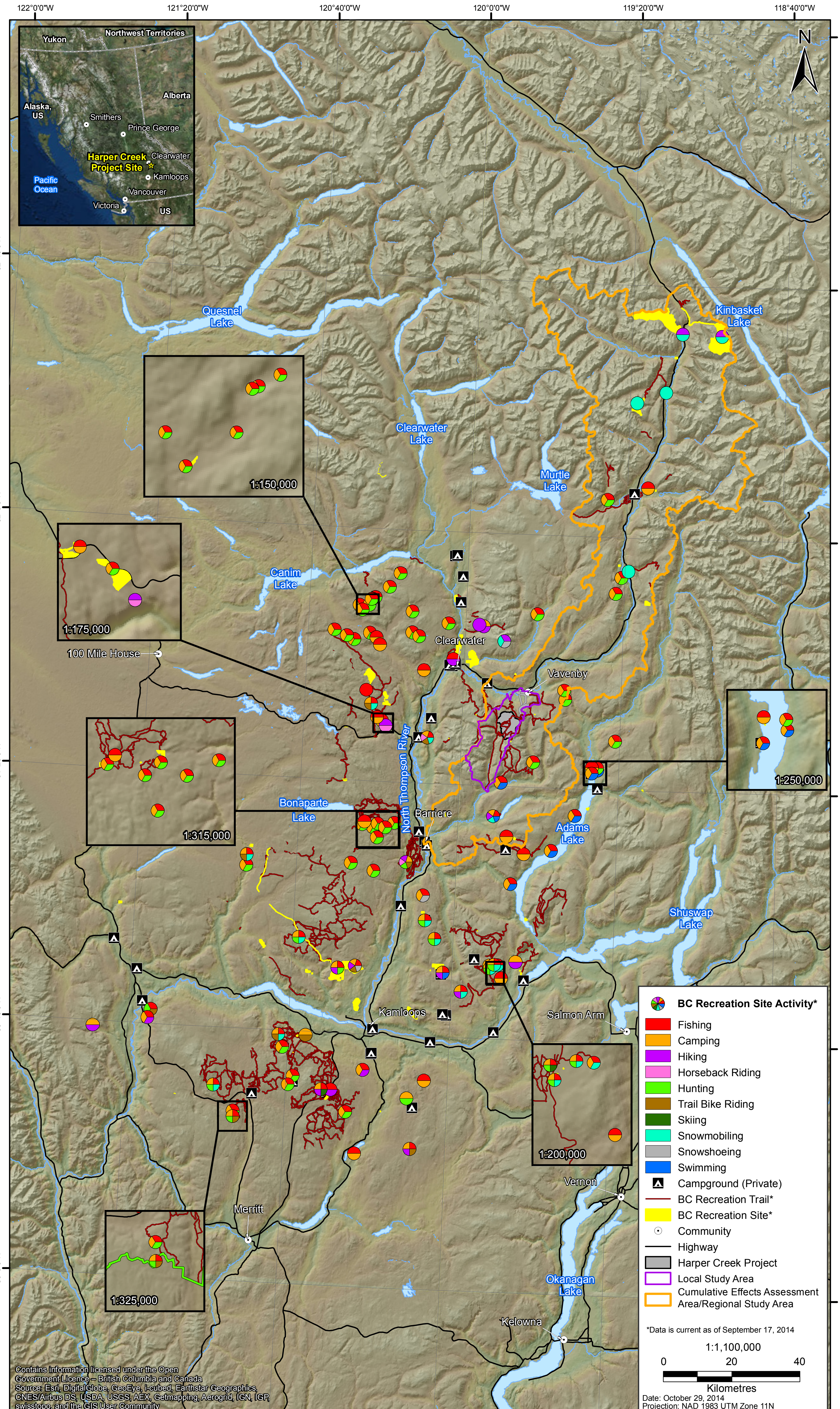


Table 13.7-1. Summary of Key Project and Cumulative Residual Effects, Mitigation, and Significance for Surface Water Quality

Key Residual Effects	Project Phase	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Change in surface water quality in P Creek	Operations	Air Quality and Dust Control Plan (Section 24.2); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Sediment and Erosion Control Plan (Section 24.11); Selenium Management Plan (Section 24.12); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.16)	Not significant (moderate)	N/A
Change in surface water quality in T Creek	Closure and Post-Closure	Air Quality and Dust Control Plan (Section 24.2); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Sediment and Erosion Control Plan (Section 24.11); Selenium Management Plan (Section 24.12); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.16)	Significant (major)	N/A
Change in surface water quality in upper Harper Creek	Construction, Operation, Closure, and Post-Closure	Air Quality and Dust Control Plan (Section 24.2); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Sediment and Erosion Control Plan (Section 24.11); Selenium Management Plan (Section 24.12); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.16)	Not significant (moderate)	N/A
Change in surface water quality in lower Harper Creek	Closure and Post-Closure	Air Quality and Dust Control Plan (Section 24.2); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Sediment and Erosion Control Plan (Section 24.11); Selenium Management Plan (Section 24.12); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.16)	Not significant (moderate)	N/A

(continued)

Table 13.7-1. Summary of Key Project and Cumulative Residual Effects, Mitigation, and Significance for Surface Water Quality (completed)

Key Residual Effects	Project Phase	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Change in surface water quality at the outlet of North Barrière Lake and in Barrière River	Closure and Post-Closure	Air Quality and Dust Control Plan (Section 24.2); Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6); Groundwater Management Plan (Section 24.8); Mine Waste and ML/ARD Management Plan (Section 24.9); Sediment and Erosion Control Plan (Section 24.11); Selenium Management Plan (Section 24.12); Site Water Management Plan (Section 24.13); Soil Salvage and Storage Plan (Section 24.16)	Not significant (moderate)	N/A

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