14. FISH AND AQUATIC RESOURCES EFFECTS ASSESSMENT

14.1 INTRODUCTION

14.1.1 Project Overview

Harper Creek Mining Corporation (HCMC) proposes to construct and operate the Harper Creek Project (the Project), an open-pit copper mine near the unincorporated community of Vavenby, British Columbia (BC). The Project has an estimated 28-year mine life based on a process plant throughput of 70,000 tonnes per day (25 million tonnes per year). Ore will be processed on site through a conventional crushing, grinding, and flotation process to produce a copper concentrate, with gold and silver by-products. These will be trucked from the Project Site along approximately 24 kilometres (km) of existing access roads to a rail load-out facility located at Vavenby. The concentrate will be transported via the existing Canadian National Railway network to the existing Vancouver Wharves storage, handling, and loading facilities located at Port Metro Vancouver for shipment to overseas smelters.

The Project is located in the Thompson-Nicola Regional District of BC, approximately 150 km northeast of Kamloops along the Southern Yellowhead Highway (Highway 5), and approximately 10 km southwest of Vavenby. The Project is within National Topographic System map sheets 82M/5 and 82M/12, is geographically centred at 51°30′N latitude and 119°48′W longitude, and is approximately 1,800 metres above sea level (masl). The mineral claims comprising the Project cover an area of 42,636 hectares (ha). The Project location is shown in Figure 14.1-1.

The Project consists of an open pit mine, on-site processing facility, tailings management facility (TMF; for tailings solids, subaqueous storage of potentially acid-generating [PAG] waste rock, and recycling of water for processing), waste rock stockpiles, low-grade and overburden stockpiles, a temporary construction camp, ancillary facilities, mine haul roads, sewage and waste management facilities, a 24-km access road between the Project Site and a rail load-out facility located on private land owned by HCMC in Vavenby, and a 12-km power line connecting the Project Site to the BC Hydro transmission line corridor in Vavenby. The Project location and infrastructure is shown in Figure 14.1-2.

Access to the Project is from Kamloops to Vavenby via Highway 5, across the North Thompson River and then eastward along the Birch Island-Lost Creek Forest Service Road (FSR) for approximately 6 km to the Jones Creek FSR. The proposed main access route to the Project Site is from Vavenby via the Vavenby Mountain FSR. This road runs along the western side of Chuck Creek for approximately 6 km before heading west toward Avery Creek and the southeastern part of the Project. This road then meets the Barriere Mountain FSR at approximately 11 km. From there, the Saskum Plateau FSR heads southwest to the eastern and central areas of the Project (See Figure 14.1-2).

Figure 14.1-1

Project Location

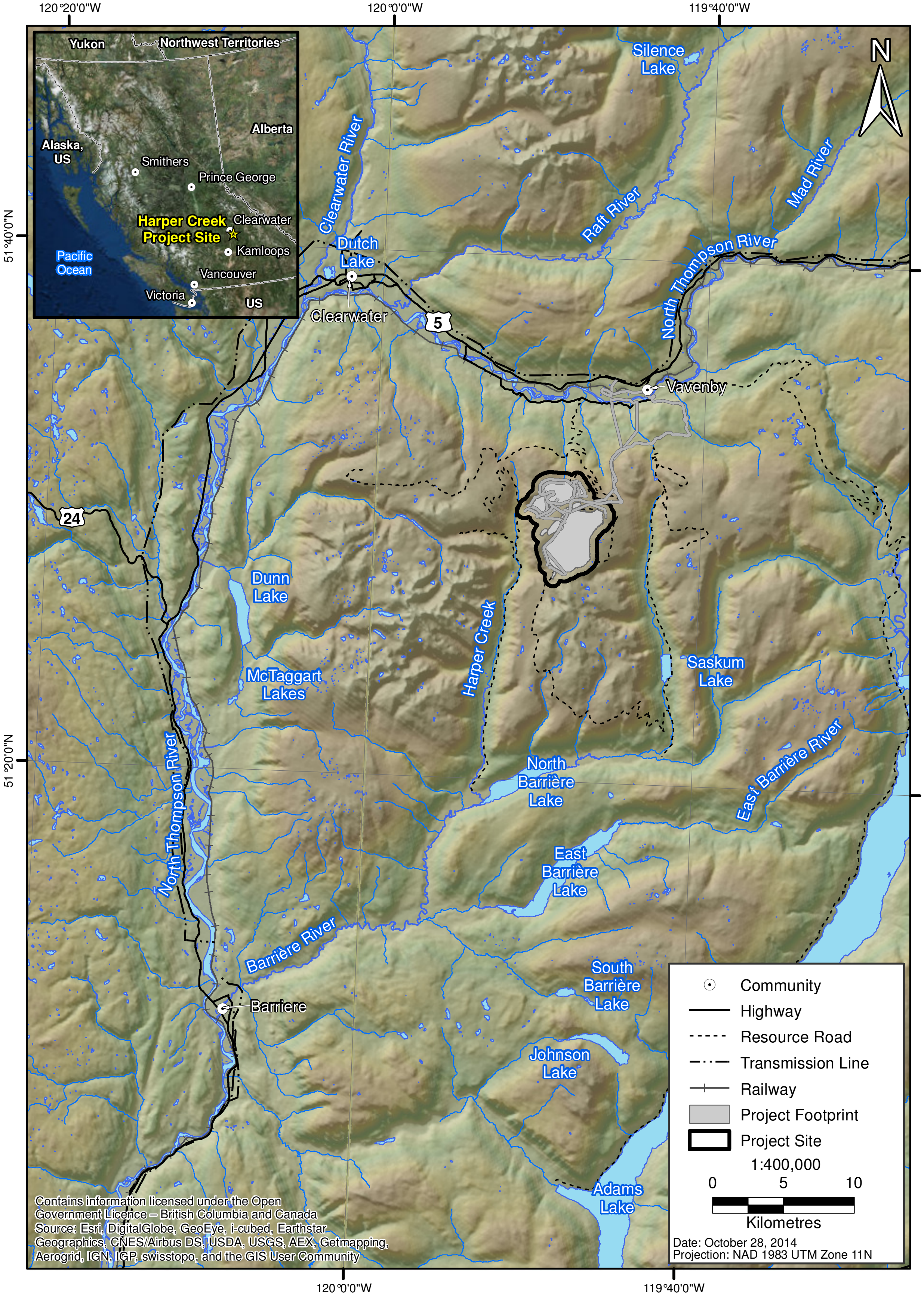

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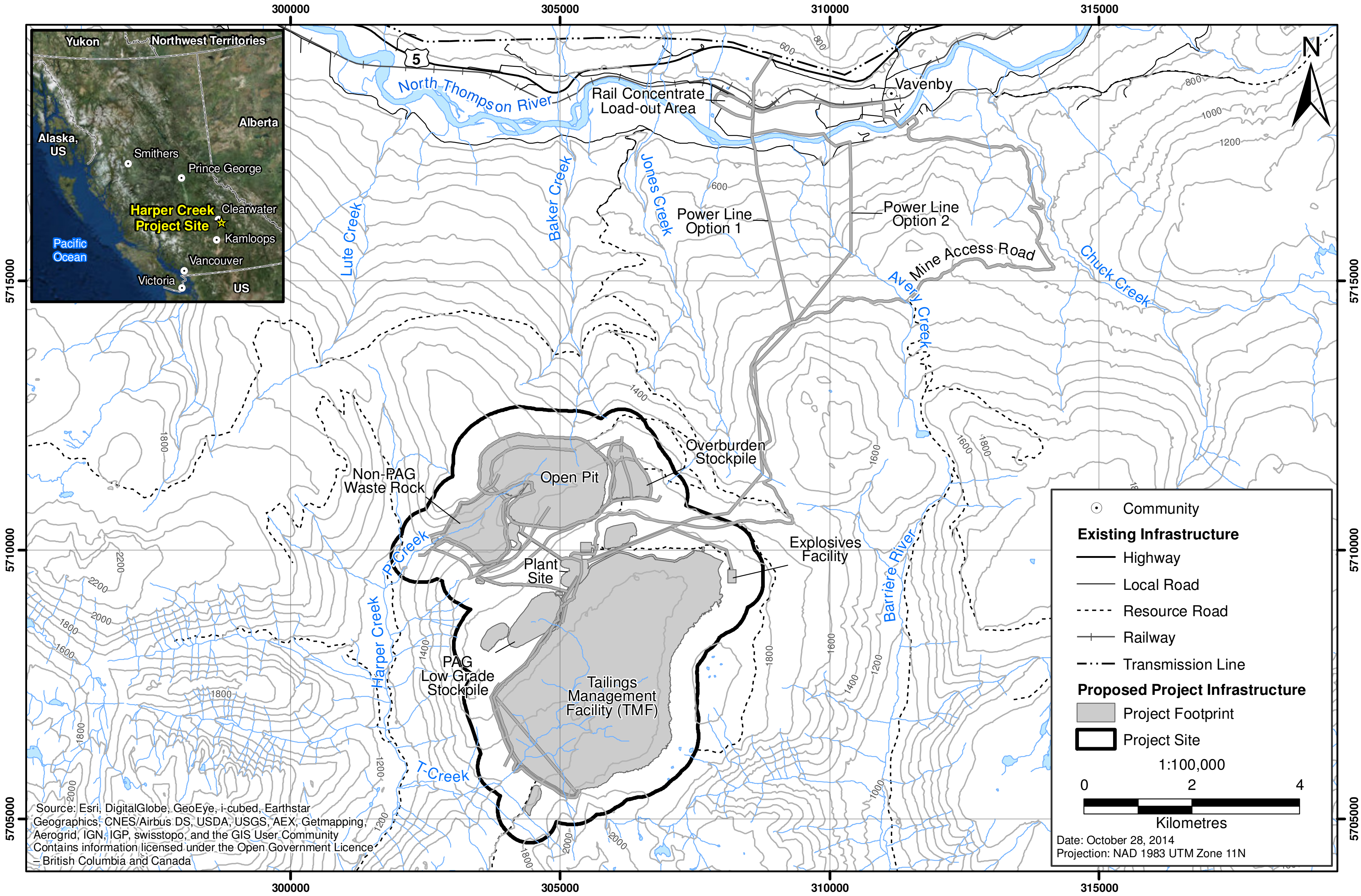
Figure 14.1-2
Project Location and Infrastructure



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14.1.2 Purpose of this Chapter

The assessment of the potential effects of the Project on fish, fish habitat, and aquatic resources is described within this chapter. Fish, fish habitat, and aquatic resources form critical components of the aquatic environment. Assessing the potential effects of the Project on these components will integrate the assessment of surface water quality and surface water quantity and inform the assessment of human health. Fish, along with their key habitat requirements, are protected under the *Fisheries Act* (1985b) through their relationship to fisheries production and are considered important to Canadians from an economic, recreational, and cultural perspective.

Prior to Project development, a baseline program was conducted to facilitate the prediction, assessment, mitigation, and management of potential Project-related effects. Project-specific baseline study reports and associated data covering years 2011 to 2013 are presented in Appendix 14-A.

This chapter follows the effects assessment methodology described in Chapter 8 of this Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS).

14.2 REGULATORY AND POLICY FRAMEWORK

Several federal and provincial regulations guide the protection of fish, fish habitat, and aquatic resources during the mine development process. These include the:

- Canada *Fisheries Act* (1985b);
- Metal Mining Effluent Regulations (SOR/2002-222);
- Canada *Species at Risk Act* (2002);
- BC *Water Act* (1996);
- BC *Fish Protection Act* (1997); and
- BC *Environmental Management Act* (Clark 2003).

This section provides an overview of the relevant legislative and regulatory framework and requirements for potential Project-related effects to fish, fish habitat, and aquatic resources as summarized in Table 14.2-1.

Section 35(1) of the *Fisheries Act* (1985b) prohibits a person from carrying on any work, undertaking, or activity that results in serious harm to fish that are part of or support commercial, recreational, or Aboriginal fisheries. Where an activity may cause serious harm, proponents are required to obtain an authorization and offset impacts to fish habitat. Also under the *Fisheries Act*, the MMER (MMER; SOR/2002-222), requires environmental effects testing and monitoring activities that must be undertaken for metal mines as a condition of depositing or releasing effluent. The stipulated activities examine aspects of aquatic ecosystems in receiving waterbodies that may indicate individual, ecosystem, and population-level health. The monitoring of these characteristics must be summarized in interpretive reports provided to Environment Canada. Permission to discharge mine effluent is contingent on the implementation of appropriate monitoring activities allowing the assessment of effects on aquatic ecosystems.

Table 14.2-1. Summary of Applicable Statutes and Regulations for Potential Fish and Aquatic Resources Effects, Harper Creek Project

Name	Level of Government	Description
Fisheries Act (1985b)	Federal	The *Fisheries Act* prohibits serious harm to fish and applies to fish and fish habitat that are part of or support commercial, recreational, or Aboriginal fisheries. Fisheries and Oceans Canada (DFO) interprets serious harm to fish as: • the death of fish; • a permanent alteration to fish habitat of a spatial scale, duration, or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds, nursery, rearing, food supply areas, migration corridors, or any other area in order to carry out one or more of their life processes; and • the destruction of fish habitat of a spatial scale, duration, or intensity that results in fish no longer being able to rely on such habitats for use as spawning grounds, nursery, rearing, food supply areas, migration corridor, or any other area in order to carry out one or more of their life processes.
Metal Mining Effluent Regulations (SOR/2002-222)	Federal	MMER regulations, under the *Fisheries Act* (1985b), set effluent discharge limits and outline guidelines for environmental effects testing and monitoring activities that must be undertaken by metal mines as a condition of depositing or releasing effluent into water.
Species at Risk Act (2002)	Federal	The federal *Species at Risk Act* (SARA; 2002) is designed to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses and identifies species at risk.
British Columbia (BC) *Water Act* (1996)	Provincial	The provincial *Water Act* (1996) regulates changes in or about a stream, ensuring that water quality, fish and wildlife habitat, and the rights of licence users are not compromised.
BC *Fish Protection Act* (1997)	Provincial	The provincial *Fish Protection Act* (1997) focuses on ensuring sufficient water for fish, protecting and restoring fish habitat, improving riparian protection and enhancement, and providing local government with more power with regard to environmental planning.
BC *Environmental Management Act (2003)*	Provincial	Prohibits pollution of the environment and requires authorization to introduce waste (i.e., effluent) into the environment for "prescribed" industries, trades, businesses, operations, and activities.
BC Water Quality Guidelines (WQG; Approved and Working; BC MOE 2006, 2014)		Water quality criteria are defined as maximum or minimum physical, chemical or biological characteristics of water, biota, or sediment and are applicable province-wide. The guidelines are intended to prevent detrimental effects on water quality or aquatic life, under specified environmental conditions.

(continued)

Table 14.2-1. Summary of Applicable Statutes and Regulations for Potential Fish and Aquatic Resources Effects, Harper Creek Project (completed)

Name	Level of Government	Description
Canadian Council of Ministers of Environment (CCME) Sediment Quality Guidelines (CCME 2014a)		Sediment quality guidelines defined as maximum chemical characteristics of sediment intended to prevent detrimental effects on aquatic life.

Other relevant statutes and their enabled regulations regarding the protection of fish, fish habitat (including water quality), and aquatic resources include the *Species at Risk Act* (2002), the *Water Act* (1996), the *Fish Protection Act* (1997), and the *Environmental Management Act* (Table 14.2-1; 2003).

14.3 SCOPING THE EFFECTS ASSESSMENT

14.3.1 Valued Components

The British Columbia Environmental Assessment Office (BC EAO) define valued components (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 Canadian Environmental Assessment Agency (CEA Agency; 2011) Background Information document.

14.3.1.1 Consultation Feedback on Proposed Valued Components

A preliminary list of proposed VCs was drafted early in project planning based on the expected physical works and activities of the reviewable project; type of project being proposed; local area and regions where the proposed project would be located; and consultation with Aboriginal groups, the public, and federal, provincial, and local government agencies. A summary of how scoping feedback was incorporated into the selection of assessment subject areas and VCs is summarized below in Table 14.3-1.

Concerns about potential effects to fish, fish habitat, and aquatic resources were raised by Aboriginal groups (Appendix 3-F), by the public and stakeholders (Appendix 3-L), and by government (Appendix 3-J).

Simpcw First Nation (SFN) expressed concern regarding the potential for effects on fish species (especially Bull Trout, *Salvelinus confluentus*) due to changes in temperature and reduced flows, and the potential for fish to adjust to these changes. SFN stated concern about habitat loss due to the Project and the proposed habitat compensation. They also requested information about baseline monitoring and the lethal sampling of fish in Harper Creek, and if interactions between the migratory Bull Trout population in North Barrière Lake and the resident population in upper Harper Creek had been observed. SFN expressed concern about potential effects to salmon fisheries in the Project area.

Table 14.3-1. Consultation Feedback on Fish and Aquatic Resources Valued Components

Subject Area	Feedback by*			Issues Raised	Proponent Response
	AG	G	P/S		
Fish	X	X	X	Effects on fish were identified as a potential issue.	The Project has the potential to affect fish (including listed species) and salmon fisheries, therefore any potential effects to fish were included in the effects assessment.
Fish Habitat	X	X	X	Effects on fish habitat were identified as a potential issue.	Changes in water quality, temperature, flow, and habitat can have a direct effect on fish habitat, thus these potential changes were assessed as a component of the assessment of effects on fish habitat. Fish habitat offsetting was also included in the effects assessment.
Aquatic Resources		X		Effects on aquatic resources identified as a potential issue.	Required for inclusion by statues and regulations such as the *Water Act* (1996) and the *Environmental Management Act*. Potential effects on aquatic resources from changes in water quantity and water quality were included in the effects assessment.

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

The Adams Lake Indian Band (ALIB) expressed concern about effects to fish and aquatic habitats from the construction of roads and power lines. They raised concern about the methods for determining fish distribution including their presence and absence in waterbodies. ALIB also expressed interest in being involved in fish offsetting options.

The Little Shuswap Indian Band expressed concern with potential Project effects to fish and fish habitat in Harper Creek and its confluence with North Barrière Lake. They were also concerned with access to fish and fish-bearing streams throughout the life of the mine and the maintenance of sufficient water flow.

Neskonlith Indian Band expressed concern about effects from mine operations on fish and fish habitat, especially in the Harper Creek watershed and the Barrière River system.

The public expressed concern about the North Thompson being habitat for Chinook Salmon (*Oncorhynchus tshawytscha*), Dolly Varden (*Salvelinus malma*), and Bull Trout. A trapline tenure holder expressed concern about Project-related disturbance to fish. A working group member expressed concern about the effect of potential flow reductions on fish populations.

The British Columbia Ministry of Forests, Lands and Natural Resource Operations expressed concern about the effects of the mine footprint on fish. The British Columbia Ministry of Environment (BC MOE) expressed concern about mine operations resulting in acute toxicity within the initial dilution zones. Environment Canada expressed concern with effects to species at risk. DFO expressed concern regarding the inclusion of food and nutrient value, in addition to flow, regardless of whether a stream is fish-bearing, as DFO requires compensation for loss of fish and nutrient value. DFO also stated that they require identification of the Area of Impact and a Habitat Suitability Index. DFO also stated that the Environmental Impact Statement (EIS) requires consideration of SARA-listed species.

14.3.1.2 Selecting Valued Components

Five potential VCs were identified during the pre-Application/EIS stage as a result of project consultations: fish, fish habitat, sediment quality, periphyton, and benthic invertebrates. Summaries of each of these VCs are described below, and their potential interaction with Project components is shown in Table 14.3-2.

14.3.1.3 Valued Components Selected for Assessment

The proposed VCs that were considered for assessment for the Project are summarized in Chapter 8, Table 8.4-3. The VCs selected for inclusion in the fish and aquatic resources effects assessment are presented in Table 14.3-3.

The following VC fish species were selected for assessment: Bull Trout throughout Harper Creek; Rainbow Trout (*Oncorhynchus mykiss*) in lower Harper Creek, Jones, and Baker creeks; and Coho Salmon (*Oncorhynchus kisutch*) in lower Harper Creek. These key species were selected due to:

- possible interaction with Project activities (Table 14.3-2);
- value to stakeholders (the public, and provincial and federal technical working group members) during consultations on the Project Description and draft AIR;
- protected status under COSEWIC (Bull Trout and Coho Salmon);
- recognition of a Comprehensive Fisheries Agreement with DFO (2007) signed with the Shuswap Nation Tribal Council (SNTC) that recognizes priority of First Nations to access salmon for food, social and ceremonial (FSC) purposes in fisheries with the potential to be affected by downstream Project effects; and
- value placed on these fish species as communicated by First Nations (see Table 22.4-1 in Chapter 22).

Table 14.3-2. Interaction of Project Components and Activities with Proposed Valued Components

Category	Project Components and Activities	Fish	Fish Habitat	Sediments	Periphyton	Benthic invertebrates
Construction						
Concrete production	Concrete batch plant installation, operation and decommissioning					
Dangerous goods and hazardous materials	Hazardous materials storage, transport, and off-site disposal					
Dangerous goods and hazardous materials	Spills and emergency management					
Environmental management and monitoring	Construction of fish habitat offsetting sites	X	X	X	X	X
Equipment	On-site equipment and vehicle use: heavy machinery and trucks					
Explosives	Explosives storage and use	X		X	X	X
Fuel supply, storage and distribution	Fuel supply, storage and distribution					
Open pit	Open pit development - drilling, blasting, hauling and dumping	X	X	X	X	X
Potable water supply	Process and potable water supply, distribution and storage	X	X	X	X	X
Power supply	Auxiliary electricity - diesel generators					
Power supply	Power line and site distribution line construction: vegetation clearing, access, poles, conductors, tie-in	X	X	X	X	X
Processing	Plant construction: mill building, mill feed conveyor, truck shop, warehouse, substation and pipelines	X	X	X	X	X
Processing	Primary crusher and overland feed conveyor installation					
Procurement and labour	Employment and labour					
Procurement and labour	Procurement of goods and services					
Project Site development	Aggregate sources/ borrow sites: drilling, blasting, extraction, hauling, crushing	X	X	X	X	X
Project Site development	Clearing vegetation, stripping and stockpiling topsoil and overburden, soil salvage handling and storage	X	X	X	X	X
Project Site development	Earth moving: excavation, drilling, grading, trenching, backfilling	X	X	X	X	X
Rail load-out facility	Rail load-out facility upgrade and site preparation	X		X	X	X
Roads	New TMF access road construction: widening, clearing, earth moving, culvert installation using non-PAG material	X	X	X	X	X
Roads	Road upgrades, maintenance and use: haul and access roads	X	X	X	X	X
Stockpiles	Coarse ore stockpile construction	X	X	X	X	X
Stockpiles	Non-PAG Waste Rock Stockpile construction	X	X	X	X	X
Stockpiles	PAG and Non-PAG Low-grade ore stockpiles foundation construction	X	X	X	X	X
Stockpiles	PAG Waste Rock stockpiles foundation construction	X	X	X	X	X
Tailings management	Coffer dam and South TMF embankment construction	X	X	X	X	X
Tailings management	Tailings distribution system construction	X		X	X	X
Temporary construction camp	Construction camp construction, operation, and decommissioning	X	X	X	X	X
Traffic	Traffic delivering equipment, materials and personnel to site	X		X	X	X
Waste disposal	Waste management: garbage, incinerator and sewage waste facilities	X	X	X	X	X
Water management	Ditches, sumps, pipelines, pump systems, reclaim system and snow clearing/stockpiling	X	X	X	X	X
Water management	Water management pond, sediment pond, diversion channels and collection channels construction	X	X	X	X	X
Operations 1						
Concentrate transport	Concentrate transport by road from mine to rail loadout					
Dangerous goods and hazardous materials	Explosives storage and use	X		X	X	X
Dangerous goods and hazardous materials	Hazardous materials storage, transport, and off-site disposal					
Dangerous goods and hazardous materials	Spills and emergency management					
Environmental management and monitoring	Fish habitat offsetting site monitoring and maintenance	X	X	X	X	X
Equipment fleet	Mine site mobile equipment (excluding mining fleet) and vehicle use					
Fuel supply, storage and distribution	Fuel storage and distribution					

(continued)

Table 14.3-2. Interaction of Project Components and Activities with Proposed Valued Components (continued)

Category	Project Components and Activities	Fish	Fish Habitat	Sediments	Periphyton	Benthic invertebrates
Operations 1 *(cont'd)*						
Mining	Mine pit operations: blast, shovel and haul	X	X	X	X	X
Ore processing	Ore crushing, milling, conveyance and processing	X		X	X	X
Potable water supply	Process and potable water supply, distribution and storage	X	X	X	X	X
Power supply	Backup diesel generators					
Power supply	Electrical power distribution					
Processing	Plant operation: mill building, truck shop, warehouse and pipelines	X	X	X	X	X
Procurement and labour	Employment and labour					
Procurement 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	X	X	X	X
Stockpiles	Construction of Non-PAG tailings beaches	X	X	X	X	X
Stockpiles	Construction of PAG and Non-PAG Low Grade Ore Stockpile	X	X	X	X	X
Stockpiles	Non-PAG Waste Rock Stockpiling	X	X	X	X	X
Stockpiles	Overburden stockpiling	X	X	X	X	X
Tailings management	Reclaim barge and pumping from TMF to Plant Site	X	X	X	X	X
Tailings management	South TMF embankment construction	X	X	X	X	X
Tailings management	Sub-aqueous deposition of PAG waste rock into TMF	X	X	X	X	X
Tailings management	Tailings transport and storage in TMF	X	X	X	X	X
Tailings management	Treatment and recycling of supernatant TMF water	X	X	X	X	X
Traffic	Traffic delivering equipment, materials and personnel to site					
Waste disposal	Waste management: garbage and sewage waste facilities					
Water management	Monitoring and maintenance of mine drainage and seepage	X	X	X	X	X
Water management	Surface water management and diversions systems including snow stockpiling/clearing	X	X	X	X	X
	Includes the Operations 1 non-mining Project Components and Activities, with the addition of these activities:					
Processing	Low grade ore crushing, milling and processing	X	X	X	X	X
Reclamation and decommissioning	Partial reclamation of Non-PAG waste rock stockpile	X	X	X	X	X
Reclamation and decommissioning	Partial reclamation of TMF tailings beaches and embankments	X	X	X	X	X
Tailings management	Construction of North TMF embankment and beach	X	X	X	X	X
Tailings management	Deposit of low grade ore tailings into open pit	X	X	X	X	X
Water management	Surface water management	X	X	X	X	X
Environmental management and monitoring	Environmental monitoring including surface and groundwater monitoring	X	X	X	X	X
Environmental management and monitoring	Monitoring and maintenance of mine drainage, seepage, and discharge	X	X	X	X	X
Environmental management and monitoring	Reclamation monitoring and maintenance	X	X	X	X	X
Open pit	Filling of open pit with water and storage of water as a pit lake	X	X	X	X	X
Procurement and labour	Employment and labour					
Procurement and labour	Procurement of goods and services					
Reclamation and decommissioning	Decommissioning of rail concentrate loadout area	X		X	X	X
Reclamation and decommissioning	Partial decommissioning and reclamation of mine site roads	X	X	X	X	X
Reclamation and decommissioning	Decommissioning and removal of plant site, processing plant and mill, substation, conveyor, primary crusher, and	X	X	X	X	X

(continued)

Table 14.3-2. Interaction of Project Components and Activities with Proposed Valued Components (completed)

Category	Project Components and Activities	Fish	Fish Habitat	Sediments	Periphyton	Benthic invertebrates
Closure *(cont'd)*						
Reclamation and decommissioning	Decommissioning of diversion channels and distribution pipelines	X	X	X	X	X
Reclamation and decommissioning	Decommissioning of reclaim barge					
Reclamation and decommissioning	Reclamation of Non-PAG LGO stockpile, overburden stockpile and Non-PAG waste rock stockpile	X	X	X	X	X
Reclamation and decommissioning	Reclamation of TMF embankments and beaches	X	X	X	X	X
Reclamation and decommissioning	Removal of contaminated soil	X	X	X	X	X
Reclamation and decommissioning	Use of topsoil for reclamation	X	X	X	X	X
Stockpiles	Storage of waste rock in the non-PAG waste rock stockpile	X	X	X	X	X
Tailings management	Construction and activation of TMF closure spillway	X	X	X	X	X
Tailings management	Maintenance and monitoring of TMF	X	X	X	X	X
Tailings management	Storage of water in the TMF and groundwater seepage	X	X	X	X	X
Tailings management	Sub-aqueous tailing and waste rock storage in TMF	X	X	X	X	X
Tailings management	TMF discharge to T-Creek	X	X	X	X	X
Waste disposal	Solid waste management					
Post-Closure						
Environmental management and monitoring	Environmental monitoring including surface and groundwater monitoring	X	X	X	X	X
Environmental management and monitoring	Monitoring and maintenance of mine drainage, seepage, and discharge	X	X	X	X	X
Environmental management and monitoring	Reclamation monitoring and maintenance	X	X	X	X	X
Open pit	Construction of emergency spillway on open pit	X	X	X	X	X
Open pit	Storage of water as a pit lake	X	X	X	X	X
Procurement and labour	Procurement of goods and services					
Stockpiles	Storage of waste rock in the non-PAG waste rock stockpile	X	X	X	X	X
Tailings management	Storage of water in the TMF and groundwater seepage	X	X	X	X	X
Tailings management	Sub-aqueous tailing and waste rock storage	X	X	X	X	X
Tailings management	TMF discharge	X	X	X	X	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.

Table 14.3-3. Fish and Aquatic Resources Valued Components Selected for Assessment

Assessment Category	Subject Area	Valued Components
Environment	Aquatic environment	Fish Fish habitat Aquatic resources

Bull Trout in BC are considered a Species of Special Concern and are considered vulnerable to extirpation or extinction (ranked as S3 – Blue; BC CDC 2014). They are also considered a Species of Special Concern by the most recent 2012 COSEWIC assessment (BC CDC 2014 and (COSEWIC 2012a) respectively). Coho Salmon originating from the interior Fraser River watershed, which includes drainages confluent with the North Thompson River, are considered an endangered population that is facing imminent extirpation or extinction. The status of Coho Salmon populations within BC as a whole, however, are considered stable (ranked as S4 – Yellow provincially; COSEWIC 2012b; BC CDC 2014). Rainbow Trout are not a species of concern in BC; however, they are an important recreational fish species and valued by stakeholders.

The proposed VCs of sediment quality, periphyton, and benthic invertebrates (Table 14.3-2) were assessed together under the collective VC of "aquatic resources" (Table 14.3-3). The interactions between the Project and aquatic resources are the same for each of sediment quality, periphyton, and benthic invertebrates (Table 14.3-2); potential effects for each are driven by the potential for change in water quantity and quality. All three components are closely connected—sediment quality describes many relevant characteristics of the habitat for both primary and secondary producers, whereas periphyton and benthic invertebrates are ecologically linked through grazing and competition. Assessing them together as the aquatic resources VC provides a more integrated assessment of the potential effects on these inter-related components of the aquatic environment.

14.3.2 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 the areas within, and times during which, the Project is expected to interact with the VCs, as well as any constraints due to political, social, and economic realities, and limitations in predicting or measuring changes. Boundaries relevant to fish, fish habitat, and aquatic resources are described below.

14.3.2.1 Temporal Boundaries

Temporal boundaries are the time periods considered in the assessment for various Project phases and activities, and are shown in Table 14.3-4. Temporal boundaries reflect those periods during which planned Project activities are reasonably expected to potentially affect a VC. Potential effects will be considered for each phase of the Project as described in Table 14.3-4.

14.3.2.2 Spatial Boundaries

Spatial boundaries are determined based on the anticipated magnitude and spatial extent of Project related effects. They are determined by the location and distribution of VCs and can be defined as the anticipated zone of influence between the Project component/activity and the VC being studied. There are three zones of influence between the Project and the VC being studied: the Project Site, the local study area (LSA), and the regional study area (RSA).

Table 14.3-4. Temporal Boundaries used in the Assessment for Fish and Aquatic Resources

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 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 reclamation, with ongoing discharge from the TMF and monitoring.

Project Site

The Project footprint includes the Project Site which is defined by a 500-m buffer around the primary Project components as shown in Figure 14.1-2. 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; TMF; overburden, topsoil, PAG waste rock, and non-PAG waste rock stockpiles; and non-PAG and PAG low-grade ore stockpiles.

Local Study Area

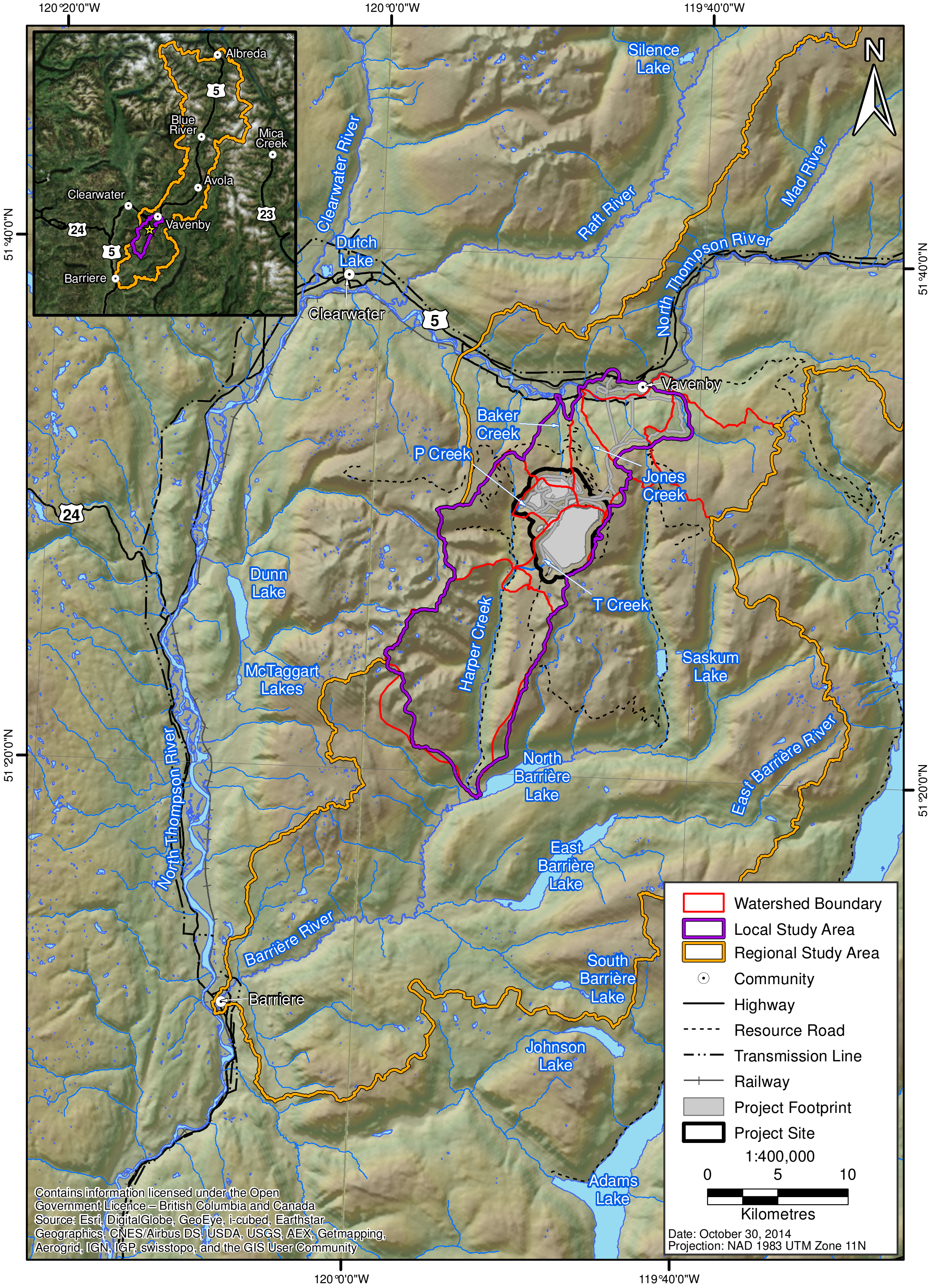
The LSA was selected to focus on the Project Site and infrastructure and surrounding area within which there is a reasonable potential for immediate direct and indirect effects on fish, fish habitat, and aquatic resources due to an interaction with a Project component(s) or activities. The LSA has been defined using the catchment boundaries of Harper Creek, Jones Creek, Baker Creek, and extends to the outflow of Harper Creek into North Barrière Lake (Figure 14.3-1). Catchments describe the hydrologic connections between the landscape and the aquatic environment, and are therefore the primary physical links between Project activities and aquatic VCs.

The fish, fish habitat, and aquatic resources effects assessment considers the three following subsets of the Harper Creek watershed:

- T Creek and P Creek;
- upper Harper Creek; and
- lower Harper Creek.

Figure 14.3-1

Regional and Local Study Areas for Fish, Fish Habitat, and Aquatic Resources Effects Assessment



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T Creek and P Creek are headwater streams within the catchments where much of the Project infrastructure and activities will occur, and thus share similar potential effects, mitigation measures, and potential residual effects. Both creeks are only fish-bearing in the lowest sections near their confluences with Harper Creek. Upper Harper Creek is the immediate receiving environment for headwater streams, including T and P creeks, and is habitat for Bull Trout (Section 14.4.3). The upper and lower sections of Harper Creek are divided by a 2-m waterfall at mainstem km 18.5. Only adult adfluvial Bull Trout and resident Bull Trout have been observed above the 2-m falls. This waterfall represents the upper-most distribution for Coho Salmon, Rainbow Trout, and other fish species found in lower Harper Creek (Section 14.4.3; Figure 14.4-4).

Regional Study Area

The RSA for the fish, fish habitat, and aquatic resources VCs was selected as the spatial area within which there is potential for direct and indirect interaction and/or cumulative effects to occur. The northern boundary of the RSA includes a portion of the North Thompson River and its catchment (Figure 14.3-1). The remainder of the RSA is defined as the Barrière River watershed down to the confluence of the Barrière River with the North Thompson River at Barriere (Figure 14.3-1).

Potential effects and habitat losses are considered with respect to fish, fish habitat, and the aquatic resources existing in the RSA. Potential effects are assessed at the scale of the entire length of a tributary stream, or river reach, as appropriate for that local biological community, and to the extent that these potential effects could affect an entire community rather than individuals. Applicable potential effects on a sub-local scale are noted and considered in this assessment and in the cumulative environmental effects assessment.

14.3.3 Administrative and Technical Boundaries

No administrative or technical boundaries were applied to the fish, fish habitat, and aquatic resources effects assessment.

14.4 BASELINE CONDITIONS

Fish, fish habitat, and aquatic resources baseline studies have been conducted for the Project from 2008 to 2014 (Appendices 14-A and 14-C) to describe baseline conditions and support the assessment of Project effects. The objectives of the studies were to:

- assess the quality of fish habitat in streams, rivers, and wetlands;
- locate and document barriers to fish movement;
- identify important habitat, particularly for Bull Trout, Coho Salmon, and Rainbow Trout;
- determine fish presence, community composition, and distribution in streams, rivers, and wetlands;
- characterize aspects of the physiology and biology of sentinel fish species in the baseline study area, including tissue metal concentrations in accordance with applicable guidelines and the *Fisheries Act* (1985b); and

- characterize the aquatic resources in the study area, including the abundance and diversity of primary producers (e.g., photosynthetic organisms) and secondary producers (e.g., aquatic invertebrates), and sediment quality.

The specific objectives and sampling design varied from year-to-year within the baseline sampling program.

14.4.1 Regional and Historical Setting

The Project is located within the Shuswap Highlands in the western foothills of the Columbia Mountains. This is a transitional region between the interior plateaus and the eastern mountain ranges. The Project is in the North Thompson River watershed on the sub-watershed divide between two small tributaries that drain into the North Thompson River (Baker and Jones creeks) and Harper Creek, a tributary of the Barrière River that drains into the North Thompson River near the town of Barriere.

Weather systems typically track from west to east over the region. Precipitation and runoff generally increase with elevation, as weather systems are forced up and over the Columbia Mountains. Air temperatures are cool with a mean annual temperature near 0°C at the Project Site which has an elevation of 1,800 masl. Minimum and maximum mean monthly temperatures are approximately -10°C and 10°C, occurring in December and July, respectively. The mean annual precipitation at the Project Site is estimated to be in the order of 1,050 millimetres (mm), with 40% falling as rain and 60% falling as snow (Appendix 12-A, Surface Hydrology Baseline Report).

Regional runoff patterns are characterized by low flows during the winter months when precipitation falls almost exclusively as snow, high flows during the spring and early summer snowmelt-freshet, low flows during the dry late summer months, and moderate flows during the fall months as precipitation increases. The increase in runoff with elevation is evident, with an earlier onset of the spring freshet in lower elevation watersheds resulting from warm spring temperatures arriving earlier at the lower elevations. Annual hydrographs in the region typically have a uni-modal shape, with the majority of runoff occurring in May and June during the snowmelt freshet. Minimum low flows typically occur during late summer or late winter. Peak flows occur primarily during the spring and early summer snowmelt freshet, and may result from either snowmelt or from rainfall precipitation events combined with snowmelt (rain-on-snow events) although high flow events can occur in autumn due to intense convective or frontal rainfall (Appendix 12-A, Surface Hydrology Baseline Report). A number of historical studies provide information on the main waterbodies in the baseline study area. Historical information relating to waterbodies, fish communities, and fish habitat were compiled from a variety of sources, including:

- BC MOE Fisheries Information Summary System database (BC MOE 2014b);
- BC Conservation Data Centre Species and Ecosystem Explorer database (BC CDC 2014);
- BC MOE EcoCat: the Ecological Reports Catalogue (BC MOE 2014a);
- Federal Species at Risk Public Registry (Government of Canada 2014);
- DFO Mapster (DFO 2014); and
- BC MOE Habitat Wizard (BC MOE 2014c).

Appendix 14-A, Section 2.3 summarizes historical fisheries information for the Barrière River and North Thompson River drainages. The Barrière River supports populations of Pink Salmon (*Oncorhynchus gorbuscha*), Chinook Salmon, Sockeye Salmon (*O. nerka*), and Coho Salmon as well as migratory Rainbow Trout, Bull Trout, Mountain Whitefish (*Prosopium williamsoni*), and other non-salmonid fish species. The Barrière River upstream of North Barrière Lake and lower Fennel Creek supports both Coho and Sockeye Salmon populations (DFO 1995; Irvine et al. 1999; Withler et al. 2000; Hobbs and Wolfe 2008).

North Barrière and Saskum lakes are large lakes with similar habitat. Migratory trout, char, salmon, and whitefish inhabit both systems through their connection via the Barrière River (BC MOE 2014b, 2014a). Both North Barrière Lake and Saskum Lake contain sizable populations of Bull Trout, and past surveys suggest that populations are relatively healthy and may be the source of adfluvial spawners for portions of Harper Creek and the Barrière River near Saskum Lake (Appendix 14-A, Fish and Aquatic Habitat Baseline Report).

The historical fisheries literature for Harper Creek is limited. Rainbow Trout, Bull Trout, and Sockeye Salmon were sampled during surveys between 1979 through to 1994 (BC MOE 2014b). Bull Trout were recorded in upper Harper Creek, whereas Rainbow Trout and Torrent Sculpin (*Cottus rhotheus*) have been observed only in lower Harper Creek downstream of mainstem km 6.5 (Appendix 14-A). Little historical fish distribution information exists for the drainages that are confluent with the North Thompson River near Vavenby and Birch Island; however, Rainbow Trout and juvenile Bull Trout were observed in the lower reaches of Chuck Creek in 1992 (Hagen and Baxter 1992).

14.4.2 Baseline Studies

The results of baseline studies specific to project components and activities for fish, fish habitat, and aquatic resources is summarized in the following sections and presented in Appendix 14-A, Fish and Aquatic Habitat Baseline Report.

14.4.2.1 Fish

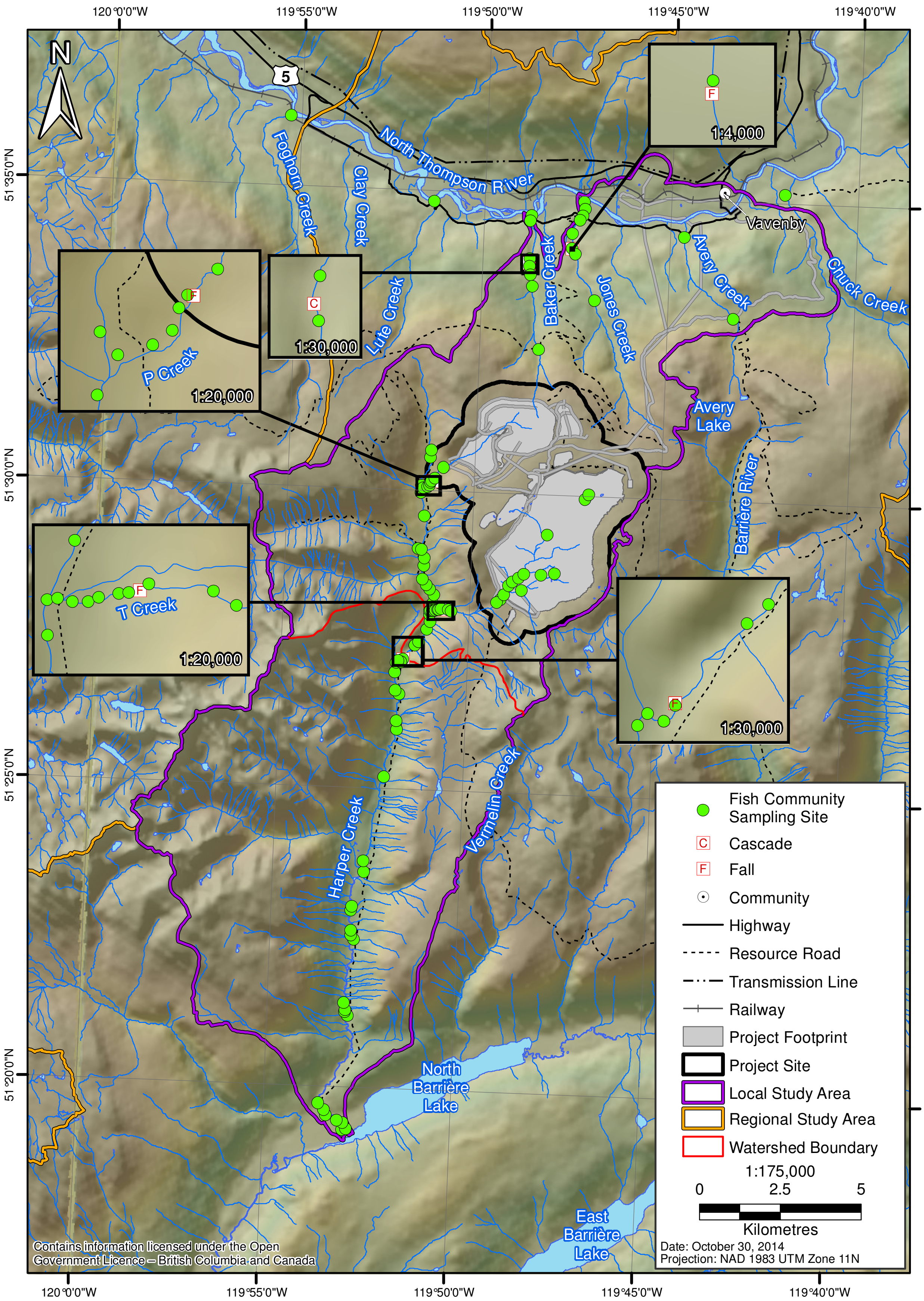
Fish community and biology sampling methods are described in detail in Appendix 14-A, Section 3.3. Extensive baseline fish sampling was conducted in 2008, 2011, 2012, and 2013 at a total of 101 sites within the RSA to determine fish-bearing status; species composition, distribution, and relative abundance in streams; identification of any regionally important, threatened, or endangered species; and to identify the temporal distribution of fish species/life stages. Figure 14.4-1 shows the location and distribution of baseline fish community sampling sites in the RSA. Additional studies were conducted in 2014 to supplement historical and baseline fish tissue metals data (Appendix 14-B), and fish habitat in upper Harper Creek (Appendix 14-C).

The methods used to document fish and fish habitat followed direction provided by provincial and federal agency staff, and the following guidance documents:

- *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures* (Version 2.0; RIC 2001);
- *Fish Collection Methods and Standards* (RIC 1997); and

Figure 14.4-1

Baseline Fish Community Sampling Sites, 2008 to 2013



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- *Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations* (Johnson 2007).

In summary, fish community composition was sampled using single-pass backpack electrofishing. A systematic sweep was conducted across the entire wetted width while moving from downstream to upstream. Estimates of Bull Trout density in P and T creeks were conducted during low flow conditions by enumerating total catches by single-pass electrofishing within a closed portion of the creek using stop nets. Electrofishing effort was not pre-determined due to differences between site length and available habitat. Electrofisher voltage (V), duty cycle (%) and frequency (Hz) settings remained consistent.

Sampling programs were conducted to establish baseline metal concentration in fish tissue in 2011 and 2012 at Harper Creek (T and P creeks) and North Thompson tributaries (Jones, Baker and Lute creeks). In 2014, a similar sampling program was carried out at Harper Creek, North Barrière Lake, and a reference site located on Dunn Creek (Appendix 14-B). Sample sizes for each waterbody were restricted to equal to or less than 10 to minimize population impacts due to lethal sampling. In 2011, a total of 10 Bull Trout (ranging 103 to 238 mm in length) were lethally sampled from both P and T creeks, while 10 Rainbow Trout (ranging 112 to 190 mm in length) were lethally sampled from Baker, Jones, and Lute creeks, respectively. Samples were analyzed to determine the concentration of 25 metals in fish muscle and liver tissues (Appendix 14-A and 14-B). Fork length, wet weight, condition, and age (using otoliths and scales) were also documented.

14.4.2.2 Fish Habitat

Fish habitat sampling methods are described in detail in Appendix 14-A, Section 3.3. Fish habitat assessments were conducted in 2008, 2011, 2012, and 2013 at 98 sites in the RSA to document physical habitat characteristics in streams draining the Project Site. An additional 11 Detailed Level 1 fish habitat sites were surveyed between P and T creeks along upper Harper Creek in 2014 (Appendix 14-C). Figure 14.4-2 illustrates the location and distribution of habitat survey sites conducted in the LSA.

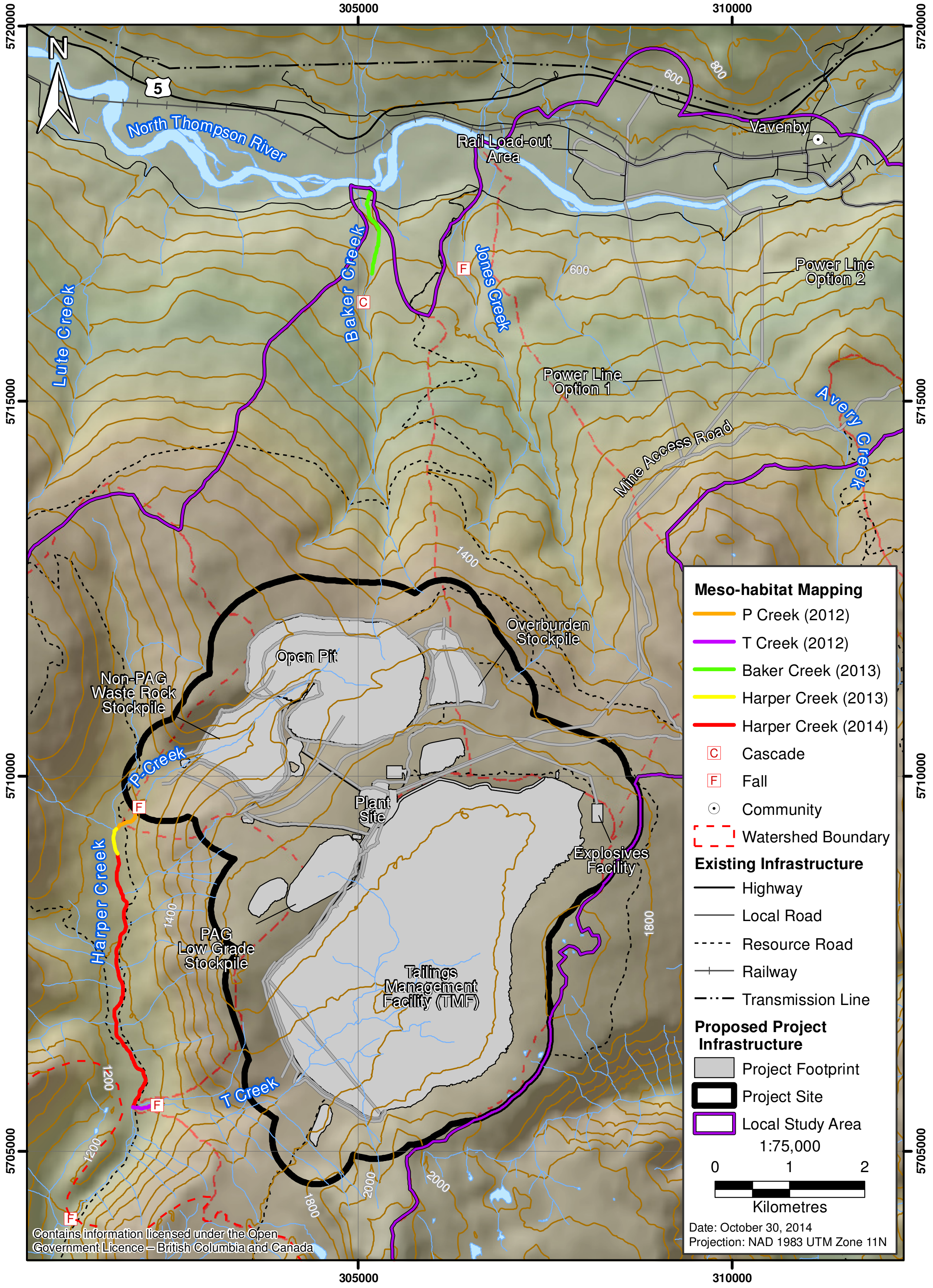
Methods for habitat assessments were implemented following the guidelines outlined in:

- *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures* (Version 2.0; RIC 2001);
- *Fish-stream Identification Guidebook* (BC MOF 1998);
- *Fish Habitat Assessment Procedures* (Johnston and Slaney 1996); and
- Guidelines for the Collection and Analysis of Fish and Fish Habitat Data for the Purpose of Assessing Impacts from Small Scale Hydro Power Projects in British Columbia (Hatfield, Lewis, and Babakaiff 1997).

Figure 14.4-2

Baseline Fish Habitat Survey Sites, 2008 to 2014

ERM



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In summary, barriers to upstream fish migration were identified through field reconnaissance surveys by helicopter overview flights and repeated ground surveys. Stream reaches were delineated from stream channel profiles by satellite imagery, air photos, and field reconnaissance following protocols developed by BC MOF (1998). Detailed Level 1 fish habitat surveys (adopted from: Simonson, Lyons, and Kanehl 1994; Johnston and Slaney 1996) were conducted in the fish-bearing sections of T and P creeks during late summer 2012; upper Harper Creek and Baker Creek during September 2013 (Figure 3.2-1 in Appendix 14-A); and upper Harper Creek between P and T creeks in September 2014 (Appendix 14-C). Visual surveys and observations were used to document adfluvial Bull Trout migration and spawning habitat use in lower and upper Harper Creek (Appendix 14-A, Section 4.2; Appendix 14-C).

14.4.2.3 Aquatic Resources

Aquatic resources baseline data were collected for the Project from June 2011 to September 2013 (Figure 14.4-3; Appendix 14-A) and again in June 2014 (Appendix 14-B; complete data available in December 2014). The primary objective was to characterize the spatial and temporal variability of aquatic resources in the RSA for the proposed Project. Sampling was focussed on watercourses that have the potential to be affected by Project activities. In total, 10 creek/river locations and four lake locations within three watersheds were sampled (Figure 14.4-1). A summary of the 2011 to 2013 aquatic resources sampling program is presented in Table 14.4-1. The available aquatic resources baseline data included:

- Stream periphyton communities (biomass, abundance, community composition, richness, and diversity);
- Stream benthic invertebrate communities (abundance, community composition, richness, and diversity); and
- Stream and lake sediment quality (particle size, organic carbon, metals and polycyclic aromatic hydrocarbons [PAHs]).

Periphyton, benthic invertebrate, and sediment quality samples were collected at each of the 10 creek/river sites. Site BC10 is located in Baker Creek which drains north from the Project Site to the North Thompson River. Seven sampling sites were located within the Harper Creek watershed, including four along the Harper Creek mainstem (HC-40, HC-30, HC-20, and HC-10), and three along tributaries of Harper Creek (OP-10 in P Creek; TMF-10 and TMF-20 in T Creek). Within the Barrière River watershed, site BR-20 was sampled as an upstream reference site and BR-10 to assess potential effects downstream of the Project Site. Sediment quality samples were collected from an additional four locations in North Barrière Lake within the Barrière River watershed. In general, sampling sites were selected to correspond with surface water quality sampling locations.

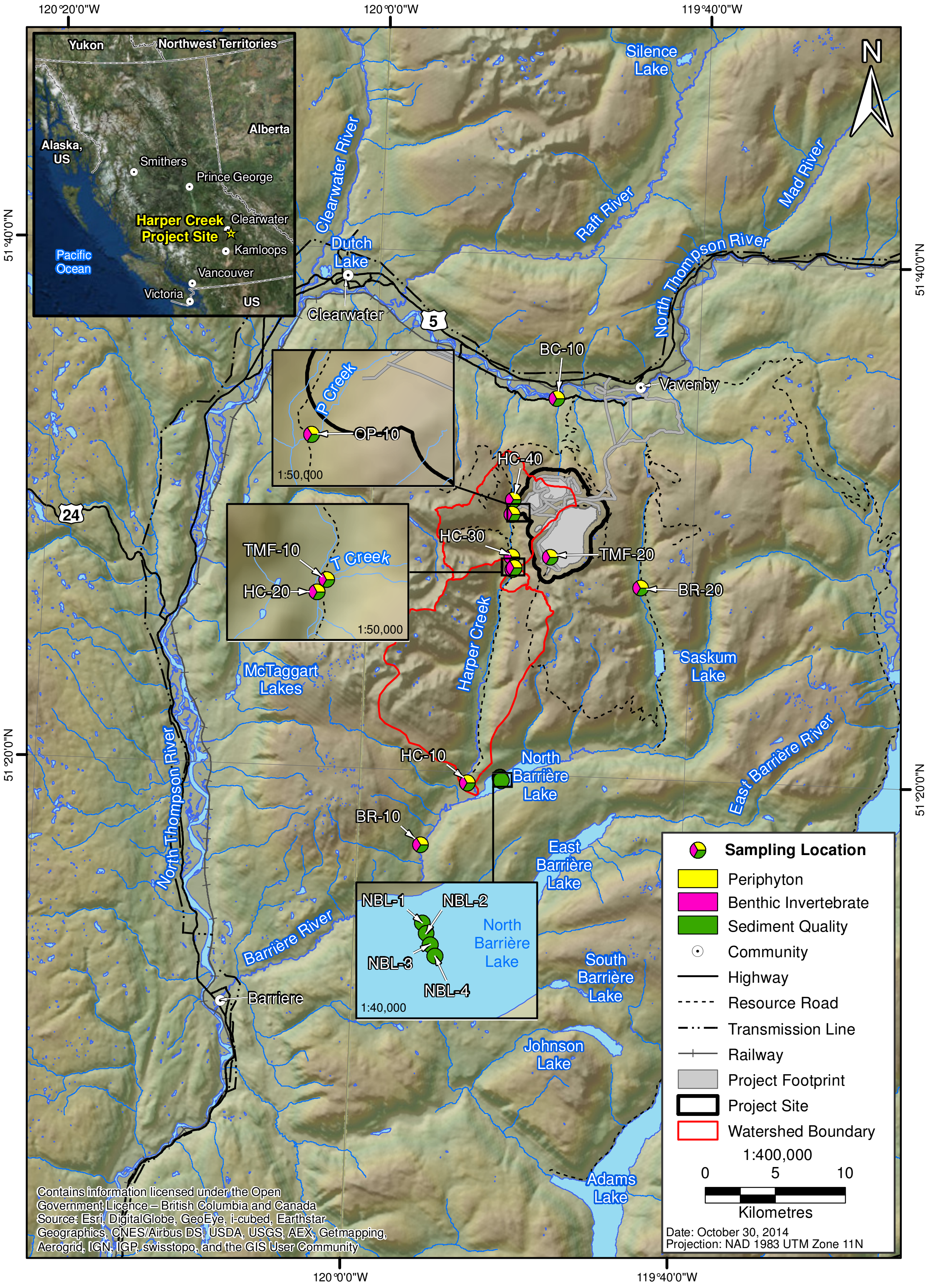
Aquatic Resources Sampling Methodology

Data were collected during late summer/fall of 2011, 2012, and 2013. Sampling methods are described in detail in the baseline report (Appendix 14-A) and briefly summarized below. The study design and sampling methods were derived based on guidance from:

- the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2012b);
- the *British Columbia Field Sampling Manual* (Clark 2003);

Figure 14.4-3

Aquatic Resources Sampling Locations, 2011 to 2013



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Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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- the *Metal Mining Technical Guidance for Environmental Effects Monitoring* (Environment Canada 2012c); and
- the *Freshwater Biological Sampling Manual* (Cavanagh, Nordin, and Warrington 1997).

Table 14.4-1. Summary of Aquatic Resource Sampling for the Harper Creek Project, 2011 to 2013

Watershed	Waterbody	Site Name	Periphyton Taxonomy	Periphyton Biomass	Benthic Invertebrates	Sediment Quality
Baker Creek	Baker Creek	BR-10	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
Harper Creek	Harper Creek	HC-40	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	Harper Creek	HC-30	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	Harper Creek	HC-20	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	Harper Creek	HC-10	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	P Creek	OP-10	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	T Creek	TMF-20	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	T Creek	TMF-10	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
Barrière River	Barrière River	BR-20	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	Barrière River	BR-10	2011, 2013	2011, 2012, 2013	2011, 2012, 2013	2011, 2012, 2013
	North Barrière Lake	NBL-40	-	-	-	2011
	North Barrière Lake	NBL-30	-	-	-	2011
	North Barrière Lake	NBL-20	-	-	-	2011
	North Barrière Lake	NBL-10	-	-	-	2011

Periphyton samples were collected from similar substrate/habitat types at each site, and each replicate was a composite of a series of subsamples. Biomass samples were collected during all three sampling events, whereas taxonomy samples were collected in 2011 and 2013 only. For biomass, five subsamples were collected per replicate during all sampling years. For taxonomy, the number of subsamples collected per replicate was 15 in 2011 and five in 2013. All periphyton results were standardized to the area sampled. For each subsample, periphyton was scraped from a defined area on the top of a submerged rock using a circular template pressed against the rock surface. Cobble and boulders were randomly selected from the channel, working in an upstream direction.

Taxonomy samples were preserved with Lugol's iodine solution and sent to Fraser Environmental Services for taxonomic identification. Biomass samples were preserved in the field with $MgCO_3$, filtered through a 0.45-micrometre (µm) membrane filter, and sent to ALS Environmental (ALS) in Burnaby, BC for analysis of chlorophyll *a* concentration.

Benthic invertebrate samples were collected within riffle and run habitats with cobble/gravel substrates at water depths from 15 to 25 centimetres (cm). Sampling was conducted using a 250-µm mesh Surber sampler. Similar to periphyton, invertebrate replicates were collected at each site, with each replicate being a composite of three subsamples. Benthic invertebrates were collected by placing the Surber sampler on the stream bottom and disturbing the substrate to a depth of 10 cm within the Surber sampler's footprint. The samples were preserved with buffered formalin and sent to Lesley Davenport in Victoria, BC for taxonomic identification and enumeration.

Sediment sampling was conducted in both lakes and streams. Similar to benthic invertebrates, sediment replicates were collected at each site and each replicate was a composite of three subsamples. Samples were collected from depositional areas of the stream, near the stream bank, at approximately 10 to 20 cm depth. Samples were collected from the top 4 to 6 cm layer. Stream samples were collected according to Clark (2003). Lake samples were collected using an Ekman dredge. Laboratory quantification of metals (2011, 2012, and 2013) and hydrocarbons (2011) was conducted by ALS in Burnaby, BC. Analysis of metals was completed on the < 63 µm fraction of the sample as this is more bioavailable to benthic organisms and contains higher concentrations of metals than the coarse sediment fraction (Horowitz 1985; BC MOE 2012b).

Aquatic Resources Data Analysis

Periphyton and benthic invertebrate samples cm^2 were analyzed for abundance, community composition, richness, and diversity. Algal biomass was estimated from the periphyton samples by measuring chlorophyll *a*. Chlorophyll *a* concentrations were compared to the BC Water Quality Criteria for Nutrients and Algae (10 $\mu g/cm^2$ for aquatic life in streams and 5 $\mu g/cm^2$ for stream recreation; BC MOE 2001). For the description of baseline conditions for periphyton and benthic invertebrates below (Section 14.4.3.3), the aforementioned metrics were derived from data presented in Appendices F and G of Appendix 14-A. For periphyton, taxa identified in the diversity scans (i.e., reported as "< *x*"), and cells not identified to division (e.g., UID colonial algae) were excluded from the dataset used for all calculations. Cells for which taxonomic uncertainty existed (i.e., reported as "cf." or "?") and taxa not identified to family were also excluded for community composition, richness, diversity and dominant taxa calculations. For benthic invertebrates, Ostracoda, Cladocera, Nematoda, Copepoda, Collemba, Platyhelminthes and terrestrial organisms were excluded from all analysis following Environment Canada (2012c). Immature, damaged or specimens not identified to the family level were included in abundance estimations, but excluded from all other analyses.

Sediment quality results were compared to BC sediment quality guidelines for the protection of freshwater aquatic life (Table 14.4-2; BC MOE 2014d; CCME 2014a). The BC guidelines consist of a Lowest Effect Level (LEL) and Severe Effect Level (SEL). A sediment parameter concentration below the LEL is not expected to be associated with any adverse biological effects, while concentrations above the SEL are expected to be frequently associated with adverse biological effects. CCME sediment quality guidelines consist of Interim Sediment Quality Guidelines (ISQG) and Probable

Effects Levels (PEL) and are analogous to the BC LEL and SEL, respectively. Table 14.4-2 presents a summary of the existing guidelines for sediment metals. Guidelines for PAHs are not shown as measurable concentrations of PAHs were not found at the Project area sites (analytical results of PAH measurements reported in Appendix 14-A.

Table 14.4-2. Provincial and Federal Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life.

Metal	BC Guideline[a]		CCME Guideline[b]	
	LEL[c]	SEL[d]	ISQG[e]	PEL[f]
Arsenic (As)	5.9	17.0	5.9	17.0
Cadmium (Cd)	0.6	3.5	0.6	3.5
Chromium (Cr)	37.3	90.0	37.3	90.0
Copper (Cu)	35.7	197	35.7	197
Iron (Fe)	21,200	43,766	-	-
Lead (Pb)	35.0	91.3	35.0	91.3
Manganese (Mn)	460	1,100	-	-
Mercury (Hg)	0.170	0.486	0.170	0.486
Nickel (Ni)	16	75	-	-
Selenium (Se)	2	-	-	-
Silver (Ag)	0.5	-	-	-
Zinc (Zn)	123	315	123	315

[a] *British Columbia working sediment guideline for the protection of freshwater aquatic life; all units are in mg/kg (BC MOE 2014d).*
[b] *Canadian sediment quality guideline for the protection of freshwater aquatic life; all units are in mg/kg (CCME 2014a).*
[c] *BC lowest effect level based on the screening level concentration.*
[d] *BC severe effect level based on the screening level concentration.*
[e] *CCME interim sediment guideline.*
[f] *CCME probable effects level.*

14.4.3 Existing Conditions

14.4.3.1 Valued Component Species Life History and Periodicity

Table 14.4-3 presents a summary of VC fish-specific life history periodicity and habitat distribution within the LSA. Detailed descriptions of Bull Trout, Coho Salmon, and Rainbow Trout life history and periodicity are described below.

Bull Trout

Bull Trout in the LSA area originate from the evolutionarily distinct interior unit (Taylor, Pollard, and D. Louie 1999) and can exhibit one of three life history strategies (Scott 1973; McPhail and J. S. Baxter 1996). These three life history forms are defined as: 1) adfluvial, 2) fluvial, or 3) stream resident. Adfluvial Bull Trout reside in lakes and migrate into creeks and tributary streams for spawning. Fluvial Bull Trout remain in large rivers or streams throughout their life, and move into creeks and smaller, accessible tributaries for spawning. Bull Trout from fluvial populations can vary greatly in terms of movement and dispersal within watersheds (Bryant, Zymonas, and Wright 2004). Stream resident Bull Trout are non-migratory and reside in creeks and headwater tributaries for their entire life.

Table 14.4-3. Project Specific Bull Trout, Rainbow Trout and Coho Salmon Life History Periodicity Table

		Month											
Species	**Life History Stage**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Resident Bull Trout	Juvenile Summer to Fall Rearing				▨	▨	▨	▨	▨	▨	▨		
	Adult Summer to Fall Rearing				▨	▨	▨	▨	▨	▨	▨		
	Overwintering	▨	▨	▨								▨	▨
	Spawning								▨	▨	▨		
	Egg Incubation	▨	▨	▨							▨	▨	▨
Adfluvial Bull Trout	Migration								▨	▨	▨		
	Spawning								▨	▨	▨		
	Egg Incubation	▨	▨	▨								▨	▨
Rainbow Trout	Juvenile Summer to Fall Rearing				▨	▨	▨	▨	▨	▨	▨		
	Adult Summer to Fall Rearing				▨	▨	▨	▨	▨	▨	▨		
	Overwintering	▨	▨	▨								▨	▨
	Spawning					▨	▨						
	Egg Incubation						▨	▨					
Juvenile Coho Salmon	Juvenile Summer to Fall Rearing				▨	▨	▨	▨	▨	▨	▨		
	Adult Summer to Fall Rearing				▨	▨	▨	▨	▨	▨	▨		
	Overwintering	▨	▨	▨								▨	▨
	Spawning										▨	▨	
	Egg Incubation	▨	▨	▨								▨	▨

Bull Trout typically reach sexual maturity between five and seven years of age, although they can mature between three and eight years (Hagen and Baxter 1992; McPhail and J. S. Baxter 1996). Bull Trout typically spawn between September and October at temperatures below 9°C (Hagen and Baxter 1992; McPhail and J. S. Baxter 1996), with confirmed adfluvial spawning occurring in lower and upper Harper creek (between T and P creeks; Appendix 14-A and 14-C; Table 14.4-3). Preferred spawning areas are typically shallow (less than 1 m deep), slow moving (less than 93 cm/second [s]) laminar or upwelling flow located in the tail-outs of glides or pools, coarse gravel substrate, overhead cover (e.g., riparian vegetation, undercut bank, or large woody debris), and often fed by groundwater to maintain suitable incubation and rearing conditions through the winter (Baxter and Hauer 2000; Stewart D. B. et al. 2007 and references therein). Eggs incubate in the gravel over the winter until hatching occurs in late March. Alevin will subsequently absorb their yolk sac over the next two or three months, emerging as fry in late spring/early summer. Following emergence, fry will move to low-velocity channel margins, side channels, and small pools with abundant instream cover for summer feeding (Stewart D. B. et al. 2007 and references therein). Like other stream-dwelling juvenile salmonids, Bull Trout will establish feeding stations in the summer near cover and abundant food supply. Bull Trout, responding to decreases in water temperature and photoperiod in late fall, will move to deep pools, off-channel ponds, and/or cover in the form of coarse substrates, in search of anchor ice-free habitat (Thurow 1997). Additional Bull Trout life history and biological characteristics are described in Appendix 14-A, Section 2.4.2.

Coho Salmon

Coho Salmon are native to North Pacific Ocean drainages and widely distributed, extending from western North America and as far as Japan and Russia. Coho Salmon are culturally and economically important commercial, recreational, and aboriginal fish. Populations of unenhanced Coho Salmon in the North and South Thompson River watersheds have historically been reported to have declined at rates over 50% per generation since 1988, leading to fishery management changes made by DFO in 1998 (Irvine and Bradford 2000).

Life history and periodicity of Coho Salmon specific to the Project area are summarized in Table 14.4-3. Coho Salmon in the Project area are exclusively anadromous (i.e., migrate to sea and return to freshwater to spawn). After spending approximately six months (for precocious male Coho or “jacks”) to 18 months (for mature adults) at sea, Coho Salmon return to freshwater for spawning. The spawning migration usually occurs in late fall (Table 14.4-3) when water temperatures range from 1°C to 8°C (McPhail 2007). All Coho Salmon will die post-spawning. Females typically construct nests in shallow areas (30 cm) with gravel less than 15 cm diameter and good circulation of well-oxygenated water (Sandercock 1991). Eggs will hatch in late winter or early spring following a six to seven week incubation. Alevin will subsequently remain in the gravel for an additional six to seven weeks until their yolk sac is fully resorbed. This stage can be particularly sensitive to contaminants. At emergence, Coho fry will typically move to side channels for foraging/rearing, and will generally reside in freshwater for a year before migrating to sea as smolts. Others will either migrate to the sea immediately at emergence, or will spend two years in freshwater prior to migration. Additional descriptions of Coho Salmon life history and biological characteristics are found within Appendix 14-A, Section 2.4.4.

Rainbow Trout

A description of Rainbow Trout life history and biological characteristics are found in Appendix 14-A, Section 2.4.3, and Ford et al. (1995). Life history and periodicity of Rainbow Trout specific to the LSA are summarized in Table 14.4-3. As with Bull Trout, Rainbow Trout in the LSA may exhibit adfluvial, fluvial, or stream resident life history forms. Anadromous Rainbow Trout (or Steelhead) have not been documented in the LSA.

Rainbow Trout typically reach maturity between three and five years of age (Ford et al. 1995). They spawn in spring (Table 14.4-3) when water temperatures range from 7.2°C to 13.3°C. Ideal spawning habitat consists of small gravel substrates (less than 100 mm diameter), relatively low current velocities (30 to 90 cm/s), and at mixed depths (0.5 to 2.5 m deep). Females will construct redds into which eggs are deposited. Fry will eventually emerge in the summer from the gravel and will migrate into rearing areas of streams, rivers, or lakes within the year. Rearing Rainbow Trout will typically remain in its rearing stream, river, or lake until they reach maturity two to four years later, and will then return to natal streams for spawning.

14.4.3.2 Fish

Fish distribution and diversity in creeks within the LSA are heavily influenced by the presence of permanent barriers to fish migration (i.e., waterfalls, over 20%gradient cascade). These barriers also delineate the boundaries of upper and lower sections of creeks. Figure 14.4-4 shows the spatial distribution of fish-bearing reaches and location of permanent barriers to fish migration in the LSA. Table 14.4-4 provides descriptions of each barrier to fish migration in the LSA.

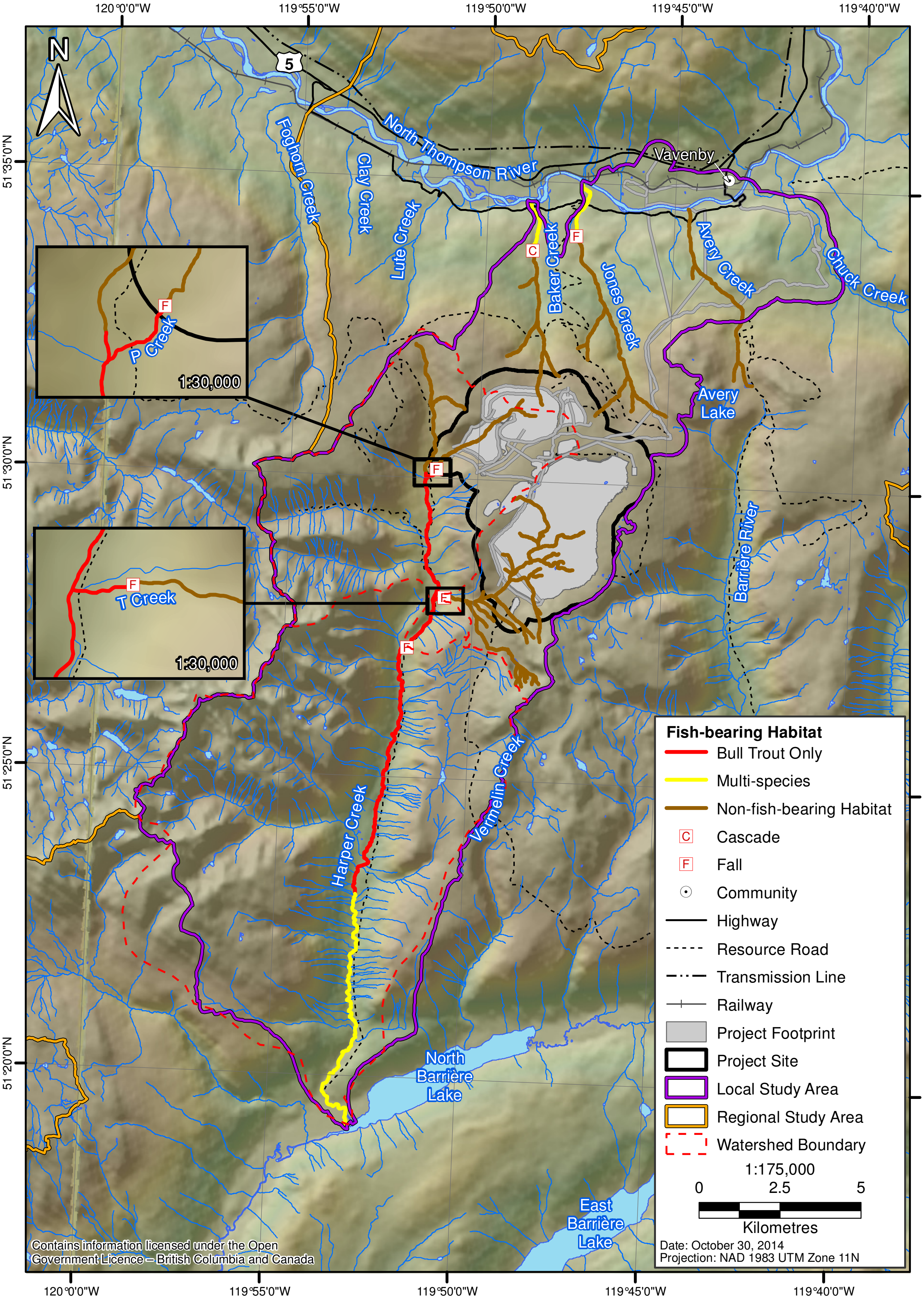
Lower Harper Creek

For the purposes of baseline fish and fish habitat studies, Harper Creek was divided into lower and upper sections, and delineated at a 2-m waterfall at mainstem km 18.5 (Figure 14.4-3; Table 14.4-4).

Lower Harper Creek fish community surveys were conducted in 2008, 2011, 2012, and 2013. A total of 17,141 s of backpack electrofishing effort was exerted to determine fish species presence and distribution, relative abundance, and biological characteristics (Appendix 14-A, Section 4.2.3). Fish community survey sites were located from the inflow at North Barrière Lake to the 2-m waterfall at mainstem km 18.5.

Figure 14.4-4

Spatial Distribution of Fish-Bearing Reaches and Barriers to Fish Migration in the LSA



Date: October 30, 2014
Projection: NAD 1983 UTM Zone 11N

Table 14.4-4. Location and Description of Barriers to Fish Migration in the LSA

		UTM Coordinates					
Waterbody	Watershed	Zone	Easting	Northing	Height (m)	Barrier Type	Comment
Lower Harper Creek	Barrière River	11U	301300	5704313	2	Waterfall	Division between lower and upper Harper Creek, passable by adfluvial Bull Trout only
Upper Harper Creek	Barrière River	11U	301734	5709456	–	Unsuitable habitat	No fish present above mainstem km 24.5 at site HC F450
T Creek	Barrière River	11U	302243	5705600	1.8	Waterfall, High gradient cascade	No fish captured above waterfall
P Creek	Barrière River	11U	302070	5709605	3	Waterfall	No fish captured above waterfall
Baker Creek	N. Thompson River	11U	305089	5716204	–	High gradient cascade	No fish captured above cascade
Jones Creek	N. Thompson River	11U	306401	5716731	–	Series of small waterfalls	No fish captured above series of waterfalls

Dashes (–) indicate no data available

Fish community studies indicated that lower Harper Creek contains the highest species diversity of waterbodies within the LSA (Table 14.4-5). A total of eight fish species are documented to be present in lower Harper Creek, including: Coho Salmon, Longnose Dace (*Rhinichthys cataractae*), Mountain Whitefish, Prickly Sculpin (*Cottus asper*), Rainbow Trout, Sockeye Salmon, and Torrent Sculpin. Of fish captured in Project-specific baseline studies, Bull Trout were the most abundant species, followed by Coho Salmon, Rainbow Trout, Mountain Whitefish, Torrent Sculpin, and Longnose Dace. Resident, sessile species (e.g., Torrent Sculpin and Longnose Dace) were found in the low gradient reaches approximately 2 km from North Barrière Lake. Increasingly motile species, such as Mountain Whitefish, Rainbow Trout, Coho Salmon, and Bull Trout were captured from North Barrière Lake to mainstem km 9.5.

Coho Salmon fry were observed between mainstem km 8.0 and 9.5, and were associated with off channel habitat. Coho Salmon parr were associated with pools and woody debris in lower Harper below mainstem km 2.0. The presence of two juvenile cohorts (fry and age 1+ parr) indicated that Coho Salmon use lower Harper Creek for spawning.

Bull Trout were the most frequently observed fish species in lower Harper Creek. All life stages of Bull Trout were found in lower Harper Creek, including adults, juveniles, and young-of-the-year (YOY). Bull Trout were the only species observed upstream of mainstem km 9.5 to the 2-m waterfall at km 18.5. The relative abundance of fry, juveniles, and spawners was highest between mainstem km 17.0 to the 2-m waterfall at km 18.5. The relatively high number of fry and spawning adfluvial Bull Trout suggests that this section of lower Harper Creek supplies important spawning and rearing habitat.

Table 14.4-5. Summary of Known Fish Species Occurrence in the LSA

		Barrière River Sub-watershed				North Thompson Watershed	
Species Common Name	**Species Scientific Name**	**Lower Harper Creek**	**Upper Harper Creek**	**T Creek**	**P Creek**	**Baker Creek**	**Jones Creek**
Bull Trout*	*Salvelinus confluentus*	X	X[a]	X[a]	X[a]	X[a]	
Coho Salmon†	*Oncorhynchus kisutch*	X[a]				X[a]	X[a]
Rainbow Trout	*Oncorhynchus mykiss*	X[a]				X[a]	X[a]
Longnose Dace	*Rhinichthys cataractae*	X[a]					X[a]
Mountain Whitefish	*Prosopium williamsoni*	X[a]					
Prickly Sculpin	*Cottus asper*	O[a]					
Sockeye/ Kokanee Salmon	*Oncorhynchus nerka*	O[a]					
Torrent Sculpin	*Cottus rhotheus*	X[a]					X[a]

** Blue-listed species*

† Yellow-listed species

X = indicates that Project-specific sampling was utilized to confirm fish species presence in the Project LSA.

O = indicates that other sources of existing inventory data (e.g., historical literature, Habitat Wizard) were utilized to confirm fish species presence within the LSA.

[a] Present below permanent barrier to fish migration (e.g., waterfall, >20% cascade, unsuitable habitat).

Empty cells indicate fish species not present

The 2-m waterfall is a permanent barrier to fish species other than Bull Trout occurring in lower Harper Creek, and represents the upper limit of their distribution within the Harper Creek sub-watershed. Appendix 14-A, Section 4.2.1 provides detailed data analysis and discussion of fish species distribution, relative abundance, and biological characteristics of fish species found in lower Harper Creek.

Upper Harper Creek

Upper Harper Creek fish community surveys were conducted in 2008, 2011, 2012, and 2013. A total of 13,079 s of backpack electrofishing was exerted to determine fish species presence and distribution, relative abundance, and biological characteristics. Bull Trout were the only fish species observed in upper Harper Creek (Table 14.4-5) and their relative abundance was approximately three times that observed in lower Harper Creek. Bull Trout were observed in upper Harper Creek from km 19.0 (above the 2-m waterfall) to the upper portions of the watershed near river km 24.2. All life history stages (including emergent fry, rearing juveniles, resident adults, and adfluvial spawning adults) were present. Baseline studies suggest that the 2-m waterfall at mainstem km 18.5 may differentially restrict adfluvial Bull Trout migration based upon seasonal flow, and adfluvial Bull Trout biological variables (e.g., size, maturity, burst swimming ability). Based upon baseline observations and professional judgment, only larger adfluvial Bull Trout are able to ascend the 2-m falls, and only when freshet flow has declined during mid-summer and into the summer low flow period. Appendix 14-A, Section 4.2.2 provides detailed data analysis and discussion of Bull Trout distribution, relative abundance, and biological characteristics in upper Harper Creek.

Bull Trout were not captured or observed at sampling sites upstream of km 24.2. Therefore, upper Harper Creek immediately upstream of the P Creek confluence (km 24.2) was classified as non-fish-bearing due to the presence of unsuitable habitat (Figure 14.4-4). Additional information regarding non-fish-bearing habitat is provided in Appendix 14-A, Section 4.2.8.1.

T Creek

T Creek becomes confluent with upper Harper Creek at mainstem km 20.2. Fish-bearing habitat occurs from the T Creek/upper Harper Creek confluence to 336 m upstream, where a 1.8-m waterfall and high gradient cascade prevents further Bull Trout distribution (Figure 14.4-3; Table 14.4-4). Additional information regarding non-fish-bearing habitat of T Creek is provided in Appendix 14-A, Section 4.2.8.2.

The fish community of T Creek was surveyed in 2008, 2011, 2012, and 2013. A total of 6,937 s of backpack electrofishing was conducted from the T Creek/upper Harper Creek confluence to the uppermost headwaters (Figure 14.4-1). Only Bull Trout were captured in the lower, fish-bearing reach of T Creek (Table 14.4-5). Fish were not captured above the 1.8-m waterfall despite 4,699 s of electrofishing effort exerted on habitat within upper T Creek. Bull Trout captured from lower T Creek were predominantly parr or larger juveniles. Some YOY Bull Trout were captured near the T creek/upper Harper Creek confluence, and one adult afluvial Bull Trout was observed in spawning condition in early September 2012. The relative abundance of Bull Trout juveniles observed within T Creek varied by sampling date and suggests that Bull Trout abundance may be higher during low flow (August–September). The seasonally averaged relative abundance of Bull Trout in T Creek is similar to those observed in upper Harper Creek. Appendix 14-A, Section 4.2.2.1 provides detailed data analysis and discussion of fish species distribution, relative abundance, and biological characteristics in T Creek.

P Creek

P Creek is a tributary to upper Harper Creek. The confluence of P Creek and upper Harper Creek is located at mainstem km 24. Fish-bearing habitat occurs from the confluence and extends 469 m upstream where a 3-m waterfall, as well as high gradient cascade and multiple small waterfalls, prevent further upstream distribution (Figure 14.4-3; Table 14.4-4). Additional information regarding non-fish-bearing habitat of P Creek is provided in Appendix 14-A, Section 4.2.8.3.

The fish community of P Creek was surveyed in 2011, 2012, and 2013. A total of 6,861 s of backpack electrofishing was conducted at sites downstream and upstream of the barrier (Figure 14.4-1). Only Bull Trout were captured in the lower, 469 m fish-bearing reach of P Creek (Table 14.4-5). Fish were not captured above the 3-m waterfall, and therefore, P Creek above the waterfall is considered non-fish-bearing. Sampled Bull Trout were predominately juveniles; however, one YOY Bull Trout was observed. Mature, spawning adults were not observed during fish community surveys of P Creek. The relative abundance of Bull Trout in P Creek was slightly less than half the average values observed in T Creek and upper Harper Creek. Densities of Bull Trout in both T Creek and P Creek averaged approximately 1.5 to 2 times higher than those observed in three East Kootenay watersheds (Cope 2007). These data suggest that T and P creeks are productive rearing environments for both juvenile and resident Bull Trout. Appendix 14-A, Section 4.2.2.2 provides detailed data and discussion of fish species distribution, relative abundance, and biological characteristics in P Creek.

Baker Creek

Baker Creek is in the northern portion of the LSA and drains into the North Thompson River. Its headwater is within the Project Footprint. Fish-bearing habitat within Baker Creek extends from the North Thompson River to a series of high gradient cascades approximately 1,600 m upstream (Figure 14.4-3; Table 14.4-4). Additional information regarding non-fish-bearing habitat of Baker Creek is provided in Appendix 14-A, Section 4.2.8.4. Fish distribution is also influenced by a high gradient stream segment located at the Birch Island-Lost Creek Road crossing.

Fish community surveys were conducted in 2008, 2011, and 2012. A total of 4,551 s electrofishing effort was exerted on Baker Creek at sites upstream and downstream of the road crossing and high gradient cascades. Juvenile Rainbow Trout, a single Bull Trout juvenile, and a single Coho Salmon juvenile were captured within the 150 m reach downstream of the Birch Island-Lost Creek Road crossing (Table 14.4-5). Only Rainbow Trout (YOY, juveniles, and adults) were captured from the road crossing to below the high gradient cascades, while fish were not captured upstream. The relative abundance and size distribution of Rainbow Trout sampled from Baker Creek were similar to that observed at Jones Creek, and the relative abundance of Rainbow Trout in Baker Creek was nearly twice that of lower Harper Creek. Appendix 14-A, Section 4.2.3.1 provides detailed data and discussion of fish species distribution, relative abundance, and biological characteristics in Baker Creek.

Jones Creek

Similar to Baker Creek, Jones Creek is in the northern portion of the LSA. Jones Creek drains into the North Thompson River, and a small portion of a headwater tributary is within the Project Site. Fish community studies were conducted in 2008, 2011, and 2012 on Jones Creek. As with Baker Creek, fish-bearing habitat is influenced by a culvert crossing for the Birch Island-Lost Creek Road. This culvert is approximately 600 m upstream of the North Thompson River confluence. Fish-bearing habitat continues upstream from the road crossing for approximately 1.25 km to a series of small waterfalls (Figure 14.4-3; Table 14.4-4). Additional information regarding non-fish-bearing habitat of Jones Creek is provided in Appendix 14-A, Section 4.2.8.5.

A total of 3,843 s electrofishing effort was conducted throughout Jones Creek (Figure 14.4-1). Rainbow Trout (juveniles and adults), Torrent Sculpin, and a single YOY Coho Salmon were captured within the 600 m low gradient reach below the road crossing (Table 14.4-5). Only Rainbow Trout (all life stages) were captured above the road crossing and upstream to the series of waterfalls. The length-frequency distribution of Rainbow Trout from Jones Creek was similar to that of lower Harper Creek, while the relative abundance was almost twice that observed in lower Harper Creek. Appendix 14-A, Section 4.2.3.1 provides detailed data and discussion of fish species distribution, relative abundance, and biological characteristics in Jones Creek.

14.4.3.3 Fish Tissue Metals

Detailed fish tissue metals results for samples collected up until the end of 2013 for P,T, Baker, Jones, and Lute creeks are presented in Appendix 14-A, Section 4.2.6. Preliminary tissue metals data for fish sampled from North Barrière Lake in 2014 are presented in Appendix 14-B.

Tissue metals data (including sample size, sample number, metals concentrations, percent moisture content, and lipid content of muscle tissue, and detection limits) for Bull Trout and Rainbow Trout muscle and liver are presented in Appendix 14-A. Metals of importance, including mercury, lead, and selenium are summarized below. Further details for mercury, lead, and selenium in both muscle and liver tissues are presented in Figure 4.2.10 through Figure 4.2.12 in Appendix 14-A.

Mercury concentrations in all tissues from P, T, Baker, Jones, and Lute creeks were low (i.e., less than 0.05 mg/kg) and well below accepted Provincial and Canada Food Agency guideline limits (0.2 mg/kg to 0.5 mg/kg wet weight; Appendix 14-A, Figure 4.2.10).

Lead concentrations in Bull Trout tissues from Harper Creek tributaries (T Creek and P Creek) were higher in liver tissues (less than 0.008 mg/kg to 0.0216 mg/kg) than muscle tissues (less than 0.004 mg/kg), and mean concentrations of lead in liver tissues in samples from P Creek were approximately twice those observed in T Creek. Lead concentrations in all Bull Trout tissues were well below accepted Provincial and Canada Food Agency guideline limits (0.8 mg/kg wet weight; Appendix 14-A, Figure 4.2-11). Mean lead concentrations in Rainbow Trout tissues from those tributaries confluent with the North Thompson River (Baker, Lute, and Jones creeks) were markedly higher in liver tissues than muscle tissues, and all but one Rainbow Trout liver from Lute Creek had lead concentrations well above accepted Provincial and Canada Food Agency guideline limits (0.8 mg/kg wet weight). This Rainbow Trout from Lute Creek (4.68 mg/kg) had lead liver concentrations over five times the guideline limits and over 90 times greater than the average of other liver samples collected concurrently (Appendix 14-A, Figure 4.2-11).

Mean selenium concentrations in Bull Trout muscle tissues (122 to 200 mm fork length) from Harper Creek tributaries (T Creek and P Creek) ranged from 0.25 mg/kg to 0.49 mg/kg, and none of the muscle tissue samples collected during 2011 and 2012 reported above guideline limits for selenium (4.0 mg/kg - BC MOE 2014d). Mean 2011 and 2012 selenium concentrations in Rainbow Trout muscle tissues (112 mm to 172 mm fork length) from Baker, Lute, and Jones creeks reported below guideline limits for selenium (4.0 mg/kg; Appendix 14-A, Figure 4.2-12).

14.4.3.4 Fish Habitat

Lower Harper Creek

Fish habitat data for lower Harper Creek are discussed in Appendix 14-A, Section 4.1.2.1. Lower Harper Creek contains the most diverse habitat types and greatest fish diversity in the LSA. The dominant stream morphology in lower Harper Creek is cascade-pool, although the low gradient reaches immediately upstream of North Barrière Lake are classified as riffle-pool. Alluvial bed material consisting primarily of cobble interspersed with boulder and gravel are present throughout lower Harper Creek. Functional large woody debris and log jams are important habitat features for trapping gravel and increasing habitat complexity (i.e., scour pool formation). The upper reaches of lower Harper Creek generally exhibit higher stream gradient, confined cascade-pool morphology, cobble/boulder substrate, and decreasing habitat complexity. However, critical and important habitat for Bull Trout spawning and rearing was identified from mainstem km 17 to 18.5 in past baseline studies (Appendix 14-A, Section 5.2.1.4). The uppermost reach of lower Harper Creek contains several large cascades and a 2-m waterfall confined by a bedrock canyon. Overall, lower

Harper Creek primarily supplies rearing habitat for Bull Trout, Coho Salmon and Rainbow Trout. Spawning and overwintering habitat for resident adults are relatively less abundant, which influences fish periodicity and appears to limit fish productivity in lower Harper Creek.

Upper Harper Creek

Detailed Level 1 fish habitat data for upper Harper Creek are discussed Appendix 14-A, Section 4.1.3.3. A total of 452 m of fish-bearing habitat within upper Harper Creek immediately downstream of the P Creek confluence was categorized into 24 different mesohabitat units and details are presented in Appendix 14-A, Figure 4.1.3. The most frequent habitat was classified as riffles (38%), which had an average length of approximately 21.1 m. Pools (33%) were the next most common mesohabitat and the units averaged approximately 12.5 m in length with an average maximum and residual depth of 0.52 m and 0.10 m, respectively. Glides and riffle-pools accounted for 17% and 13% of the habitat mapped with a mean length of 21.5 m and 30.6 m, respectively. The dominant bed material in upper Harper Creek is cobble (76%), followed by gravel (26%). The dominant forms of fish cover are provided by large woody debris (36%), deeper pools (37%), overhanging riparian vegetation in the form of overhanging alder (18%), and undercut banks (9%).

Additional Detailed Level 1 fish habitat data were collected on the Harper Creek mainstem, between P and T creeks. Appendix 14-C includes data and detailed discussion of fish habitat for this approximately 4.1 km section of upper Harper Creek. Surveyed habitat were most commonly classified as riffle-pool morphology, with stream gradient ranging from 0 to 4%. Diverse habitat complexes consisting of riffles, pools, cascades, and glides were present. Large woody debris and overhanging vegetation supplied abundant cover for fish. As with lower Harper Creek, functional large woody debris and log jams acted as important features for gravel catchment and the development of pool habitat. Cobble and gravel were the dominant and sub-dominant substrate types, respectively.

Bull Trout fry, adfluvial Bull Trout redds, and spawning adfluvial Bull Trout have been consistently observed in upper Harper Creek (Appendix 14-A, Section 5.2.2; Appendix 14-C). The majority of Bull Trout fry were observed downstream of the confluence of T Creek among braided sections of Harper Creek associated with pools, loose cobble and gravel substrate, with large woody debris and riparian cover. The highest density of adfluvial Bull Trout redds were observed from the confluence of upper Harper and T creeks to approximately 1.5 km upstream on the upper Harper Creek mainstem (Appendix 14-C). Bull Trout redd sites were consistently associated with glide or pool tail-outs (which contain slow, laminar or upwelling flow), coarse gravel substrate, and overhanging cover (e.g., overhanging riparian vegetation, large woody debris, or undercut bank). Taken together, the presence of Bull Trout fry and adfluvial Bull Trout redds indicate that upper Harper Creek provides critical habitat for Bull Trout spawning and rearing, and provides habitat for all Bull Trout life stages. Overwintering habitat; however, may be limited due to the low frequency of deep (over 1 m) pool habitat. Spawning habitat may also be limited due to the low frequency and availability of suitable spawning habitat in upper Harper Creek.

T Creek

Detailed Level 1 fish habitat data are discussed in Appendix 14-A, Section 4.1.3.2. The entire 336-m fish-bearing portion of T Creek was categorized into 22 mesohabitat units (Appendix 14-A, Figure 4.1-4). The most frequent habitat was classified as short pools (32%) which averaged approximately 6.4 m in length with a mean residual depth of 0.38 m. Riffles and glides accounted for 23% and 18% of the habitat mapped with a mean length of 17.3and 9.3 m in length, respectively. Cascades and step-pools accounted for approximately 27% of the remaining habitat and these habitats averaged 6.0 to 7.0 m in length although the final 129 m of the fish-bearing reach was classified as a high gradient step-pool or cascade with an approximate gradient of between 22 and 27%. Bed material in T Creek was dominated by coarse materials with the vast majority being classified as boulder/cobble (71%), followed by boulder (19%), boulder/gravel (5%) and cobble/boulder (5%). The dominant forms of fish cover were provided by overhead riparian vegetation and boulders, with some sub-dominant cover provided by undercut banks and functional woody debris. Habitat conditions in lower T Creek are suitable for Bull Trout rearing due to the prevalence of rough cobble and boulder channel elements combined with turbulent flow. Late summer and winter low flows may be limiting for Bull Trout habitat use during these seasons, and the absence of deep pools restricts overwintering habitat use.

P Creek

Detailed Level 1 fish habitat data are discussed in Appendix 14-A, Section 4.1.3.4. The 429 m of fish bearing habitat within P Creek was categorized into 20 different mesohabitat units (Appendix 14-A, Figure 4.1.3). The most frequent habitat was classified as step-pools (37%) which had an average length of approximately 37 m and an average gradient of about 8%. Short pools (32%) were the next most common mesohabitat and the units averaged approximately 3.8 m in length with a mean residual depth of 0.34 m. Riffles and glides accounted for 16 and 11% of the habitat mapped with a mean length of 42.5 and 10.5 m in length, respectively. Cascades accounted for 11% of the remaining habitat and these units averaged 10.5 m in length. Bed material in P Creek is dominated by coarse materials with the vast majority being classified as angular cobble (65%), followed by boulder (30%), with a small proportion of sandy fines (5%). The dominant forms of fish cover are provided by overhead riparian vegetation and boulders with sub-dominant cover provided by functional woody debris. Late summer and winter low flows may be limiting for Bull Trout due to lack of flow, unconfined channel sections, and relative absence of deep pools. Thus, habitat for Bull Trout in lower P Creek is largely confined to juvenile rearing.

Baker Creek

Fish habitat data are discussed in Appendix 14-A, Section 4.1.3.1. A total of 1,250 m of fish-bearing habitat within Baker Creek was categorized into 66 different mesohabitat units. The dominant stream morphology of Baker Creek was classified as confined cascade-pool. The most frequent habitat was classified as small pools (45%) which had an average length of approximately 4.8 m, with an average maximum and residual depth of 0.58 m and 0.12 m, respectively. Step pools (34%) were the next most common mesohabitat and the units averaged approximately 29.9 m in length with a mean residual depth of 0.34 m. Riffle-pools and riffles accounted for 12 and 8% of the habitat mapped with a mean length of 38.2 and 14.8 m in length, respectively. Cascades accounted for 2% of the remaining habitat and these units averaged 41 m in length. Bed material in Baker Creek was dominated by coarse materials with the majority being classified as either boulder (45%), followed by cobble (44%), with a small proportion of gravels (11%). The dominant forms of fish cover were provided by overhanging riparian vegetation (56%), undercut banks (20%) and large woody debris (21%), with a small proportion of instream boulders (3%). Late summer and winter flows may be limiting for Rainbow Trout due to low flows, water abstraction, and lack of deep pool habitat.

Jones Creek

Fish habitat data are discussed in Appendix 14-A, Section 4.1.2.2. Five reaches were identified on the mainstem of Jones Creek from its confluence with the North Thompson River to its headwaters approximately 8.7 km upstream. The average channel gradient of Jones Creek is 15.0% (Appendix 14-A, Table 4.1.2). The dominant stream morphology of Jones Creek was classified as confined cascade-pool, with riffle-pool morphology present in the lower reach near the North Thompson River. Alluvial bed materials consisted primarily of cobbles and gravels. Cover for fish was provided by abundant overhanging riparian vegetation. Late summer and winter flows may be limiting for Rainbow Trout due to low flows, water abstraction, and lack of deep pool habitat.

14.4.3.5 Aquatic Resources

Periphyton

Periphyton biomass (measures as chlorophyll *a*) was consistently low in the Project area creeks and rivers compared to the BC water quality criteria of 5 μg/cm^2 and 10 μg/cm^2 for recreation in streams and aquatic life in streams (Table 14.4-6; BC MOE 2001). The low periphyton biomass corresponded with the low nutrient supply observed in Project area stream surface water quality (Appendix 13-A) and was consistent with low chlorophyll *a* concentrations measured in other streams of the BC interior (Reece and Richardson 2000). High interannual variation was observed for both periphyton biomass and periphyton density. For example, Baker Creek (site BC-10) had both the lowest mean biomass (0.07 μg chl *a*/cm^2) and second highest mean biomass (1.7 μg chl *a*/cm^2) in 2012 and 2011, and mean periphyton abundance ranged from 510,000 cells/cm^2 in 2011 to 1,590,000 cells/cm^2 in 2013 (Table 14.4-3). Spatial trends were not apparent for periphyton biomass or abundance, except periphyton biomass was consistently greater in the Barrière River at the downstream receiving environment site BR-10 than the upstream reference site BR-20. Temporally, periphyton biomass was generally greater in 2011 compared to 2012 or 2013 and the greater biomasses observed in 2011 generally corresponded with lower cell abundances.

Periphyton communities were generally dominated by filamentous Myxophyceae (also known as Cyanophyta, cyanobacteria, or blue-green algae) common to mountain creeks (genus *Homoeothrix* and/or *Chamaesiphon*) and Bacillariophyceae (diatoms; genus *Achnanthes*) in both 2011 and 2013. The Myxophyceae were most often dominant, except at sites BR-10 and HC-20 where Bacillariophyceae were consistently dominant (Table 14.4-6). Chlorophyta and Chyrsophyta were also identified in small relative abundances at all sites (mean ≤ 3%; Appendix 14-A). Taxonomic richness and Simpson's diversity were variable spatially and temporally, with no notable patterns or associations with periphyton biomass or cell density. The one exception was periphyton genus richness and Simpson's diversity was consistently greatest in the Barrière River at the downstream receiving environment site BR-10 in both 2011 and 2013. Overall, mean genus richness and Simpson's diversity were moderate to high (mean: 10 to 37 genera; mean Simpson's diversity: 0.40 to 0.84) at all sites, except at site HC-20 in 2011 (mean Simpson's diversity of 0.17; Table 14.4-3). The pollution tolerance index calculated for diatoms (Appendix 14-A) generally indicated good water quality conditions in the RSA consistent with undisturbed environments.

Table 14.4-6. Summary of Baseline Periphyton Conditions in the Harper Creek Local Study Area and Regional Study Area

Waterbody (Sites)	Description	Community Composition	Biomass and Abundance
Baker Creek (BC-10)	Flows north into the North Thompson River after receiving runoff from proposed open pit. Channel is 6.7 km long with a mean channel width of 4 m and a mean slope of 18.4%. Creek dominated by confined cascade-pool habitat with cobble and gravel substrate (Appendix 14-A).	Dominated by Myxophyceae (mean 92% to 94%). Mean richness of 10 to 15 genera. Mean Simpson's diversity of 0.52 (2011 and 2013).	Mean biomass 0.07 µg chl *a*/cm^2 to 1.7 µg chl *a*/cm^2. Mean abundance 510,000 cells/cm^2 to 1,590,000 cells/cm^2.
Harper Creek (HC-10, HC-20, HC-30, HC-40)	Flows south into North Barrière Lake after receiving runoff from the proposed Project Site. Channel is 28.9 km long with a mean channel width of 15 m and a mean slope of 2.8%. Creek dominated by confined cascade-pool habitat with cobble substrate interspersed with boulders and gravel (Appendix 14-A).	HC-10, HC-30 and HC-40) generally dominated by Myxophyceae (mean 25% to 95%), HC-20 dominated by Bacillariophyceae (mean 65% to 98%). Mean richness of 12 to 21 genera. Mean Simpson's diversity of 0.17 to 0.64.	Mean biomass 0.09 µg chl *a*/cm^2 to 1.8 µg chl *a*/cm^2. Mean abundance 460,000 cells/cm^2 to 2,090,000 cells/cm^2.
Harper Creek Tributaries - P Creek (OP-10) and T Creek (TMF-10 and TMF-20)	Upper portions of P Creek and T Creek are proposed locations of open pit and TMF, respectively. P Creek and T Creek channel lengths are 4.4 and 9.1 km, mean widths are 5 and 6 m, mean slopes are 10.1 and 7.7%, respectively. Both creeks are dominated by confined cascade-pool habitat. Dominant substrate in P Creek is angular cobble and gravel, while cobble and boulder are dominant in T Creek (Appendix 14-A).	Dominated by Myxophyceae (mean 69% to 92%) and Bacillariophyceae (mean 8% to 31%). Mean richness of 11 to 27 genera. Mean Simpson's diversity of 0.53 to 0.71.	Mean biomass 0.17 µg chl *a*/cm^2 to 0.92 µg chl *a*/cm^2. Mean abundance 310,000 cells/cm^2 to 2,870,000 cells/cm^2.

(continued)

Table 14.4-6. Summary of Baseline Periphyton Conditions in the Harper Creek Local Study Area and Regional Study Area (completed)

Waterbody (Sites)	Description	Community Composition	Biomass and Abundance
Barrière River (BR-10, BR-20)	Upper Barrière River is east of Project area and flows south into Saskum Lake then SW into North Barrière Lake before flowing into the North Thompson River approximately 25 km downstream. BR-20 is approximately 5 km upstream of Saskum Lake and BR-10 is approximately 5 km downstream of North Barrière Lake (Appendix 13-A).	BR-10 dominated by Bacillariophyceae (mean 61% to 66%) and Myxophyceae (mean 32% to 37%). BR-20 dominated by Myxophyceae (mean 84% to 94%). Mean richness (36 and 37 genera) and Simpson's diversity (0.78 to 0.84) compared to BR-20 (mean richness 13 genera and mean Simpson's diversity 0.61 to 0.63).	Mean biomass 0.20 µg chl *a*/cm^2 to 1.3 µg chl *a*/cm^2; means were consistently higher downstream at BR-10 than BR-20. Mean abundance 420,000 cells/cm^2 to 1,100,000 cells/cm^2.

Benthic Invertebrates

Benthic invertebrate abundances were generally similar among sites, but were consistently greatest in Harper Creek just downstream of T Creek (Site HC-20; Table 14.4-7). Mean abundance ranged from 5,500 organisms/m^3 (BR-10 in 2011) to 23,000 organisms/m^3 (HC-20 in 2011). Benthic invertebrate abundances in Project area streams were similar to abundances documented in other streams within the interior of BC (Reece and Richardson 2000). No rare or endangered aquatic invertebrates were observed in the baseline sampling program.

Most stream benthos communities were dominated by Ephemeroptera (mayflies) and Plecoptera (stoneflies). The Ephemeroptera family Heptageniidae was ubiquitous among sites. Reece and Richardson (2000) also found members of the Heptageniidae family to be widespread among their eight BC coastal and interior study sites, and were particularly abundant at interior sites. Baetiidae and Ephemerellidae were also common mayfly families, present at approximately half of the sampling locations. Chloroperlidae was the most common Plecoptera family, present at seven of the 10 sites. Trichoptera (caddisflies) and Diptera (true flies) were also common among in the Project streams (mean 2 to 32%, and 4 to 22%, respectively). In general, the large presence of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa found in Project area streams indicated good water quality as these members within these groups tend to be sensitive to pollution. The EPT indices calculated for the baseline study support this statement (Appendix 14-A). Coleoptera (beetles), Oligochaeta (worms), Hydracarina (water mites), and Bivalvia (clams) were present at most sites in low relative abundances (less than 5%), except Coleoptera (Elmidae; riffle beetles) which were more abundant (less than 20%) during certain sampling events at sites BR-10, BR-20, HC-10, and TMF-20.

Table 14.4-7. Summary of Baseline Benthic Invertebrate Conditions in the Harper Creek Local Study Area and Regional Study Area

Waterbody (Sites)	Description	Community Composition	Abundance
Baker Creek (BC-10)	Flows north into the North Thompson River after receiving runoff from the proposed open pit. Channel is 6.7 km long with a mean channel width of 4 m and a mean slope of 18.4%. Creek dominated by confined cascade-pool habitat with cobble and gravel substrate.	Dominated by Ephemeroptera (mean 25 to 50%) and Plecoptera (mean 35% to 48%) in 2011 and 2012. Trichoptera more prevalent in 2013 (32%). Mean richness of 16 to 21 families and mean EPT richness of 11 to 13 families. Mean Simpson's diversity 0.82 to 0.90.	Mean abundance 5,900 organisms/m^3 to 10,300 organisms/m^3.
Harper Creek (HC-10, HC-20, HC-30, HC-40)	Flows south into North Barrière Lake after receiving runoff from the proposed Project Site. Channel is 28.9 km long with a mean channel width of 15 m and a mean slope of 2.8%. Channel is dominated by confined cascade-pool habitat with cobble substrate interspersed with boulders and gravel.	Dominated by Ephemeroptera (mean 29% to 53%) and Plecoptera (mean 11% to 55%). Mean richness of 19 to 24 families and mean EPT richness of 13 to 16 families. Mean Simpson's diversity 0.85 to 0.90.	Mean abundance 8,100 organisms/m^3 to 23,300 organisms/m^3; greatest at HC-20.
Harper Creek Tributaries – P Creek (OP-10) and T Creek (TMF-10 and TMF-20)	Upper portions P Creek and T Creek are proposed locations of open pit and TMF, respectively. P Creek and T Creek channel lengths are 4.4 and 9.1 km, mean widths are 5 and 6 m, mean slopes are 10.1 and 7.7%, respectively. Both creeks are dominated by confined cascade-pool habitat. Dominant substrate in P Creek is angular cobble and gravel, while cobble and boulder are dominant in T Creek.	Dominated by Plecoptera (mean 25 to 51%) and Ephemeroptera (mean 21 to 59%). Mean richness of 16 to 25 families and mean EPT richness of 12 to 18 families. Mean Simpson's diversity 0.81 to 0.91.	Mean abundance 5,800 organisms/m^3 to 16,400 organisms/m^3.
Barrière River (BR-10, BR-20)	Upper Barrière River is east of Project area and flows south into Saskum Lake then SW into North Barrière Lake before flowing into the North Thompson River approximately 25 km downstream. BR-20 is approximately 5 km upstream of Saskum Lake and BR-10 is approximately 5 km downstream of North Barrière Lake (Appendix 13-A)	BR-20 dominated by Ephemeroptera (mean 45 to 48%) and Plecoptera (mean 24 to 34%). BR-10 dominated by Coleoptera (mean 21 to 31%) and Ephemeroptera (mean 24 to 31%) in 2011 and 2012. Ephemeroptera (mean 30%) and Diptera (mean 22%) dominant at BR-10 in 2013. Mean richness of 14 to 23 families and mean EPT richness of 6 to 15 families. Mean Simpson's diversity 0.72 to 0.90.	Mean abundance ranged from 5,400 organisms/m^3 to 15,200 organisms/m^3.

Benthos family richness, particularly EPT family richness, was similar across sites and among years. EPT families accounted for approximately two-thirds of the total family richness, except at the downstream receiving environment site in the Barrière River (BR-10) where other taxa were more prevalent. Total and EPT family richness were slightly greater at downstream sites in Harper and T creeks when compared to upstream sites within the same waterbody closer to the proposed Project Site; the same was not true for the Barrière River. Total and EPT Simpson's diversity were high at all sites and exhibited little inter-annual variation. Means ranged from 0.81 to 0.91, and 0.72 to 0.88, respectively, excluding results from BR-10 in 2011 which was notably less diverse.

Sediment Quality

River and creek sediments were primary composed of sand, and to a lesser extent gravel. In rivers or creeks with multiple sites, proportions of gravel were generally greatest at upstream sites while sand was generally greater at downstream sites. Proportions of silts and clay were similar across sites, except in upper Harper Creek above P and T creeks (site HC-40) which had 1.5 to 23% silt on average, depending on the year. Site HC-40 also had the highest total organic carbon (TOC) concentration (0.4%), although it was consistently low at all sites (less than 0.5%).

Sediment metal concentrations were variable among sites, and were generally consistent with the mineralogy of the region. Metal concentrations were particularly high at site OP-10 and other sites close to the proposed open pit. Within North Barrière Lake, sites NBL-3 and NBL-4 had greater metal concentrations compared to NBL-1 and NBL-2. Mean concentrations were greater than BC and CCME sediment quality guidelines for the protection of aquatic life at one or more sites in one or more years for the following metals: arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, selenium, silver, nickel and zinc. The annual mean at most sites was greater than several BC LEL guidelines and some SEL guidelines (Table 14.4-8). At least 50% of samples had concentrations greater than the LEL for arsenic, copper, iron, manganese, nickel and zinc. Concentrations in more than 50% of the samples also had arsenic concentrations greater than the SEL. Results are discussed in relation to BC guidelines because CCME guidelines are identical to BC guidelines where they exist (Table 14.4-2). Metals in T Creek were often low compared to other sites. Sediment PAH concentrations were below detection at all sites in 2011 which was the only year in which PAHs were measured.

14.5 EFFECTS ASSESSMENT AND MITIGATION

14.5.1 Screening and Analyzing Project Effects

Activities during the Construction, Operations, Closure, and Post Closure phases vary depending upon the type of infrastructure. Some of these activities could potentially affect fish, fish habitat, and aquatic resources. The analysis of potential effects from the Project identified three major interaction pathways.

1. Direct mortality, which is the immediate mortality or lethal harm to fish from Project-related activities.
2. Changes in water quantity, which are increases or decreases in the timing and discharge of streams and creeks, and/or changes in the volume of lotic habitats.
3. Changes in water quality, which describe changes in the concentration of suspended sediments, metals, or nutrients.

Table 14.4-8. Summary of Baseline Sediment Quality Conditions in the Harper Creek Local Study Area and Regional Study Area

Waterbody (Sites)	Description	Sediment Quality	Background Metal Concentrations > Guidelines[a]
Baker Creek (BC-10)	Flows north into the North Thompson River after receiving runoff from the proposed open pit. Channel is 6.7 km long with a mean channel width of 4 m and a mean slope of 18.4%. Channel is dominated by confined cascade-pool habitat with cobble and gravel substrate.	Mainly sand (mean 78%) and gravel (mean 17%). Low TOC (0.10%). PAHs below detection.	Mean arsenic and iron greater than SEL. Mean chromium, copper, iron, manganese, and nickel greater than LEL.
Harper Creek (HC-10, HC-20, HC-30, HC-40)	Flows south into North Barrière Lake after receiving runoff from the proposed Project Site. Channel is 28.9 km long with a mean channel width of 15 m and a mean slope of 2.8%. Channel is dominated by confined cascade-pool habitat with cobble substrate interspersed with boulders and gravel.	Mainly sand (mean range 66 to 88%) and gravel (mean 10 to 25%). Low TOC (0.11% to 0.35%). PAHs below detection.	Mean cadmium, copper, selenium, and zinc greater than LEL. Mean arsenic, chromium, iron, lead, manganese and nickel greater than SEL. Mean selenium greater than LEL at HC-40 only.
Harper Creek Tributaries – P Creek (OP-10) and T Creek (TMF-10 and TMF-20)	Upper portions P Creek and T Creek are proposed locations of open pit and TMF, respectively. P Creek and T Creek channel lengths are 4.4 and 9.1 km, mean widths are 5 and 6 m, mean slopes are 10.1 and 7.7%, respectively. Both creeks are dominated by confined cascade-pool habitat. Dominant substrate in P Creek is angular cobble and gravel, while cobble and boulder are dominant in T Creek.	Mainly sand (mean 68 to 76%) and gravel (mean 18 to 28%). Low TOC (mean 0.11 to 0.18%). PAHs below detection.	Mean arsenic, cadmium, chromium, copper, iron, nickel and zinc greater than LEL, mean manganese greater than SEL. In P Creek mean arsenic, copper, iron and zinc also greater than SEL.

(continued)

Table 14.4-8. Summary of Baseline Sediment Quality Conditions in the Harper Creek Local Study Area and Regional Study Area (completed)

Waterbody (Sites)	Description	Sediment Quality	Background Metal Concentrations > Guidelines[a]
Barrière River (BR-10, BR-20)	Upper Barrière River is east of Project area and flows south into Saskum Lake then SW into North Barrière Lake before flowing into the North Thompson River approximately 25 km downstream. BR-20 is approximately 5 km upstream of Saskum Lake and BR-10 is approximately 5 km downstream of North Barrière Lake (Appendix 13-A)	Mainly sand (77 to 90%) and gravel (5 to 19%). Low TOC (0.16 to 0.30%) PAHs below detection.	Mean arsenic, chromium, copper, iron, lead, manganese, nickel, and zinc greater than LEL. Mean lead and zinc greater than guideline at BR-10 only.
North Barrière Lake (NBL-1, NBL-2, NBL-3, NBL-4)	497 ha lake within Barrière River watershed, receives water from upper Barrière River and Harper Creek.	No particle size, TOC or PAH data available.	Mean cadmium, copper, lead, nickel, silver, and zinc greater than LEL. Mean arsenic, iron, and manganese greater than SEL. Concentrations greater than cadmium, lead, mercury, and silver guidelines at NBL-3 and NBL-4 only.

[a] *Annual means were considered when reporting background concentrations above guidelines in this table. If the annual average for a site was greater than the guideline in one or more years it was reported in the above table.*

The grouping of interactions into these pathways is valuable because it identifies common mitigation and management measures (see Section 14.5.2) and focusses the assessment on well-understood indicators, such as water quality relative to BC guidelines for the protection of aquatic life (see Section 13.5.3). A number of the activities identified in Table 14.5-1 may involve multiple interaction pathways with the freshwater environment. For example, road widening activities may cause direct harm to fish by in-water works and may also change water quality by increasing suspended sediment concentrations through enhanced erosion. The potential effects on each VC from Project for each of the pathways are discussed below in Sections 14.5.1.1 to 14.5.1.3. Each of these potential effects, including mitigation and residual effects, will be discussed in detail in the following sections.

Table 14.5-1. Risk Ratings of Project Effects on Fish and Aquatic Resources Valued Components

Project Components and Activities	Fish	Fish Habitat	Aquatic Resources
Construction			
Construction of fish habitat offsetting sites	🟡	🟡	🟡
Explosives storage and use	🟡		🟡
Open pit development - drilling, blasting, hauling and dumping	🟡	🟡	🟡
Process and potable water supply, distribution and storage	🟡	🟡	🟡
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	🟡	🟡	🟡
Earth moving: excavation, drilling, grading, trenching, backfilling	🔴	🔴	🔴
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	🟢	🟢	🟢
Ditches, sumps, pipelines, pump systems, reclaim system and snow clearing/stockpiling	🟡	🟡	🟡
Water management pond, sediment pond, diversion channels and collection channels construction	🔴	🔴	🔴
Operations*			
Explosives storage and use	🟡		🟡
Fish habitat offsetting site monitoring and maintenance	🟢	🟢	🟢
Mine pit operations: blast, shovel and haul	🟡	🟡	🟡
Ore crushing, milling, conveyance and processing	🟡	🟡	🟡
Process and potable water supply, distribution and storage	🟡	🟡	🟡

(continued)

Table 14.5-1. Risk Ratings of Project Effects on Fish and Aquatic Resources Valued Components (continued)

Project Components and Activities	Fish	Fish Habitat	Aquatic Resources
Operations ***(cont'd)***			
Plant operation: mill building, truck shop, warehouse and pipelines	🟢	🟢	🟢
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	🟡	🟡	🟡
Monitoring and maintenance of mine drainage and seepage	🟢	🟢	🟢
Surface water management and diversions systems including snow stockpiling/clearing	🔴	🔴	🔴
Low grade ore crushing, milling and processing	🟡	🟢	🟡
Partial reclamation of non-PAG waste rock stockpile	🟡	🟢	🟡
Partial reclamation of TMF tailings beaches and embankments	🟡	🟡	🟡
Construction of North TMF embankment and beach	🔴	🔴	🔴
Deposit of low grade ore tailings into open pit	🟡	🟢	🟡
Surface water management	🔴	🔴	🔴
Closure			
Environmental monitoring including surface and groundwater monitoring	🟢	🟢	🟢
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 load-out area	🟢		🟢
Partial decommissioning and reclamation of Project 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 low-grade ore stockpile, overburden stockpile and Non-PAG waste rock stockpile	🟢	🟢	🟢
Reclamation of TMF embankments and beaches	🟡	🟢	🟡
Removal of contaminated soil	🟡	🟡	🟡

(continued)

Table 14.5-1. Risk Ratings of Project Effects on Fish and Aquatic Resources Valued Components (completed)

Project Components and Activities	Fish	Fish Habitat	Aquatic Resources
Closure ***(cont'd)***			
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	🔴	🔴	🔴

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.*

The fish, fish habitat, and aquatic resources effects assessment was prepared according to applicable scientifically defensible management guidelines. The assessment was based upon current knowledge of species behaviour, presence, distribution, population biology, and ecology. Consideration was also given to linkages between predicted physical and biological changes resulting from the proposed development on both the individual and local population levels. The assessment of effects from Project activities on the aquatic resources VC take into consideration the potential for effects to primary producers, secondary producers, and sediment quality since they are closely linked ecologically.

The assessment of effects considers the potential effects from normal operations within the designed scope of the Project. Potential effects due to emergencies, malfunctions, spills, or accidents are assessed in Environmental Effects of Accidents and Malfunctions (Chapter 26) and are not discussed further in this assessment.

14.5.1.1 Direct Mortality Potential Effects

Project-specific activities with the potential to impose direct mortality on fish in the LSA include access road upgrades and maintenance activities that cross fish-bearing watercourses (Table 14.5-1), or increased fishing pressure and harvesting of fish species arising from an influx of people into the area (e.g., camp workers). Access to sport fishing for Bull Trout and Rainbow Trout in the LSA and RSA is already established via Highway 5, Birch Island-Lost Creek Road, Jones Creek FSR, Vavenby FSR, Avery Creek FSR, Saskum Plateau FSR, and Vavenby-Saskum FSR. Fishing lodges, resorts, cabins, and camp sites are located at North Barrière Lake. Upgrades to the planned access roads will not improve access for sport fishing above what is currently available. However, there exists the potential for an increase in fishing pressure and harvesting due to the presence of the mine's Construction and Operations phases workforces. Although all of the Project workers will not be anglers, some proportion of the workforce will be, and this influx has the potential to increase the fishing pressure on sport and traditional fish populations in reaches of Harper Creek within the LSA and the North Thompson River and Barrière River systems in the RSA. Increased fishing access could affect fish species by causing mortality to all fish life history stages. Direct mortality is not considered a potential effect for aquatic resources; primary and secondary producers are not direct targets of harvesting and other potential effects are better assessed at the population and community levels. No blasting is planned to occur near waters frequented by fish; therefore no direct mortality due to blasting is predicted to occur.

14.5.1.2 Water Quantity Potential Effects

Project-related changes to surface water hydrology (assessed in Chapter 12) have the potential to affect fish, fish habitat, and aquatic resources through alteration of water levels, stream discharge, and channel morphology. Changes to water quantity and their associated effects on fish, fish habitat, and aquatic resources were important issues raised by Aboriginal and public groups, and government agencies (Appendices 3-E, F, and L). Potential sources of changes to water quantity across all Project phases include:

- the establishment and operation of water management structures (e.g., runoff diversion channels, sediment ponds, coffer dam, and the TMF embankment);
- earth moving, road widening, culvert installation, and site clearing and stripping activities (e.g., erosion and sedimentation alter infiltration);
- the construction/decommissioning of camp and mine infrastructure (e.g., plant site, stockpiles, erosion and sedimentation ponds) and the initiation of open pit mining;
- mine pit operation and waste rock stockpiling; and
- water use and management activities (i.e., TMF discharge, reclaim water from TMF, mine drainage, seepage, and discharge).

The maintenance activities associated with the access road, pads, and water management infrastructure can alter natural flow pathways and change the timing and magnitude of surface water flows. Seepage and discharge from the TMF and seepage from the open pit can increase flows or volumes in receiving waterbodies.

Changes in water quantity can alter fish production. Water quantity or flow is a fundamental abiotic factor controlling ecological processes in streams (Poff et al. 1997). The natural flow regime of a watershed, characterized by the magnitude of discharge, duration, frequency, timing and rate of change, regulates both the physical and ecological processes of a lotic ecosystem. Many channel and floodplain features such as pool-riffle sequences are formed and maintained by natural flow processes (Poff et al. 1997). The aquatic food organisms, nutrients, and other aspects of fish habitat that support fish production in streams are controlled and influenced by hydrological processes. Therefore, disruptions to stream processes can alter fish production (Clarke et al. 2008).

Changes in flow can be categorized as either direct effects or physical habitat effects (Lewis et al. 2004). Direct effects are stranding, inundation, or dewatering of spawning areas, displacement of fish species, creation of fish passage/migration barriers, and increased predation risk (Clarke et al. 2008). Physical habitat effects may affect functional wetted area, depth and velocity, habitat structure and cover, temperature, nutrient dynamics, substrate quality, and sediment scour and deposition (Clarke et al. 2008). Holistically, these effects alter food supply, rearing habitat, overwintering habitat, and spawning habitat. As a result, fish population ecology is affected in terms of abundance and distribution, growth, survival, reproductive success, bioenergetics, and biodiversity. Changes to surface water quantity can affect fish and primary producer productivity primarily by physical alteration of the habitat available to carry out life processes. Water management, including diversion channels for non-contact water, affects discharge rates and stream flows and therefore may alter the wetted width availability and the stream depth necessary for fish spawning and rearing, and aquatic life colonization at different times of the year. For example, decreased water flow in summer would decrease aquatic habitat available for periphyton, Rainbow Trout spawning, and salmonid rearing, and the migratory potential for salmonids. In fall, altered flow during low flow periods could change the amount of Bull Trout and Coho Salmon spawning habitat, while during winter, decreased flow rates could lead to increased ice formation and block flows in diversion channels or low-flow streams. In the other extreme, increases in water flow can cause scouring, bank erosion, and increased sediment suspension and light attenuation, all which may decrease primary producer biomass and productivity. In addition, the *in situ* retention of nutrients could be reduced, which could further reduce primary productivity and change nutrient spiraling lengths, with subsequent indirect effects on higher trophic levels (Newbold et al. 1983).

Water management within the LSA may affect secondary producers through a similar pathway involving a physical alteration in habitat. Water management may affect discharge rates and stream flows and therefore may alter the wetted width availability for aquatic life colonization at different times of the year. Higher stream discharge rates may increase scour, alter bed characteristics, and reduce the availability of suitable low-flow refuges and habitat. The timing and magnitude of stream flows has been shown to be correlated with significant differences in the composition of secondary producer communities in BC streams (Halwas, Church, and Richardson 2005).

Sediment quality in the receiving environment may also be affected by changes in water quantity. Within a stream, the deposition and distribution of particulate material is controlled by the velocity of water. Higher flows are capable of transporting larger particles and greater concentrations of smaller particles whereas low velocities encourage settling and deposition. Changes in particle size can influence invertebrate community composition physically (e.g., species preferences for large or small interstitial spaces) or chemically (e.g., silts and clays are associated with greater metal concentrations). Sediment inputs into headwater and low-order systems, like Harper Creek and its tributaries, are strongly connected to hillslope processes (Gomi, Sidle, and Richardson 2002).

14.5.1.3 Water Quality Potential Effects

Project-related changes in surface water quality can affect the fish and aquatic resources VCs through the chemical alteration of their habitat. The major pathways that can result in potential changes to surface water quality in the various phases of the Project are detailed in the surface water quality effects assessment (Section 13.5.1 and Table 13.5-1), and include:

- change in chemical concentrations in the aquatic environment due to metal leaching, seepage, and/or TMF discharge;
- nutrient additions from explosives use;
- sedimentation and erosion during site clearing, construction, maintenance, and decommissioning; and
- atmospheric deposition of dust onto surface waters.

Potential for Toxicity due to Change in Water Quality

Potential changes in water quality due to metals and other parameters are detailed in the Surface Water Quality Effects Assessment (Chapter 13). Metal leaching/acid rock drainage (ML/ARD), discharge from the TMF into T Creek, and seepage from the TMF, material storage areas, and the open pit are predicted to be the primary mechanisms that have the potential to introduce metals or other chemicals into the aquatic environment, with subsequent exposure of fish and aquatic resources (primary and secondary producers). Surface water management (e.g., management of contact water, construction of diversions) can also influence the concentrations of metals in the aquatic environment by changing the volumes of water available for dilution of loads.

In addition, water quality can affect sediment quality. Sediment and water quality tend to co-vary, as metals and organic compounds shift between particulate matter and dissolved components. Further, sediments represent a compartment in the aquatic ecosystem that may accumulate metals due to the high surface area of sediment particles, favourable redox conditions, and low oxygen concentrations. Given the close association of aquatic resources with stream substrates for habitat, shifts in sediment quality may alter primary and secondary producer community density and composition.

At high enough concentrations, metals and other chemicals can cause mortality in exposed organisms. At lower concentrations, sub-lethal effects may occur; although these effects do not necessarily cause mortality, they can affect population dynamics or stability in the long term. The interaction of water hardness/softness and pH with metals or other parameters (e.g., ammonia, sulphate) can change speciation and modify their mobility and bioavailability in the aquatic environment, thereby altering exposure and their potential influence.

Toxicity of metals or other chemicals in fish can manifest as effects on various physiological or behavioural functions, which can lead to changes at the individual, population, or community levels. Toxicity generally occurs because of chemical interaction with the external surfaces of the organism or due to uptake through water or diet. Toxicity thresholds are most often determined based on the concentration required to cause changes in ecologically-relevant endpoints (i.e., physiological functions that have been shown to be directly linked to long-term population stability and success), most typically survival, reproduction, or growth. Other types of effects (e.g., changes in osmoregulation, immune or neural system function, or olfaction) may also occur but the ecological relevance of these effects is not as clear. The type of effects that may occur depends on the specific parameter and the exposure concentration.

Exposure to metals or other chemicals in either sediment or water can affect primary or secondary producers, with exposure potentially leading to either lethal or sublethal effects. When exposure occurs at high enough concentrations, effects such as decreased biomass, densities, and diversities of primary producer communities may occur (Kimmel 1983; McKnight and Feder 1984; Niyogi, Lewis, and McKnight 2002). Similarly, potential effects to secondary producers include reduced growth or reproduction, altered physiology, or altered behaviour.

Sediment quality may be affected by transfer of metals from the overlying water and by deposition of particles with adsorbed metals. Water-sediment exchange of dissolved and particulate metals is a complex system of reactions and processes, but many metals (such as iron) tend to partition to the particulate phase and accumulate in sediments. Changes in sediment quality have the potential to affect the health or community structure of aquatic biota, particularly those organisms that reside in or on the sediment.

Nutrient Loading

The potential for effects due to nutrient loading (Project-related increases in nitrogen or phosphorus concentrations in water) are limited to primary and secondary producers, since changes in nutrient concentrations can affect aquatic resource community structure and biomass. Potential for toxicity due to nitrogen compounds (nitrate, nitrite, and ammonia), which could affect fish, primary producers, and secondary producers, is considered in the previous section.

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 leach. 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.

Nitrogen loading may increase the potential for eutrophication in nitrogen-limited aquatic systems if there is sufficient light, phosphorus, and other micronutrients for primary production. Primary producer community composition and diversity can also be affected by changes in nutrient concentrations such that one group of organisms may be selected over another. For example, freshwater primary producers exhibit marked differences in phosphorus growth requirements as well as tolerances to elevated phosphorus concentrations (Wetzel 2001). Further, changes in nutrient supply would not only influence the absolute concentration of nutrients, but also the ratio of nutrients available. The ratio of nitrogen to phosphorus is a commonly cited example driving primary producer abundance and overall community structure. For example, cyanobacteria are generally thought to have a competitive advantage in periphyton communities when nitrogen to phosphorus ratios are low, due to their ability to use atmospheric nitrogen (N_2) for growth (e.g., Havens et al. 2003; Nõges et al. 2008).

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

Sedimentation and Erosion

Physical disturbance of the terrain during all Project phases has the potential to increase surface runoff and erosion, resulting in increased turbidity, total suspended solids (TSS), particle-associated nutrients and metals, and sedimentation in receiving waters. The potential for erosion and sedimentation is greatest during periods of disturbance of natural surface cover and vegetation, such as during construction (e.g., site clearing and grubbing, excavation and foundation preparation, construction of infrastructure, and working in or near water) and site decommissioning (Table 14.5-1). Other sources of TSS include particulates from construction equipment activity, road runoff, and road maintenance. The geographic scope of erosion and sedimentation can range from localized to far-reaching events, depending on the amount and type of sediment that is introduced into the aquatic environment.

Erosion can affect the aquatic environment in many ways, similar to some of the effects described for changes in water quantity, including physical alterations to habitat in the form of increased turbidity. In turn, sedimentation has the potential to cause behavioural changes, mortality for fish eggs or larvae due to smothering or hypoxia, or respiratory and osmoregulatory stress (D. W. Chapman 1988; Newcombe and MacDonald 1991; Sutherland and Meyer 2007). Sedimentation can affect aquatic resources by smothering primary and secondary producers, altering the light penetration and intensity required to support photosynthesis, reducing visibility, diminishing feeding efficiency, increasing exposure to elevated metal concentrations, and leading to habitat avoidance or changes in aquatic community structure (Newbold, Erman, and Roby 1980; Murphy, Hawkins, and Anderson 1981; Hawkins, Murphy, and Anderson 1982).

Project-related increases in the quantity of suspended material in the freshwater environment can also alter sediment quality through the deposition of sediments and associated metals, and affect fish and aquatic resources through both physical and chemical alteration of their habitat. Sediment quality could be affected by the settling of eroded material, which would change the particle composition of sediments and potentially transport adsorbed metals.

The recovery from sedimentation will be more rapid in high-velocity streams relative to wetlands or lakes. Waterbodies in the LSA are generally low-order, moderate-to-high gradient streams with the potential for sufficiently high water velocities to flush fine sediments. Depositional environments are found in the RSA in North Barrière Lake and the North Thompson River.

Atmospheric Deposition

Air quality is a pathway VC to surface water quality and, by extension, fish, fish habitat, and aquatic resources. Aerial deposition of Project-generated dust onto surface waters may occur due to vehicle traffic and other mining activities (e.g., blasting), and has the potential to affect fish and aquatic resources during the Construction, Operations, and Closure phases. Detailed effects assessment of air quality and dustfall are presented in Chapter 9, Air Quality Effects Assessment.

Dust deposition into the freshwater environment could affect fish, fish habitat, and aquatic resources by introducing suspended material and associated metals and nutrients into receiving waters. The deposited material can have effects similar to mobilized sediments or may transport metals. The deposited dust may change sediment quality, or have biological effects (as discussed above for sedimentation and erosion) on fish or aquatic resources.

14.5.2 Mitigation Measures

The proposed mitigation and management measures are actions to prevent, avoid, minimize, offset, or restore effects to fish, fish habitat, and aquatic resources on-site 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, best management practices, regulatory requirements, and monitoring and adaptive management. Many of the mitigation and management measures are designed to avoid or minimize effects on the interaction pathways, such as changes in water quantity and quality (Section 14.5.1), and thus are applicable to all fish, fish habitat, and aquatic resources VCs. All mitigation measures will be applied, when applicable, throughout the life of the project. In addition to information provided in this section, details of mitigation and management strategies relevant to the fish, fish habitat, and aquatic resources VCs are available in the following Application/EIS chapters:

- Chapter 9, Air Quality Effects Assessment;
- Chapter 11, Hydrogeology Effects Assessment;
- Chapter 12, Hydrology Effects Assessment; and
- Chapter 13, Surface Water Quality Effects Assessment.

The following environmental management and monitoring plans will be central to the planned mitigation and management measures for Project effects on fish, fish habitat, and aquatic resources:

- 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);
- Spill Prevention and Response Plan (Section 24.15);
- Traffic and Access Management Plan (Section 24.16);
- Waste Management Plan (Section 24.18); and
- Fish Habitat Offsetting Plan (Appendix 14-E).

These Plans detail a range of mitigation measures and monitoring programs to reduce and eliminate Project effects, as well as to detect potential residual effects of the Project on fish, fish habitat, and aquatic resources. Monitoring programs will ensure detection of measureable alterations in fish, fish habitat, and aquatic resources indicators, allow for identification of potential causes, and include the provision of additional mitigation or adaptive management strategies.

The successful implementation of management and monitoring plans will require adaptation to updates in Project design as well as site conditions. Adaptive management is a process for continually improving management practices by learning from the outcomes of operational approaches. Adaptive management applies prompt responses to field observations of changing environmental conditions and limitations or deficiencies in existing water management structures. Management and mitigation of potential effects is therefore a cyclical ongoing process of monitoring, maintenance, and reassessment. Adaptive management procedures and Best Management Practices (BMPs) related to surface water quality, surface water hydrology, aquatic resources, and fish and fish habitat, are also described in corresponding management plans detailed in Chapter 24, Environmental Management and Monitoring Plans.

The effectiveness of each mitigation measure is assessed based on guidelines, guidance documents, published studies, experience, and professional judgment. The criteria used for the determination of effectiveness are as follows.

- Low effectiveness: After implementation of the mitigation measure, there is still a major change in the indicator or VC from the baseline condition.
- Moderate effectiveness: After implementation of the mitigation measure, there is a measurable change in the indicator or VC.
- High effectiveness: After implementation of the mitigation measure, there is no change in the indicator or VC from the baseline (e.g., it returns to its original condition before the construction of the Project) or an environmental enhancement is evident.

- Unknown effectiveness: The suggested mitigation measure has not been tried elsewhere in similar circumstances and the response of the indicator or VC compared to the baseline is unknown.

If the mitigation and management measures are assessed to have "high effectiveness," then no residual effects are predicted to occur, and the effect is not considered further in this assessment. If the potential effects are not predicted to be fully mitigated, then a residual effect is predicted and characterized (Sections 14.5.3 to 14.5.6). Table 14.5-2 presents a summary of the mitigation measures for potential Project effects on fish, fish habitat, and aquatic resources.

Table 14.5-2. Proposed Mitigation Measures and their Effectiveness

Potential Effect	Proposed Mitigation Measure	Effectiveness (Low/Moderate/High/ Unknown)	Residual Effect (Y/N)
Direct Mortality	Traffic and Access Management Plan (Section 24.16),	High	N
	Policy to prohibit employees from fishing while working or travelling on site roads	High	
Changes in Water Quantity	Sediment and Erosion Control Plan (Section 24.11)	High	Y
	Fish and Aquatics Effects Monitoring and Management Plan (Section 24.6)	Moderate	
	Site Water Management Plan (Section 24.13)	Moderate	
	Fish Habitat Offsetting Plan (Appendix 14-E)	High	
Change in Water Quality: *Potential for Toxicity*	Sediment and Erosion Control Plan (Section 24.11)	High	Y
	Soil Salvage and Storage Plan (Section 24.14)	High	
	Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6)	Moderate	
	Groundwater Management Plan (Section 24.8)	Moderate	
	Mine Waste and ML/ARD Management Plan (Section 24.9)	Moderate	
	Selenium Management Plan (Section 24.12)	Moderate	
	Site Water Management Plan (Section 24.13)	Moderate	
Change in Water Quality: *Nutrient Loading*	Explosives Handling Plan (Section 24.5)	Moderate	Y
	Site Water Management Plan (Section 24.13)	Moderate	

(continued)

Table 14.5-2. Proposed Mitigation Measures and their Effectiveness (completed)

Potential Effect	Proposed Mitigation Measure	Effectiveness (Low/Moderate/High/ Unknown)	Residual Effect (Y/N)
Change in Water Quality: *Erosion and Sedimentation*	Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6)	High	N
	Sediment and Erosion Control Plan (Section 24.11)	High	
	Soil Salvage and Storage Plan (Section 24.14);	High	
	Site Water Management Plan (Section 24.13)	Moderate	
Change in Water Quality: *Atmospheric Deposition*	Air Quality Management Plan (Section 24.2)	High	N
	Site Water Management Plan (Section 24.13)	Moderate	

14.5.2.1 Mitigation and Management Measures for Direct Mortality

Mitigation for increased fishing activity and harvest burden may include the following two measures:

- implementing a company policy that prohibits employees and contractors from engaging in fishing while present at the Project Site or while travelling to and from the mine on company business; and
- transporting personnel to and from the Project Site such that employees have limited opportunity to engage in angling during mine Construction and Operations phases.

As a result of these mitigation measures, there will be no sanctioned opportunities for employees or contractors to engage in fishing while on site during mine Construction or Operations phases. Access to fishing in waterbodies within the LSA and RSA are unlikely to increase as a result of the Project, thus project activity is unlikely to increase fishing pressure or harvest due to angling.

To mitigate direct mortality effects within fish-bearing streams, road upgrade and maintenance activities will be done in accordance with BMPs such as the *Land Development Guidelines for the Protection of Aquatic Habitat* (DFO 1992), *Standards and Best Practices for Instream Works* (BC MWLAP 2004), and DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013)*. Appropriate fisheries operating windows for fish-bearing streams will be adhered to where possible. Mitigation strategies include isolating Project work sites to prevent fish movement into the work site and environmental monitoring.

If BMPs and plans are implemented and followed, effects caused by direct mortality on fish will be negligible at the individual and population level.

14.5.2.2 Mitigation and Management Measures for Changes in Water Quantity

Management and mitigation measures for changes in surface water quantity are outlined in Section 12.5.2 of the Hydrology Effects Assessment (Chapter 12), with specific details presented in the Site Water Management Plan (Section 24.13), including the integration of water management activities with other management and monitoring programs. The primary objectives of the Site Water Management Plan will be to divert non-contact water into existing natural drainage networks, and to efficiently manage the use of water within the Project Site and for the milling of ore. Site water demands will be met by:

- collecting site runoff;
- recycling water from TMF;
- collecting groundwater from open pit dewatering; and
- collecting groundwater from pump-back wells located downstream of the non-PAG waste rock pile, if required.

Maintaining natural drainage networks and efficiently recycling contact water within the Project Site are predicted to mitigate potential changes in water quantity in downstream waterbodies. Potential effects to water quantity in the Barrière River and tributaries to the North Thompson (other than Jones and Baker Creeks) are expected to be mitigated because of the small footprint of Project infrastructure and the application of mitigation and management measures (Chapter 12, Hydrology Effects Assessment). Therefore, the potential effects from changes in water quantity in those waterbodies will not be considered further in this assessment.

However, hydrological modelling predicts stream flows to change in T Creek (downstream of the TMF) P Creek, Baker Creek, and Jones Creek (Chapter 12, Hydrology Effects Assessment). Therefore, the effectiveness of the water management measures to mitigate potential changes in water quantity is concluded to be **moderate** (Table 14.5-2). As a result, a residual effect on fish, fish habitat, and aquatic resources from changes in water quantity is predicted to result from the Project.

14.5.2.3 Mitigation and Management Measures for Changes in Water Quality

The following management plans are designed to mitigate potential effects to surface water quality, and by extension, to fish and aquatic resources:

<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 quantity, which will in turn minimize the potential for effects to surface water quality. . A summary of the Site Water Management Plan is provided in the preceding section on mitigation measures for changes in water quantity (Section 14.5.2.2).

Groundwater Management Plan and Control of Seepage

Section 24.8 describes the Groundwater Management Plan for the Project. Project alternative optimization, design features, and BMPs will 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 low-grade ore (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 pond, 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 pond to the TMF for storage;
  - non-contact surface water diversions surrounding a number of Project components; and
  - concurrent reclamation of the waste rock stockpiles, overburden stockpile, as well as the TMF during the Operations and Closure phases of the Project; and
- 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 would 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).

Mine Waste and ML/ARD Management Plan

The Mine Waste and ML/ARD Management Plan (Section 24.9) is designed to minimize chemical loadings to the receiving environment 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 objective of the Mine Waste and ML/ARD Management Plan is to:

- ensure the occupational health and safety of personnel responsible for the transportation, handling, and deposition of mine waste, by providing appropriate Standard Operating Procedures and Method Statements, and related training;
- minimize the water quality effects of mine waste deposition, by ensuring that PAG waste rock and tailings are placed at an adequate depth below the surface of the TMF in a timely and controlled manner;
- minimize the physical effects of waste rock and overburden storage facilities, and topsoil and low-grade ore stockpiles, by ensuring that dust, erosion, suspended solids, and gross pollutants 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 24.18, Waste Management Plan); and
- monitor the water quality of the affected catchment, per the technical indicators contained in Section 24.6, Fish and Aquatic Effects Monitoring and Management Plan, as well as Section 24.13, Site Water Management Plan, 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.

Explosives Handling Plan and Control of Nutrient Loading

Project activities involving nitrogen-based explosives could result in loading of nitrogenous compounds into the aquatic environment.

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

Explosives transportation, storage, and use will be consistent with the requirements of the federal *Explosives Act* (1985a), *Transportation of Dangerous Goods Act* (1992), and the provincial *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008). A qualified and experienced local contracting company, with good performance history, will be used. The Explosives Handling Plan (Section 24.5), to be developed prior to Construction, will guide the safe transportation, storage, use, and disposal of explosives at the site throughout the life of the Project. Effects to water quality and aquatic resources from nutrients will be monitored and adaptively managed as outlined in the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6).

The effectiveness of the mitigation and management measures for nutrient loading is assessed to be **moderate** (Table 14.5-2). This is because, once mitigation and management measures are taken into consideration, water quality modelling predicts that nitrogen compounds will be present in the aquatic environment at concentrations greater than baseline levels (Surface Water Quality Effects Assessment, Chapter 13; Surface Water Quality Modelling Report, Appendix 13-C).

Sedimentation and Erosion Control Plan

The Sediment and Erosion Control Plan (Section 24.11) describes the guidelines that the Proponent will adhere to 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 and 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.

The extent of disturbance will be limited by design as much as practical. BMPs will be established for the installation, maintenance, and reclamation of temporary sediment and erosion control structures. Guidance documents for BMPs include the *Forest Road Engineering Guidebook* (BC MOF 2002) and the *Measures to Avoid Causing Harm to Fish and Fish Habitat* guidance from DFO (2013). Widening and upgrading the access roads will be conducted according to the *Forest Road Engineering Guidebook* and maintained to ensure low landslide risk and continuous, efficient, controlled water drainage (BC MOF 2002). Additional erosion and sediment control BMPs that may be implemented during road upgrades include:

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

Effluent discharge will be required to meet permit limits under the *Environmental Management Act* (Clark 2003), which are expected to include a limit for TSS that is protective of water quality and freshwater aquatic life.

The Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) describes the monitoring program that will assess the performance and provide information for the adaptive management of erosion and sedimentation control measures. The implementation of the erosion and sedimentation mitigation measures, combined with the monitoring and inspection programs, is predicted to have a **high** effectiveness at mitigating potential effects from erosion and sedimentation (Table 14.5-2). No residual effect from erosion and sedimentation is predicted because of the expected performance of the proposed mitigation measures and adaptive management of potential effects. The effect of erosion and sedimentation was therefore not considered further in the effects assessment.

Atmospheric Deposition

The primary mitigation and management measures that decrease the potential for effects on surface water due to dust deposition are fugitive dust reduction measures. Fugitive dust sources include use of vehicles on unpaved site roads and emissions from mining activities such as bulldozing, grading, stockpiling, drilling, and blasting. Mitigation measures are incorporated into the Project during the design stage. Additional detail can be found in the Air Quality Management Plan (Section 24.2), and mitigation may include the following:

- Erection of windbreaks around identified problem areas to limit the dust emissions from equipment and stockpiles, and other activities likely to generate dust
- reclaim and re-vegetate decommissioned areas as soon as practical;
- maintenance and watering of unpaved roads;
- adherence to designated speed limits;
- conditioning of materials that may generate dust prior to transfer;
- enclosure or covering of loads where possible;
- removal of dust deposits to prevent re-entrainment;
- dust suppression/collection system for the crushing facility;
- complete or partial enclosure of conveyors;
- minimizing discharge height and enclosure of discharge from crushers onto conveyors or other equipment to the extent practicable;
- use of dust curtains on blast hole drilling equipment and timing of blasting; and
- staff training.

Dust generation is most likely to occur during dry periods when roads or land is not covered by snow or ice. Dust deposition is predicted to be highest in areas immediately surrounding the Project (i.e., within the Project Site or near roads or other infrastructure), with fugitive dust deposition rates decreasing rapidly with distance from the source (Section 9.5.4). In addition, only some of the fugitive dust generated by the Project will be deposited on water. Given that mitigation measures would significantly reduce the amount of fugitive dust, the potential for a change in surface water quality due to dust deposition is considered to be negligible; mitigation measures are considered to have **high** effectiveness. Effects of dust deposition on surface water quality were, therefore, not considered further.

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 2012a);
    - *Fish Collection Methods and Standards* (RIC 1997);
    - *Environmental Code of Practice for Metal Mines* (Environment Canada 2012a);
    - *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 Selenium Management Plan is proposed as a follow-up program to proactively mitigate risks due to selenium in the aquatic environment. The objective of the Selenium Management Plan (Section 24.12) is to identify, characterize, and address potential environmental risks that selenium may pose to the receiving environment of the Project. The framework of the Selenium Management Plan 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 Selenium Management Plan is supported by four aspects: prediction, prevention, mitigation, and monitoring that together form an effective strategy to achieve environmental protection. Monitoring of water quality, sediment quality, and tissue residues in biota is included as part of the Selenium Management Plan. Potential risks due to selenium will be adaptively managed based on the results of the proposed monitoring plan to ensure that risks are mitigated before adverse effects occur in the receiving environment.

14.5.3 Predicted Residual Effects and Characterization

Project effects determined to not be fully mitigated, as discussed in Section 14.5.2, are determined to be residual effects (Table 14.5-2). Each residual effect on the fish, fish habitat, and aquatic resources VCs are analyzed to characterize the predicted effects of the Project on the VC, and ultimately to determine the significance of the effect. The analyses of residual effects, presented below for each VC, use a combination a qualitative and quantitative approaches that depend on the availability and suitability of data, modelling results, and scientific knowledge.

The residual effects of the Project on each VC are then characterized based on standard criteria (i.e., the magnitude, geographic extent, duration, frequency, reversibility, and resiliency). Standard ratings for these characterization criteria are provided in Chapter 8; however, Table 14.5-3 provides a summary of definitions for each characterization criterion specific to fish, fish habitat, and aquatic resources VCs. The likelihood of each residual effect is then assessed, and assigned one of the following ratings:

- High: effect has a greater than 80% chance of occurring;
- Moderate: the chance of the effect occurring is between 40 and 80%; and
- Low: the chance of the effect occurring is less than 40%.

14.5.3.1 Residual Effects on Fish and Fish Habitat Valued Components

Potential Project effects to fish and fish habitat were initially screened for direct mortality, changes to water quantity, and changes to water quality. Mitigation measures designed to inhibit direct mortality to fish were assessed to be highly effective; therefore, only changes to water quantity and quality will be considered for potential residual effects.

Changes in Water Quantity

Changes in water quantity have the potential to interact with the fish through effects on fish habitat. To avoid repetition in effects, the two VCs, Fish and Fish Habitat are assessed within this section and Section 14.5.3.2. This section describes the potential residual effects on fish and fish habitat due to changes in water quantity.

In support of the environmental assessment, quantitative surface water modelling was used to predict key effects on fish and fish habitat with respect to:

- Bull Trout in:
  - upper Harper Creek between P and T Creeks;
  - upper Harper Creek below T Creek to the 2-m waterfall at mainstem km 18.5;

Table 14.5-3. Definitions of Specific Characterization Criteria for Fish, Fish Habitat, and Aquatic Resources Valued Components

Timing*	Magnitude	Spatial 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 change in the VC is undetectable relative to natural variation, or is below an applicable guideline	**Discrete**: 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 VC or component has a high natural resilience to imposed stresses and disturbances, and can adapt to the effect and return to a pre-disturbance state.
Operations phases (Stages 1 and 2)	**Low**: the change in the VC is detectable and within the range of natural variation, or is within two times the applicable guideline and is below toxicity thresholds	**Local**: restricted to the local study area	**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 VC or component has a neutral resilience to imposed stresses and may be able to adapt and return to a pre-disturbance state.
Closure phase	**Medium**: the predicted change in the VC is beyond the range of natural variation (but within 30% of baseline concentrations), or is within five times the applicable guideline and is below toxicity thresholds	**Regional**: extends beyond the local study area but limited to the regional study area	**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 VC or component has a low resilience to imposed stresses, and will not easily adapt to the effect or will not return to a pre-disturbance state.
Post-Closure phase	**High**: the change is beyond the range of natural variation (i.e., greater than 30% of baseline values), is greater than five times the applicable guideline, or is greater than a toxicity threshold.	**Beyond regional**: extends beyond the regional study area	**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.*

  - 2-m waterfall at mainstem km 18.5 Harper Creek;
  - lower Harper Creek;
  - T Creek;
  - P Creek;
- Rainbow Trout in:
  - lower Harper Creek;
  - Baker Creek;
  - Jones Creek; and
- Juvenile Coho Salmon in:
  - lower Harper Creek.

Methodology for Screening Reaches of Potential Concern

The process used for screening reaches of potential concern was based upon a four-step process. The screening steps are outlined below.

The first step, involved using Knight Piésold's watershed model and Instream Flow Assessment (Appendix 14-D), which predicted changes in water quantity, with a monthly time-step, to estimate effects of the Project on annual and monthly streamflows. Details of the model, including input data, modelling assumptions, calibration, and results are available in Appendix 12-B, Watershed Modelling Report.

The second step, involved developing a Bull Trout, Rainbow Trout and Coho Salmon life history periodicity table specific to the Harper Creek watershed. Seasonal timing of habitat use describes when and where each species would be throughout an annual cycle. Key biological activities such as spawning, incubation, migration, rearing, and overwintering were defined for the Harper Creek reaches. The Bull Trout, Rainbow Trout and Coho Salmon life history timing and use of specific habitats was developed using project specific baseline data (Table 14.4-3). In addition, life history data was augmented from existing literature, such as government publications and peer-reviewed literature. Then critical life history stages were identified based upon peer reviewed literature. The development of a life history periodicity table allows for a comparative analysis of the timing and magnitude of predicted flows changes to specific life history requirements (Estes and Orsborn 1986).

The third step, involved applying an instream flow assessment using standard-setting methods. Standard-setting methods, are primarily office-based scoping exercises that make use of existing information to predict appropriate effects of instream flow changes (Hatfield et al. 2003). Often these standard-setting methods are explicitly conservative (i.e., biased in favour of environmental protection) to account for uncertainty in predicted effects (Hatfield et al. 2003). Standard-setting methods are typically the first tier of a two-tiered processes, which is common in many jurisdictions, including British Columbia (Kulik 1990; Hatfield et al. 2003). The following standard setting methods were applied to this instream flow assessment: BC Modified-Tennant Method and BC Instream Flow Threshold Method.The BC Modified-Tennant Method was developed by the BC MOE and is a modification of the original Tennant Method. It incorporates local biological and physical information and provides streamflow criteria for fish in the province (Table 14.5-4; Ptolemy and Lewis 2002). The timing window for each flow threshold is adjusted depending on the fish life history and ecological information for the stream. The fish life history periodicity table is used to compare predicted flows during specific time periods.

The BC Instream Flow Threshold Method for fish and fish habitat was designed to support a two-tiered review process for proposed water uses on BC streams (Hatfield et al. 2003). This method is the provincial standard. The first tier of the review is a screening level process that provides thresholds for alterations to natural stream flows that are expected to result in risks to fish, fish habitat, and productive capacity. These thresholds are meant to act as a "coarse filter" during the review of proposed water uses on BC streams. The flow threshold for fish-bearing streams is a seasonally-adjusted threshold for alterations to natural stream flows. The thresholds are calculated as percentiles of natural mean daily flows for each calendar month. These percentiles vary through the year on a sliding scale from 20% (during the month of highest median flow) to 90% (during the month of lowest median flow). The environmental risk of this method is thought to be low, simply because the thresholds employed by the method are relatively conservative (Hatfield et al. 2003).

The fourth step, involves a comparison of predicted flows throughout mine life to the standard setting flow thresholds. Flows that do not meet the flow threshold have the potential to negatively affect fish and their habitats and are evaluated further in Section 14.5.3.2. The magnitude (% change) to fish habitat was estimated in one of two ways.

1. If the BC Modified-Tennant threshold was met for pre-mine discharge, the % change was calculated as the difference between threshold value and the maximum reduction in discharge during mine-life.
2. If pre-mine discharge was less than the BC Modified-Tennant threshold, the % change was calculated as the difference between pre-mine and the maximum reduction in discharge during mine life.

Upper Harper Creek - Between P and T Creeks

For the screening assessment of this reach, Node 8 (Harper Creek Below P Creek Confluence) was used. The predicted mean monthly flow changes at Node 8 are presented in Table 14.5-5 for all stages of mine development. The results indicate that, on average, flow during Operations, Closure, and Post-Closure periods will be reduced by 27 to 29% of pre-mine flow. The greatest flow reductions are predicted to occur during February and June, when flow is reduced by 35 to 41% from pre-mine respectively. A comparison of monthly predicted flow changes indicates that reductions would occur during all Bull Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-1) show that the flow threshold was achieved for only 6% of mine life (Construction to Post-Closure). However, a more detailed examination of the Bull Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method results (Table 14.5-4; Figure 14.5-1). This shows that the flow threshold was achieved for adult resident Bull Trout summer rearing habitat during May, June, and July. During August, September, and October, the predicted pre-mine and mine-life flow supply was less than threshold requirements, which indicates a sensitive summer low flow period for reductions. Bull Trout egg incubation threshold was achieved during October and November. During December to March, the pre-mine flow supply is less than threshold requirements for overwintering and egg incubation, which indicates a sensitive winter low flow period for reductions. Juvenile Bull Trout rearing habitat threshold was achieved during all months from April to October.

Table 14.5-4. Summary of British Columbia Modified-Tennant Recommended Flows to Satisfy Biological and Physical Needs in British Columbia Streams

Biological or Physical Requirement	% Mean Annual Discharge	Duration per Annum
Biological		
Juvenile Summer to Fall Rearing	20	Months
Adult Summer to Fall Rearing	>55	Months
Overwintering	20	Months
Spawning	$1.56 \cdot MAD^{0.63}$	Weeks
Egg Incubation	20	Months
Physical		
Short-Term Maintenance	10	Days to Weeks
Channel Maintenance	>400	Days to Weeks
Wetland Linkage	100	Weeks

The adult Bull Trout spawning threshold was calculated for Node 8. This threshold provided an unrealistic threshold of 0.72 m^3/s, which is greater than three times the pre-mine discharge during spawning season in August to October. Because spawning is known to occur in this reach, egg incubation habitat was used as a surrogate for spawning habitat during August to October. As a result, adult Bull Trout spawning habitat threshold was achieved throughout the spawning season.

The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicate that the threshold conditions were achieved through mine Operations.

The results of the instream flow screening process indicated that Bull Trout and egg incubation requirements may be affected in upper Harper Creek (between P and T creeks). The effects of flow reductions on Bull Trout production will be evaluated further in Section 14.5.3.2.

Upper Harper Creek - Below T Creek to the 2-m Waterfall at Mainstem Km 18.5

For the screening assessment of this reach, Node 9 (Harper Creek Below T -Creek Confluence) was used in addition to the two-dimensional River2D habitat modelling reported in the Instream Flow Assessment for 260 m of upper Harper Creek below T Creek (Appendix 14-D). Node 9 was selected because flow changes would be attenuated further downstream at the Harper Creek falls, Bull Trout and their respective spawning and rearing habitats are present at Node 9 and throughout the reach, and the greatest degree of change would occur at Node 9. The predicted mean monthly flow changes at Node 9 are presented in Table 14.5-6 for all stages of mine development. The results indicate that, on average, flow will be reduced by 23 to 25% during the Operations phases, but will increase up to 9%

during Post-Closure. Reductions in flow are greatest in the summer months from May to July , and predicted to be reduced by up to 41% during Operations. Flows are predicted to increase during the winter months of mine Closure and Post-Closure. A comparison of monthly predicted flow changes indicates that reductions would occur during all Bull Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-2) show that the flow threshold was achieved, that is predicted reductions did not fall below the threshold for 40% of mine life (Construction to Post-Closure). Flow reductions were predicted to be minimized during Post-Closure, when thresholds were achieved for 75% of the time. However, a more detailed examination of the Bull Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method. Results showed that the flow threshold was achieved for adult resident Bull Trout summer rearing habitat from May to July in all phases and in August for Closure and Post-Closure (Figure 14.5-2). During September and October, the predicted pre-mine and mine life flow supply is less than threshold requirements, which indicates a sensitive summer low flow period for reductions. Bull Trout egg incubation threshold was achieved during October, November, and very nearly for December for all mine phases. Egg incubation thresholds were not met from January through March during the Operations and Closure phases; however, predicted pre-mine and mine life flows were similar across these months for all mine phases. Egg incubation thresholds were predicted to be met in Post-Closure. Bull Trout overwintering threshold was achieved during November and December, but not the remaining months from January to March, but again, predicted flows were similar to pre-mine conditions during this period. Juvenile Bull Trout rearing habitat threshold was achieved during all months from April to October.

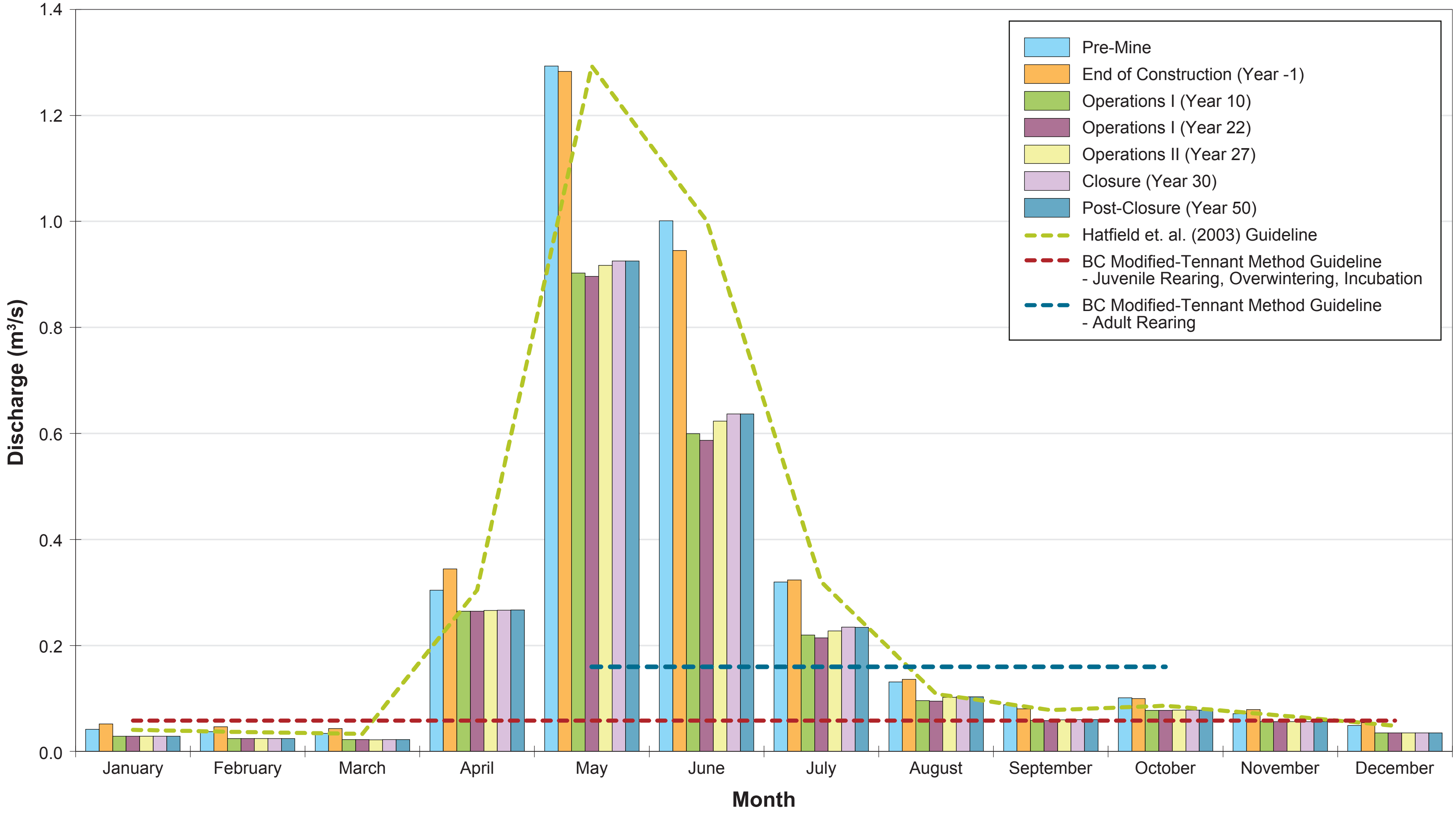
The adult Bull Trout spawning threshold was calculated for Node 9. This threshold provided an unrealistic threshold of 2.08 m^3/s, which was much greater than the pre-mine discharge during the spawning season of August to October. Therefore, egg incubation habitat was used as a surrogate for spawning habitat during August to October. As a result, adult Bull Trout spawning habitat threshold was achieved during all spawning months.

The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicated that the threshold conditions were achieved through mine Operations.

The results of the instream flow screening process indicated the predicted flow during periods sensitive to Bull Trout life history and habitat requirements will be similar to pre-mine conditions. In addition, the two-dimensional River2D habitat modelling confirmed that WUA for fish habitat (fry, juvenile rearing and spawning) would remain near pre-mine conditions (Figures 4.4-3 to 4.4-5 in Appendix 14-D). Bull Trout productivity is likely to be similar to pre-mine conditions and unaffected in Harper Creek (Between T Creek and the Harper Creek Falls). The effects of flow reductions on fish production and fish habitat will not be evaluated further.

Figure 14.5-1

Comparison of Standard Setting Instream Flow Thresholds at Node 8 (Harper Creek Below P Creek Confluence) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Bull Trout life stage.

Source: Knight Piésold Consulting (2014).

Table 14.5-5. Predicted Mean Monthly Flows at Node 8 (Harper Creek Below P-Creek Confluence) during Different Phases of the Project

Mine Stage		Units	Mean Monthly Discharge												Average Annual
Year	Description		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.04	0.04	0.03	0.30	1.29	1.00	0.32	0.13	0.09	0.10	0.07	0.05	0.29
		%MAD	14%	13%	12%	105%	445%	345%	110%	45%	30%	35%	24%	17%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	End of Construction	m^3/s	0.05	0.05	0.04	0.34	1.28	0.95	0.32	0.14	0.08	0.10	0.08	0.05	0.29
		% Pre-Mine MAD	18%	16%	15%	119%	442%	325%	111%	47%	28%	34%	27%	19%	98%
		%Pre-Mine	125%	126%	127%	113%	99%	94%	101%	103%	91%	99%	111%	111%	108%
10	Operations I	m^3/s	0.03	0.02	0.02	0.26	0.90	0.60	0.22	0.10	0.06	0.08	0.06	0.03	0.20
		% Pre-Mine MAD	10%	8%	8%	91%	311%	206%	76%	33%	20%	27%	19%	12%	69%
		%Pre-Mine	69%	65%	66%	87%	70%	60%	69%	73%	66%	77%	79%	71%	71%
22	Operations I	m^3/s	0.03	0.02	0.02	0.26	0.90	0.59	0.21	0.09	0.06	0.08	0.06	0.03	0.20
		% Pre-Mine MAD	10%	8%	8%	91%	309%	202%	74%	33%	20%	27%	19%	12%	68%
		%Pre-Mine	69%	65%	66%	87%	69%	59%	67%	72%	66%	77%	79%	71%	71%
27	Operations II	m^3/s	0.03	0.02	0.02	0.27	0.92	0.62	0.23	0.10	0.06	0.08	0.06	0.03	0.20
		% Pre-Mine MAD	10%	8%	7%	92%	316%	215%	78%	35%	21%	27%	19%	12%	70%
		%Pre-Mine	69%	65%	64%	87%	71%	62%	71%	78%	68%	77%	79%	71%	72%
30	Closure	m^3/s	0.03	0.02	0.02	0.27	0.93	0.64	0.23	0.10	0.06	0.08	0.06	0.03	0.21
		% Pre-Mine MAD	10%	8%	8%	92%	319%	219%	81%	36%	21%	27%	19%	12%	71%
		%Pre-Mine	69%	65%	66%	88%	72%	64%	73%	79%	68%	77%	79%	71%	73%
50	Post-Closure	m^3/s	0.03	0.02	0.02	0.27	0.93	0.64	0.23	0.10	0.06	0.08	0.06	0.03	0.21
		% Pre-Mine MAD	10%	8%	8%	92%	319%	219%	81%	35%	21%	27%	19%	12%	71%
		%Pre-Mine	69%	65%	66%	88%	72%	64%	73%	78%	68%	77%	79%	71%	73%

MAD = mean annual discharge

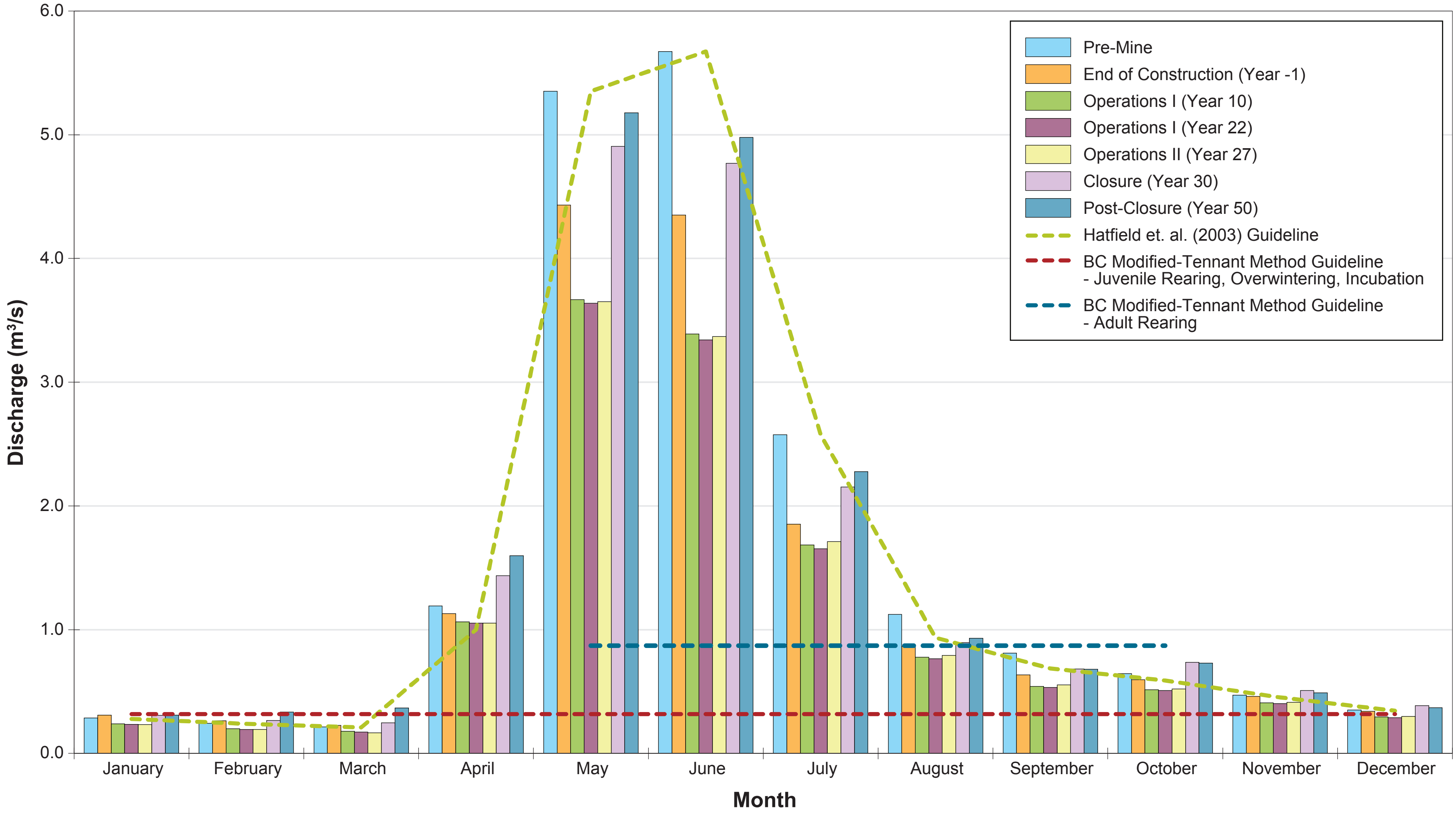
Table 14.5-6. Predicted Mean Monthly Flows at Node 9 (Harper Creek Below T-Creek Confluence) during Different Phases of the Project

Mine Stage			Mean Monthly Discharge												Average Annual
Year	Description	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.29	0.24	0.21	1.19	5.35	5.67	2.58	1.12	0.81	0.65	0.47	0.35	1.58
		%MAD	18%	15%	13%	75%	338%	358%	163%	71%	51%	41%	30%	22%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
`	End of Construction	m^3/s	0.31	0.26	0.23	1.13	4.43	4.35	1.85	0.87	0.63	0.60	0.46	0.34	1.29
		% Pre-Mine MAD	20%	17%	14%	71%	280%	275%	117%	55%	40%	38%	29%	21%	82%
		%Pre-Mine	108%	109%	106%	95%	83%	77%	72%	77%	78%	92%	98%	97%	91%
10	Operations I	m^3/s	0.24	0.20	0.18	1.06	3.67	3.39	1.68	0.78	0.54	0.52	0.41	0.29	1.08
		% Pre-Mine MAD	15%	13%	11%	67%	232%	214%	106%	49%	34%	33%	26%	19%	68%
		%Pre-Mine	84%	82%	83%	89%	69%	60%	65%	69%	67%	80%	87%	84%	77%
22	Operations I	m^3/s	0.23	0.19	0.17	1.05	3.64	3.34	1.65	0.76	0.53	0.51	0.40	0.29	1.07
		% Pre-Mine MAD	15%	12%	11%	67%	230%	211%	105%	48%	34%	32%	25%	18%	68%
		%Pre-Mine	82%	80%	81%	88%	68%	59%	64%	68%	66%	79%	85%	82%	75%
27	Operations II	m^3/s	0.23	0.19	0.17	1.05	3.65	3.37	1.71	0.79	0.55	0.52	0.41	0.30	1.08
		% Pre-Mine MAD	15%	12%	11%	67%	231%	213%	108%	50%	35%	33%	26%	19%	68%
		%Pre-Mine	82%	80%	78%	88%	68%	59%	67%	70%	68%	81%	88%	85%	76%
30	Closure	m^3/s	0.31	0.27	0.25	1.44	4.91	4.77	2.15	0.90	0.68	0.74	0.51	0.39	1.45
		% Pre-Mine MAD	19%	17%	16%	91%	310%	301%	136%	57%	43%	46%	32%	24%	91%
		%Pre-Mine	107%	109%	115%	121%	92%	84%	84%	80%	84%	114%	108%	110%	101%
50	Post-Closure	m^3/s	0.31	0.33	0.37	1.60	5.18	4.98	2.28	0.93	0.68	0.73	0.49	0.37	1.52
		% Pre-Mine MAD	20%	21%	23%	101%	327%	315%	144%	59%	43%	46%	31%	23%	96%
		%Pre-Mine	108%	137%	173%	134%	97%	88%	88%	83%	84%	113%	104%	105%	109%

MAD = mean annual discharge

Figure 14.5-2

Comparison of Standard Setting Instream Flow Thresholds at Node 9 (Harper Creek Below T Creek Confluence) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Bull Trout life stage.

Source: Knight Piésold Consulting (2014).

The results of the instream flow screening process indicated the predicted flow over the 2-m waterfall during the period of adult migration will be reduced. However, the 2-m waterfall appears to limit ascension to periods of lower flow and thus, larger adfluvial Bull Trout may continue to ascend the falls throughout the mine life. This assertion is based on professional judgment and, due to the absence of established threshold limits and lack of site specific data on Bull Trout passage, it is recommended that an instream flow study coupled with a Bull Trout migration monitoring program be implemented to identify if further mitigation through fish offsetting be required as a result of reduced flow over the waterfall.

Lower Harper Creek

For the screening assessment of this reach, Node 1 (Harper Creek at the mouth) was used. Node 1 is the only hydrology station located in this reach for which flow was assumed to be representative of the reach, and Bull Trout and their respective spawning and rearing habitats are present throughout the reach. In addition, Rainbow Trout and juvenile Coho Salmon are present within the lower portions of this reach.

The predicted mean monthly flow changes at Node 1 are presented in Table 14.5-7 for all stages of mine development. The results indicated that flow will be reduced, on average, up to 13% during the Construction and Operations phases. Average yearly flow reductions will be less during Closure (reduced by 5%) with no predicted change Post-Closure. A comparison of monthly predicted flow changes indicated that reductions would occur during all Bull Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-3) show that the flow threshold was achieved, that is predicted reductions did not fall below the threshold, for 70% of mine life (Construction to Post-Closure). However, a more detailed examination of the Bull Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method (Figure 14.5-3). Results showed that the summer rearing flow threshold was achieved for adults of all species during May through August. During the month of October, the predicted pre-mine and mine life flow supply was less than threshold requirements, which indicated a sensitive summer low flow period for reductions. Rainbow Trout egg incubation was above threshold for all months, May through July. Bull Trout and Coho Salmon egg incubation threshold was achieved during October through December, but was slightly below threshold for the remaining months from December to March. During these months, flow is predicted to be reduced by less than 9% of pre-mine conditions. Similar to pre-mine conditions, overwintering threshold for all species was achieved during November and December, but slightly under for the remaining months. Juvenile rearing habitat threshold was achieved during all months: April to October for Bull Trout and Coho Salmon, July to October for Rainbow Trout.

The adult Bull Trout and Rainbow Trout spawning threshold was calculated for Node 1 as 3.74 m^3/s. For Rainbow Trout, this threshold was achieved during the spawning period of April and May for all mine phases. However, for Bull Trout (known to spawn in this reach) and Coho Salmon the threshold value was nearly double pre-mine flow conditions during the spawning period of August to October. Therefore, for Bull Trout and Coho Salmon, egg incubation habitat was used as a surrogate for spawning habitat. As a result, adult Bull Trout and Coho Salmon spawning habitat threshold was achieved during all spawning months.

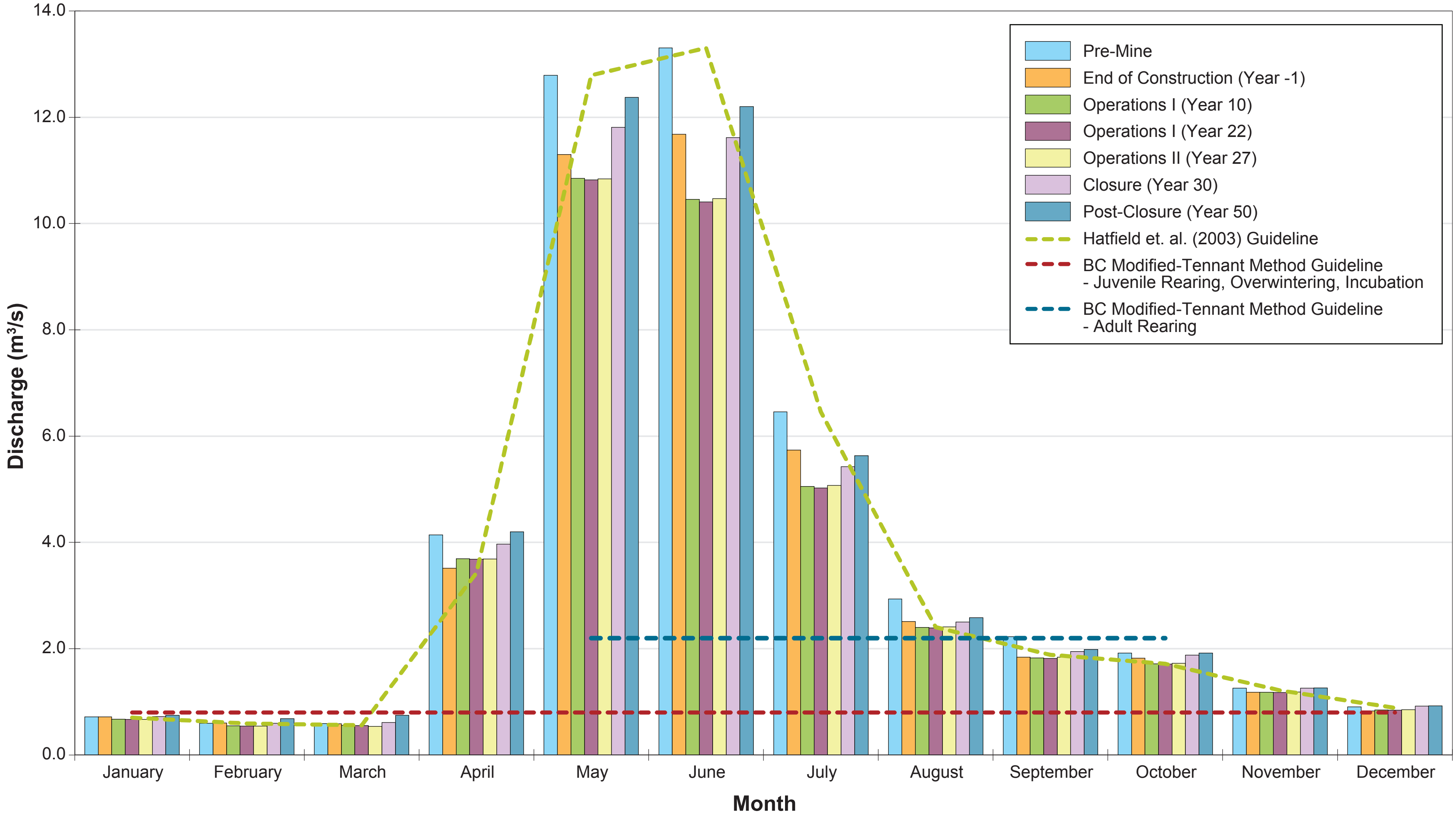
Table 14.5-7. Predicted Mean Monthly Flows at Node 1 (Harper Creek at the WSC 08LB076 Station) during Different Phases of the Project

Mine Stage		Units	Mean Monthly Discharge												Average Annual
Year	Description		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.72	0.60	0.59	4.14	12.79	13.31	6.46	2.94	2.23	1.92	1.26	0.90	4.00
		%MAD	18%	15%	15%	104%	320%	333%	161%	73%	56%	48%	31%	23%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	End of Construction	m^3/s	0.72	0.60	0.59	3.52	11.30	11.68	5.74	2.51	1.84	1.82	1.18	0.83	3.54
		% Pre-Mine MAD	18%	15%	15%	88%	283%	292%	143%	63%	46%	46%	29%	21%	88%
		%Pre-Mine	100%	101%	100%	85%	88%	88%	89%	86%	83%	95%	94%	92%	92%
10	Operations I	m^3/s	0.67	0.55	0.56	3.69	10.85	10.46	5.05	2.40	1.83	1.71	1.18	0.85	3.33
		% Pre-Mine MAD	17%	14%	14%	92%	271%	262%	126%	60%	46%	43%	30%	21%	83%
		%Pre-Mine	94%	92%	95%	89%	85%	79%	78%	82%	82%	90%	94%	94%	88%
22	Operations I	m^3/s	0.67	0.54	0.55	3.68	10.82	10.41	5.02	2.39	1.82	1.71	1.18	0.84	3.31
		% Pre-Mine MAD	17%	14%	14%	92%	271%	260%	126%	60%	45%	43%	29%	21%	83%
		%Pre-Mine	93%	91%	94%	89%	85%	78%	78%	81%	82%	89%	94%	93%	87%
27	Operations II	m^3/s	0.67	0.54	0.54	3.69	10.84	10.47	5.07	2.41	1.84	1.72	1.19	0.85	3.33
		% Pre-Mine MAD	17%	14%	13%	92%	271%	262%	127%	60%	46%	43%	30%	21%	83%
		%Pre-Mine	93%	91%	91%	89%	85%	79%	79%	82%	83%	90%	94%	94%	87%
30	Closure	m^3/s	0.72	0.60	0.61	3.97	11.81	11.62	5.43	2.50	1.95	1.88	1.26	0.92	3.62
		% Pre-Mine MAD	18%	15%	15%	99%	295%	291%	136%	63%	49%	47%	31%	23%	90%
		%Pre-Mine	101%	100%	103%	96%	92%	87%	84%	85%	87%	98%	100%	102%	95%
50	Post-Closure	m^3/s	0.74	0.68	0.75	4.20	12.38	12.20	5.63	2.59	1.98	1.92	1.26	0.92	3.78
		% Pre-Mine MAD	19%	17%	19%	105%	310%	305%	141%	65%	50%	48%	32%	23%	95%
		%Pre-Mine	104%	114%	127%	101%	97%	92%	87%	88%	89%	100%	100%	102%	100%

MAD = mean annual discharge

Figure 14.5-3

Comparison of Standard Setting Instream Flow Thresholds at Node 1 (Lower Harper Creek at the mouth) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Bull Trout life stage.

Source: Knight Piésold Consulting (2014).

The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicated that the threshold conditions were achieved through mine Operations.

The results of the instream flow screening process indicated that the predicted flows required to sustain Bull Trout, Rainbow Trout and Coho Salmon life history, productivity and habitat were similar to pre-mine conditions, especially during sensitive low flow summer (October) and winter months (December to March). These species are unlikely to be affected by flow alteration in lower Harper Creek (downstream of Harper Creek falls). The effects of flow reductions on fish production and fish habitat in this reach will not be evaluated further.

T Creek

For the screening assessment of the 336 m^2 fish-bearing section of this tributary, Node 3 (T Creek at Harper Creek Confluence) was used in addition to the one-dimensional Physical Habitat Simulation (PHABSIM) modelling reported in the Instream Flow Assessment (Appendix 14-D). The predicted mean monthly flow changes at Node 3 are presented in Table 14.5-8 for all stages of mine development. The results indicate that flow will be reduced by 100% (flow ceases) from December to March during mine Construction and Operations. Discharge is predicted to increase considerably over pre-mine values in Closure and Post-Closure. A comparison of monthly predicted flow changes indicates that reductions during this time would occur during all Bull Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-4) showed that the minimum flow threshold was achieved for 32% of mine life only during Closure and Post-Closure phases. However, a more detailed examination of the Bull Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method (Table 14.5-4; Figure 14.5-1). Results show that predicted flows are below threshold for all stages of Bull Trout over most months during the Construction and Operations phases. Pre-mine flow during November to March is also less than threshold requirements for egg incubation, juvenile rearing, and overwintering, indicating a sensitive period for flow reductions. The Closure and Post-Closure phases are predicted to result in a return of flows above threshold values for all life stages from April to July, with the exception of adult rearing in August through October. Egg incubation thresholds were not achieved from September to March during the Construction and Operation phases. Egg incubation thresholds were predicted to be met in Closure and Post-Closure for the months of September and October and in Post-Closure for February.

The adult Bull Trout spawning threshold was calculated for Node 3. This threshold provided an unrealistic threshold of 1.03 m^3/s, which was much greater than the pre-mine discharge during the spawning season of August to October. Therefore, egg incubation habitat was used as a surrogate for spawning habitat during August to October. Adult Bull Trout spawning habitat threshold was not achieved from August to October for Construction and Operations phases, but returned to near Pre-Mine values and above threshold guidelines in Closure and Post-Closure phases. The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicate that the threshold conditions were not achieved under operational conditions.

The results of the instream flow screening process indicate that Bull Trout life history requirements and productivity will likely be affected in T Creek during the Construction and all Operations phases. The instream flow assessment using PHABSIM presented in Appendix 14-D corroborates this conclusion. Habitat modeling predicts that Weighted Usable Area (WUA) for Bull Trout fry and juvenile rearing will decrease by up to 64% across most mine phases and reductions to spawning habitat may total 83% during mine life. The effects of flow reductions on Bull Trout production will be evaluated further in Section 14.5.3.2.

P Creek

For the screening assessment of the 469 m^2 fish bearing section of this tributary, Node 5 (P Creek at Harper Creek Confluence) was used in addition to the one-dimensional PHABSIM modelling reported in the Instream Flow Assessment (Appendix 14-D). The predicted mean monthly flow changes at Node 5 are presented in Table 14.5-9 for all stages of mine development. The results indicate that, on average, yearly flow will be reduced by 13% during mine construction, and flows are predicted to be reduced by 54-59% of pre-mine across all months during Operations, Closure, and Post-Closure. A comparison of monthly predicted flow changes indicates that reductions would occur during all Bull Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-5) show that the minimum flow threshold was achieved for only 13% of mine life (Construction to Post-Closure). However, a more detailed examination of the Bull Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method (Figure 14.5-5). Results predicted that flows will be below threshold for adult Bull Trout summer rearing from July to October for the mine life. During August to October, the predicted pre-mine and mine life discharge was less than threshold requirements, which indicates a sensitive period for flow reductions. During these months, there is a 55% (during Construction) to 90% (Operations I) reduction from pre-mine discharge. During the months from November to March, the pre-mine flow supply is below threshold requirements, which may indicate a sensitive winter period for flow reductions. Juvenile Bull Trout overwintering threshold was not achieved from December to March during all phases and was reduced by 41% (during Construction) to 98% (during Closure and Post-Closure) from pre-mine levels. Juvenile Bull Trout rearing habitat threshold was achieved between June to August during Construction, but fell below threshold from August to October for the Operations, Closure, and Post-Closure phases. Pre-mine discharge was above threshold for the entire juvenile summer rearing period. Spawning habitat was not found during pre-mine habitat assessments of the fish-bearing portion of P Creek, thus no assessment of Bull Trout spawning or egg incubation was warranted.

The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicate that the threshold conditions were not achieved under operational conditions.

Table 14.5-8. Predicted Mean Monthly Flows at Node 3 (T-Creek at Harper Creek Confluence) during Different Phases of the Project

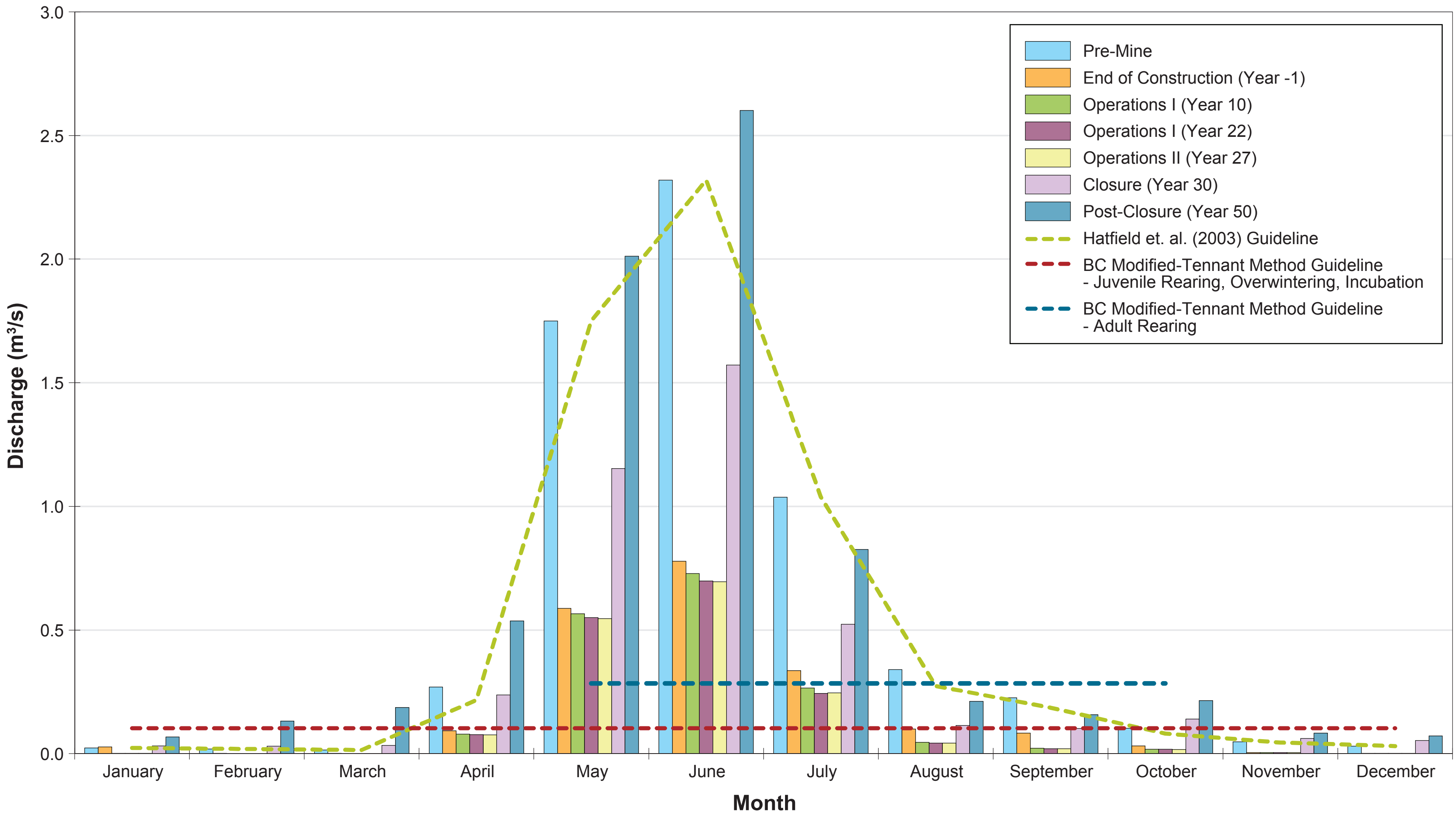
Mine Stage			Mean Monthly Discharge												Average Annual
Year	Description	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.02	0.02	0.01	0.27	1.75	2.32	1.04	0.34	0.23	0.10	0.05	0.03	0.52
		%MAD	5%	4%	3%	52%	339%	449%	201%	66%	44%	20%	9%	6%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	End of Construction	m^3/s	0.03	0.00	0.00	0.09	0.59	0.78	0.34	0.10	0.08	0.03	0.00	0.00	0.17
		% Pre-Mine MAD	5%	0%	0%	18%	114%	151%	65%	19%	16%	6%	1%	0%	33%
		%Pre-Mine	116%	9%	3%	34%	34%	34%	32%	29%	37%	31%	9%	0%	31%
10	Operations I	m^3/s	0.00	0.00	0.00	0.08	0.57	0.73	0.27	0.05	0.02	0.02	0.00	0.00	0.14
		% Pre-Mine MAD	0%	0%	0%	15%	110%	141%	51%	9%	4%	4%	1%	0%	28%
		%Pre-Mine	0%	0%	0%	29%	32%	31%	26%	14%	10%	18%	9%	0%	14%
22	Operations I	m^3/s	0.00	0.00	0.00	0.08	0.55	0.70	0.24	0.04	0.02	0.02	0.00	0.00	0.14
		% Pre-Mine MAD	0%	0%	0%	15%	106%	135%	47%	8%	4%	3%	1%	0%	27%
		%Pre-Mine	0%	0%	0%	29%	31%	30%	24%	12%	9%	17%	9%	0%	13%
27	Operations II	m^3/s	0.00	0.00	0.00	0.08	0.55	0.70	0.25	0.04	0.02	0.02	0.00	0.00	0.14
		% Pre-Mine MAD	0%	0%	0%	15%	106%	135%	48%	8%	4%	3%	1%	0%	27%
		%Pre-Mine	0%	0%	0%	28%	31%	30%	24%	13%	9%	16%	9%	0%	13%
30	Closure	m^3/s	0.03	0.03	0.03	0.24	1.15	1.57	0.52	0.11	0.10	0.14	0.06	0.05	0.34
		% Pre-Mine MAD	6%	6%	6%	46%	223%	304%	101%	22%	20%	27%	12%	10%	65%
		%Pre-Mine	135%	163%	224%	88%	66%	68%	51%	34%	45%	136%	129%	173%	109%
50	Post-Closure	m^3/s	0.07	0.13	0.19	0.54	2.01	2.60	0.83	0.21	0.16	0.21	0.08	0.07	0.59
		% Pre-Mine MAD	13%	26%	36%	104%	389%	503%	160%	41%	31%	42%	16%	14%	115%
		%Pre-Mine	286%	696%	1258%	199%	115%	112%	80%	62%	70%	208%	173%	234%	291%

note: ** discharge for December in Operations II shows a very slight increase from 0.0003 to 0.003 m3/s, but results in large percentage increase.*

MAD = mean annual discharge

Figure 14.5-4

Comparison of Standard Setting Instream Flow Thresholds at Node 3 (T Creek at Harper Creek Confluence) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Bull Trout life stage.
Mean monthly discharge from watershed model results for 1974-2000, and 2003-2010.

Source: Knight Piésold Consulting (2014).

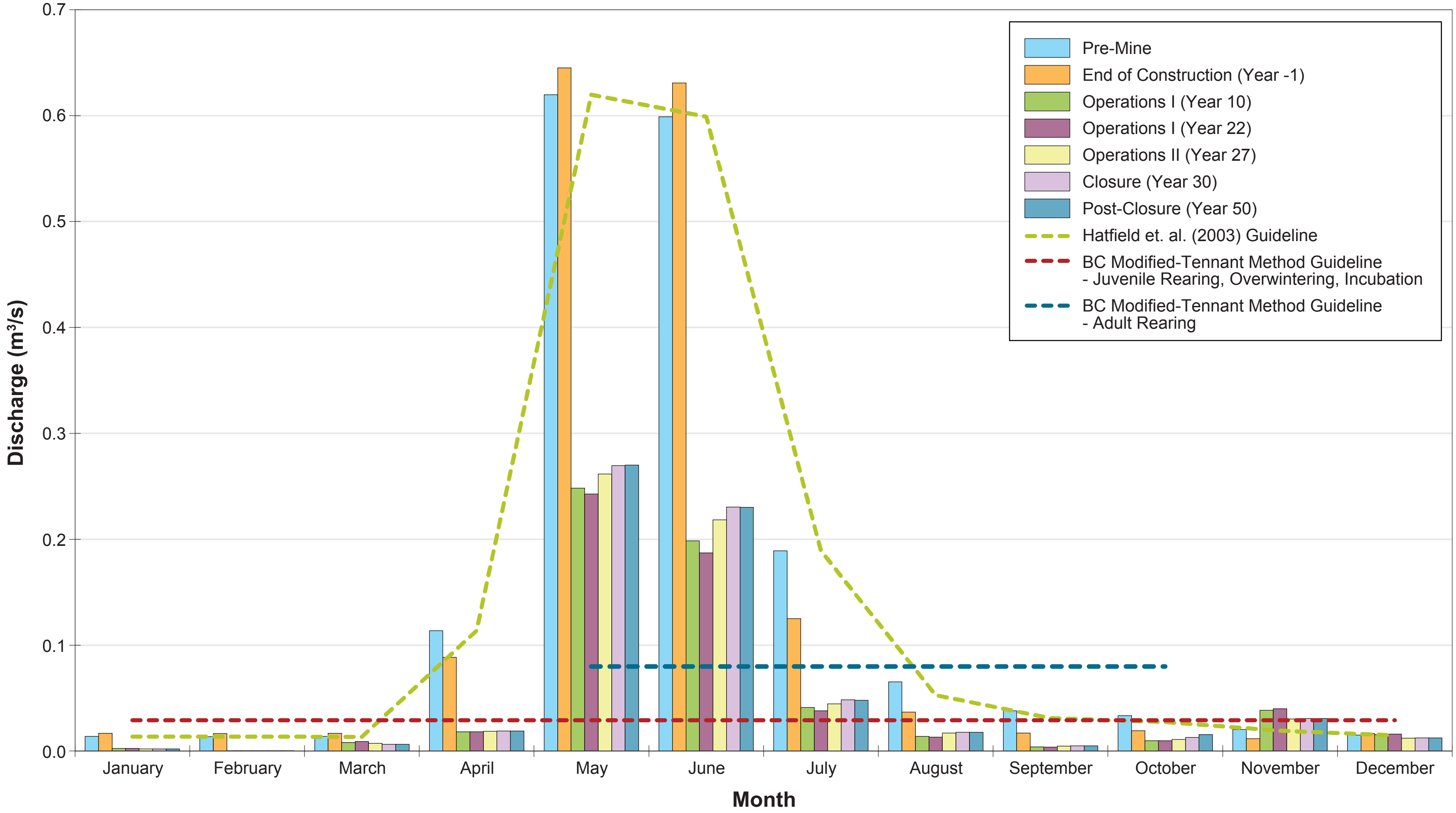
Table 14.5-9. Predicted Mean Monthly Flows at Node 5 (P-Creek at Harper Creek Confluence) during Different Phases of the Project

Mine Stage			Mean Monthly Discharge												Average Annual
Year	Description	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.01	0.01	0.01	0.11	0.62	0.60	0.19	0.07	0.04	0.03	0.02	0.02	0.15
		%MAD	10%	9%	10%	78%	427%	413%	130%	45%	26%	23%	14%	10%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	End of Construction	m^3/s	0.02	0.02	0.02	0.09	0.65	0.63	0.12	0.04	0.02	0.02	0.01	0.02	0.14
		% Pre-Mine MAD	12%	11%	12%	61%	445%	435%	86%	25%	12%	13%	8%	11%	95%
		%Pre-Mine	121%	121%	121%	78%	104%	105%	66%	56%	45%	58%	57%	109%	87%
10	Operations I	m^3/s	0.00	0.00	0.01	0.02	0.25	0.20	0.04	0.01	0.00	0.01	0.04	0.02	0.05
		% Pre-Mine MAD	2%	0%	6%	13%	171%	137%	28%	9%	3%	7%	27%	11%	35%
		%Pre-Mine	17%	3%	59%	16%	40%	33%	22%	21%	10%	29%	188%	102%	45%
22	Operations I	m^3/s	0.00	0.00	0.01	0.02	0.24	0.19	0.04	0.01	0.00	0.01	0.04	0.02	0.05
		% Pre-Mine MAD	2%	0%	6%	13%	167%	129%	26%	9%	3%	7%	27%	11%	34%
		%Pre-Mine	19%	3%	65%	16%	39%	31%	20%	20%	10%	29%	195%	106%	46%
27	Operations II	m^3/s	0.00	0.00	0.01	0.02	0.26	0.22	0.04	0.02	0.00	0.01	0.03	0.01	0.05
		% Pre-Mine MAD	1%	0%	5%	13%	180%	150%	31%	12%	3%	8%	21%	8%	36%
		%Pre-Mine	15%	3%	53%	16%	42%	36%	24%	26%	12%	33%	149%	81%	41%
30	Closure	m^3/s	0.00	0.00	0.01	0.02	0.27	0.23	0.05	0.02	0.00	0.01	0.03	0.01	0.05
		% Pre-Mine MAD	1%	0%	4%	13%	186%	159%	33%	12%	3%	9%	21%	9%	38%
		%Pre-Mine	14%	2%	47%	17%	44%	38%	26%	27%	13%	38%	150%	82%	41%
50	Post-Closure	m^3/s	0.00	0.00	0.01	0.02	0.27	0.23	0.05	0.02	0.00	0.02	0.03	0.01	0.05
		% Pre-Mine MAD	1%	0%	4%	13%	186%	159%	33%	12%	3%	11%	21%	9%	38%
		%Pre-Mine	14%	2%	47%	17%	44%	38%	25%	27%	13%	47%	151%	82%	42%

MAD = mean annual discharge

Figure 14.5-5

Comparison of Standard Setting Instream Flow Thresholds at Node 5 (P Creek at Harper Creek Confluence) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Bull Trout life stage.

Source: Knight Piésold Consulting (2014).

The results of the instream flow screening process indicate that Bull Trout life history requirements and productivity will be affected in P Creek. The instream flow assessment using PHABSIM presented in Appendix 14-D corroborates this conclusion. Habitat modeling predicts that WUA for Bull Trout fry and juvenile rearing will increase in early summer, but decrease by up to 88% in later months across most mine phases. The effects of flow reductions on fish and fish habitat will be evaluated further in Section 14.5.3.2.

Baker Creek

For the screening assessment of this tributary, Node 7 (Baker Creek at North Thompson River Confluence) was used to examine potential effects on Rainbow Trout. Rainbow Trout were the principal species using this tributary; over three years of sampling (4,551 s electrofishing), one Bull Trout and one Coho Salmon were captured along with 77 Rainbow Trout. The predicted mean monthly flow changes at Node 7 are presented in Table 14.5-10 for all stages of mine development. The results indicate that flow will be reduced by, on average, 30% during Construction and 4 to 10% during Operations, Closure, and Post-Closure. A comparison of monthly predicted flow changes indicates that reductions would occur during all Rainbow Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-6) show that the minimum flow threshold was achieved for 60% of mine life (Construction to Post-Closure). However, a more detailed examination of the Rainbow Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method (Figure 14.5-6). Predicted flows are below threshold for adult Rainbow Trout summer rearing from August to October during most phases. In addition, during September and October, both the predicted pre-mine and mine life flow supply is less than threshold requirements, which indicates a sensitive period for flow reductions for adult rearing. During December to February, the pre-mine flow supply is below the threshold requirements for juvenile overwintering, which may indicate a sensitive winter period for flow reductions. Juvenile Rainbow Trout overwintering threshold was also not achieved from December to February during all mine phases, but the discharge rate was very similar between pre-mine and mine-life predictions. Juvenile Rainbow Trout incubation and rearing habitat threshold was achieved from May to August for all phases, but fell slightly below threshold in September. However, during this one month period for egg incubation and juvenile rearing, predicted discharge was 80 to 90% of the BC Modified Tenant Guideline value of 0.04 m^3/s.

The adult Rainbow Trout spawning threshold was calculated for Node 7, providing a threshold of 0.58 m^3/s. The Rainbow Trout spawning habitat threshold during spawn in May and July was predicted to be within 6.5% of the threshold throughout the life of mine.

The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicate that the threshold conditions were achieved through mine Operations.

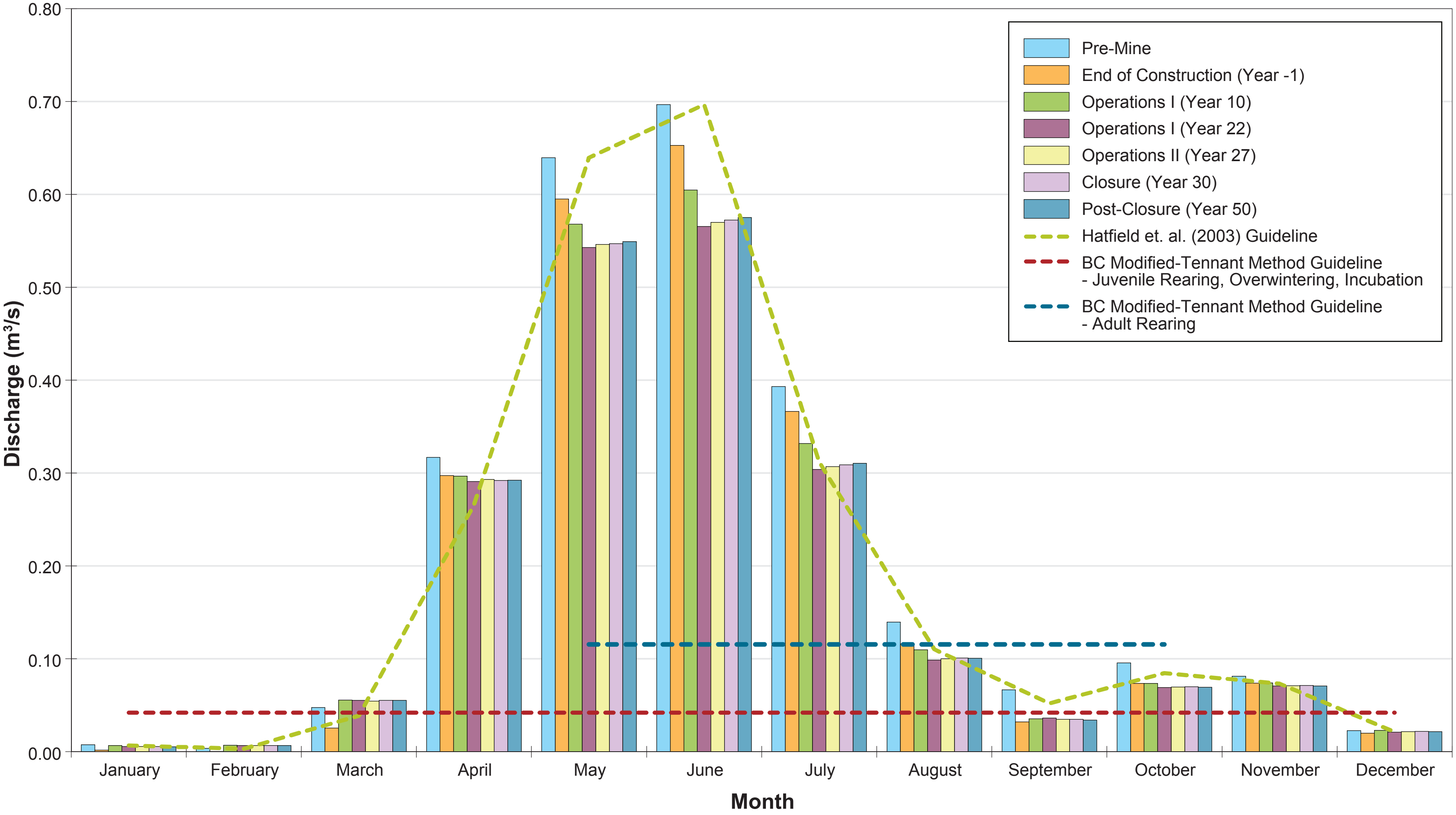
Table 14.5-10. Predicted Mean Monthly Flows at Node 7 (Baker Creek at North Thompson River Confluence) during Different Phases of the Project

Mine Stage			Mean Monthly Discharge												Average Annual
Year	Description	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.01	0.00	0.05	0.32	0.64	0.70	0.39	0.14	0.07	0.10	0.08	0.02	0.21
		%MAD	4%	2%	23%	151%	305%	332%	187%	67%	32%	46%	39%	11%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	End of Construction	m^3/s	0.00	0.00	0.03	0.30	0.60	0.65	0.37	0.12	0.03	0.07	0.07	0.02	0.19
		% Pre-Mine MAD	1%	0%	12%	142%	283%	311%	174%	55%	15%	35%	35%	9%	90%
		%Pre-Mine	23%	5%	53%	94%	93%	94%	93%	83%	48%	77%	91%	87%	70%
10	Operations I	m^3/s	0.01	0.01	0.06	0.30	0.57	0.60	0.33	0.11	0.04	0.07	0.07	0.02	0.18
		% Pre-Mine MAD	3%	3%	27%	141%	271%	288%	158%	52%	17%	35%	35%	11%	87%
		%Pre-Mine	92%	184%	117%	94%	89%	87%	84%	79%	53%	77%	91%	101%	96%
22	Operations I	m^3/s	0.01	0.01	0.06	0.29	0.54	0.57	0.30	0.10	0.04	0.07	0.07	0.02	0.17
		% Pre-Mine MAD	3%	3%	26%	139%	259%	269%	145%	47%	17%	33%	34%	10%	82%
		%Pre-Mine	76%	174%	116%	92%	85%	81%	77%	71%	54%	72%	87%	92%	90%
27	Operations II	m^3/s	0.01	0.01	0.05	0.29	0.55	0.57	0.31	0.10	0.03	0.07	0.07	0.02	0.17
		% Pre-Mine MAD	3%	3%	26%	140%	260%	272%	146%	48%	17%	33%	34%	10%	83%
		%Pre-Mine	75%	177%	114%	92%	85%	82%	78%	72%	52%	73%	87%	95%	90%
30	Closure	m^3/s	0.01	0.01	0.06	0.29	0.55	0.57	0.31	0.10	0.03	0.07	0.07	0.02	0.17
		% Pre-Mine MAD	3%	3%	26%	139%	261%	273%	147%	48%	17%	33%	34%	10%	83%
		%Pre-Mine	76%	178%	116%	92%	86%	82%	79%	72%	52%	73%	87%	96%	91%
50	Post-Closure	m^3/s	0.01	0.01	0.06	0.29	0.55	0.58	0.31	0.10	0.03	0.07	0.07	0.02	0.17
		% Pre-Mine MAD	3%	3%	26%	139%	262%	274%	148%	48%	16%	33%	34%	10%	83%
		%Pre-Mine	72%	176%	116%	92%	86%	83%	79%	72%	51%	73%	87%	94%	90%

MAD = mean annual discharge

Figure 14.5-6

Comparison of Standard Setting Instream Flow Thresholds at Node 7 (Baker Creek at North Thompson River Confluence) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Rainbow Trout life stage.

Source: Knight Piésold Consulting (2014).

The results of the instream flow screening process indicate that Rainbow Trout life history requirements and productivity are above BC Modified-Tennant Method thresholds, or, when below, very similar to pre-mine discharge. Rainbow Trout and their habitat are unlikely to be affected in Baker Creek. The effects of flow reductions on fish production and fish habitat in this reach will not be evaluated further.

Jones Creek

For the screening assessment of this tributary, Node 6 (Jones Creek above the North Thompson River Confluence) was used to examine potential effects on Rainbow Trout. Rainbow Trout were the principal species using this tributary; over three years of sampling (3,843 s electrofishing) two Coho Salmon were captured along with 65 Rainbow Trout. The predicted mean monthly flow changes at Node 6 are presented in Table 14.5-11 for all stages of mine development. The results indicate that flow will increase, on average, by 23 to 32 % over the life of mine. Changes to predicted flow, however, depend strongly on seasonality, with flow predicted to decrease during late winter periods, and flow increases during summer periods. A comparison of monthly predicted flow changes indicates that reductions would occur during all Rainbow Trout life history stages (Table 14.4-3).

The predicted mean monthly flow changes were compared to the instream flow standard setting methods. The BC Instream Flow Threshold Method results (Figure 14.5-7) show that the minimum flow threshold was achieved for 50% of mine life (Construction to Closure). However, a more detailed examination of the Rainbow Trout life-stages affected by flow was assessed using the BC Modified-Tennant Method (Figure 14.5-7). Predicted flows are above threshold for adult Rainbow Trout summer rearing from May to July during all phases. During August to October, the predicted mine life and pre-mine (September and October only) flow supply is less than threshold requirements, which indicates a sensitive period for flow reductions. During the months from December to March, the predicted pre-mine and mine life flow supply is under threshold requirements, which may indicate a sensitive winter period for flow reductions; however, pre-mine and mine life flows are predicted to be very similar during this period (with the exception of March; Figure 14.5-7). Juvenile Rainbow Trout overwintering threshold was not achieved from December during the Construction and Operations I phases, but again, the predicted life of mine flows are similar to pre-mine values. Juvenile Rainbow Trout rearing habitat threshold was achieved during June to July and October for all phases. During September, predicted flow was within 28% of the juvenile rearing threshold.

The adult Rainbow Trout spawning threshold was calculated for Node 6, resulting in a value of 0.70 m^3/s. The Rainbow Trout spawning habitat threshold was achieved for all mine phases in Jones Creek.

The duration of short-term maintenance, channel maintenance, and wetland linkages under operational conditions were evaluated through a review of flow duration curves (Appendix 14-D). The results indicate that the threshold conditions were not achieved under operational conditions, but also indicate that pre-mine discharge was similar to mine life and under threshold values.

The results of the instream flow screening process indicate that Rainbow Trout life history requirements, productivity, and habitat are unlikely to be affected in Jones Creek. The effects of flow reductions on fish production and fish habitat will not be evaluated further.

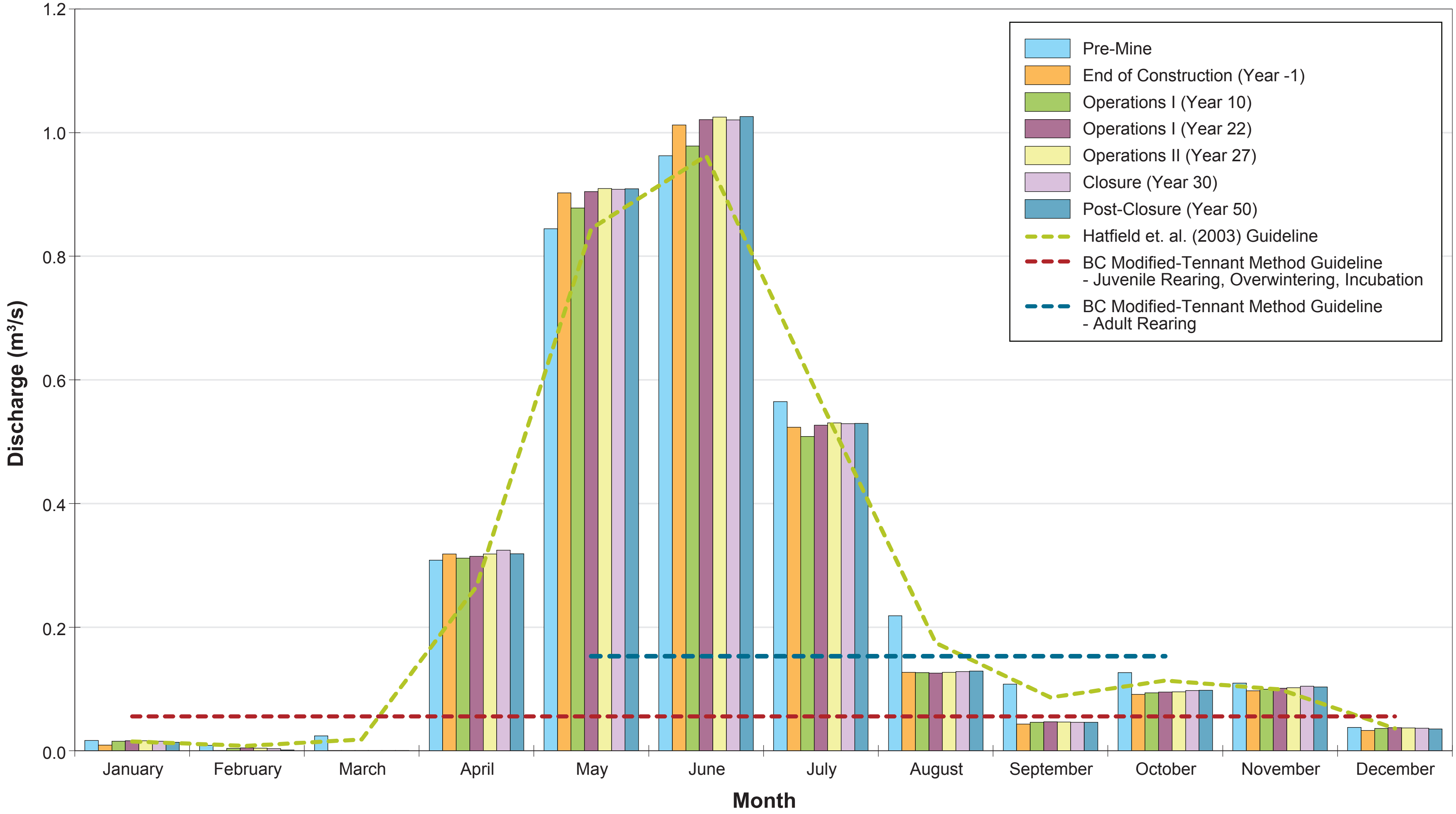
Table 14.5-11. Predicted Mean Monthly Flows at Node 6 (Jones Creek Above North Thompson River Confluence) during Different Phases of the Project

Mine Stage		Units	Mean Monthly Discharge												Average Annual
Year	Description		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
-	Pre-Mine	m^3/s	0.02	0.01	0.02	0.31	0.84	0.96	0.56	0.22	0.11	0.13	0.11	0.04	0.28
		%MAD	6%	3%	9%	111%	303%	346%	203%	78%	39%	45%	39%	14%	100%
		%Pre-Mine	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	End of Construction	m^3/s	0.01	0.00	0.00	0.32	0.90	1.01	0.52	0.13	0.04	0.09	0.10	0.03	0.26
		% Pre-Mine MAD	3%	0%	0%	114%	324%	364%	188%	46%	16%	33%	35%	12%	95%
		%Pre-Mine	54%	4%	0%	103%	107%	105%	93%	58%	40%	72%	89%	87%	68%
10	Operations I	m^3/s	0.02	0.00	0.00	0.31	0.88	0.98	0.51	0.13	0.05	0.09	0.10	0.04	0.26
		% Pre-Mine MAD	6%	1%	0%	112%	315%	351%	183%	45%	17%	34%	36%	13%	93%
		%Pre-Mine	93%	43%	0%	101%	104%	102%	90%	58%	43%	74%	91%	95%	75%
22	Operations I	m^3/s	0.02	0.00	0.00	0.31	0.90	1.02	0.53	0.13	0.05	0.09	0.10	0.04	0.27
		% Pre-Mine MAD	6%	2%	0%	113%	325%	367%	189%	45%	17%	34%	36%	13%	96%
		%Pre-Mine	99%	55%	0%	102%	107%	106%	93%	58%	43%	75%	93%	98%	77%
27	Operations II	m^3/s	0.02	0.00	0.00	0.32	0.91	1.03	0.53	0.13	0.05	0.10	0.10	0.04	0.27
		% Pre-Mine MAD	6%	2%	0%	114%	327%	368%	190%	46%	17%	34%	37%	13%	96%
		%Pre-Mine	97%	50%	0%	103%	108%	106%	94%	58%	43%	76%	93%	97%	77%
30	Closure	m^3/s	0.02	0.00	0.00	0.32	0.91	1.02	0.53	0.13	0.05	0.10	0.10	0.04	0.27
		% Pre-Mine MAD	6%	1%	0%	117%	326%	367%	190%	46%	17%	35%	38%	13%	97%
		%Pre-Mine	93%	38%	1%	105%	108%	106%	94%	59%	43%	77%	95%	96%	76%
50	Post-Closure	m^3/s	0.01	0.00	0.00	0.32	0.91	1.03	0.53	0.13	0.05	0.10	0.10	0.04	0.27
		% Pre-Mine MAD	5%	1%	0%	114%	327%	369%	190%	46%	17%	35%	37%	13%	96%
		%Pre-Mine	82%	18%	2%	103%	108%	107%	94%	59%	43%	78%	94%	93%	73%

MAD = mean annual discharge

Figure 14.5-7

Comparison of Standard Setting Instream Flow Thresholds at Node 6 (Jones Creek Above North Thompson River Confluence) during Different Phases of the Project



Notes: Hatfield et. al. guideline calculated for fish-bearing streams.
Monthly durations for biological requirments for BC Modified-Tennant Method guideline flow recommendations assigned for Rainbow Trout life stage.

Source: Knight Piésold Consulting (2014).

Temperature

Temperature is an important environmental factor in aquatic ecosystems as it plays a pivotal role over biological processes. For salmonids, increases in surface water temperature beyond diurnal or seasonal averages have the potential to prevent or accelerate embryo development; alter the timing of emergence, growth, and migration; reduce metabolic efficiency; alter spawning timing; increase susceptibility to disease; and alter the competitive characteristic of fish assemblages.

To assess the scale of changes to stream temperature arising from alteration of water quantity, temperature modelling was completed between pre-mine and Operations I Year 22 conditions to calculate the magnitude of predicted temperature change at several model nodes along Harper Creek, T Creek, P Creek, Backer Creek, and Jones Creek (Appendix 14-D).

The difference in temperature change per km between pre-mine and Year 22 conditions was calculated to assess the predicted temperature change due to change in streamflow (Appendix 14-D). The modelling results suggest a small increase in water temperature (approximately 0.05 to 0.09°C) will occur as a result of a change in water quantity (flow) in streams.

The results of the temperature modelling process indicate that fish life history requirements, productivity and habitat are unlikely to be affected by the Project. The effects of temperature on fish production and fish habitat will not be evaluated further.

Potential for Toxicity due to Changes in Water Quality

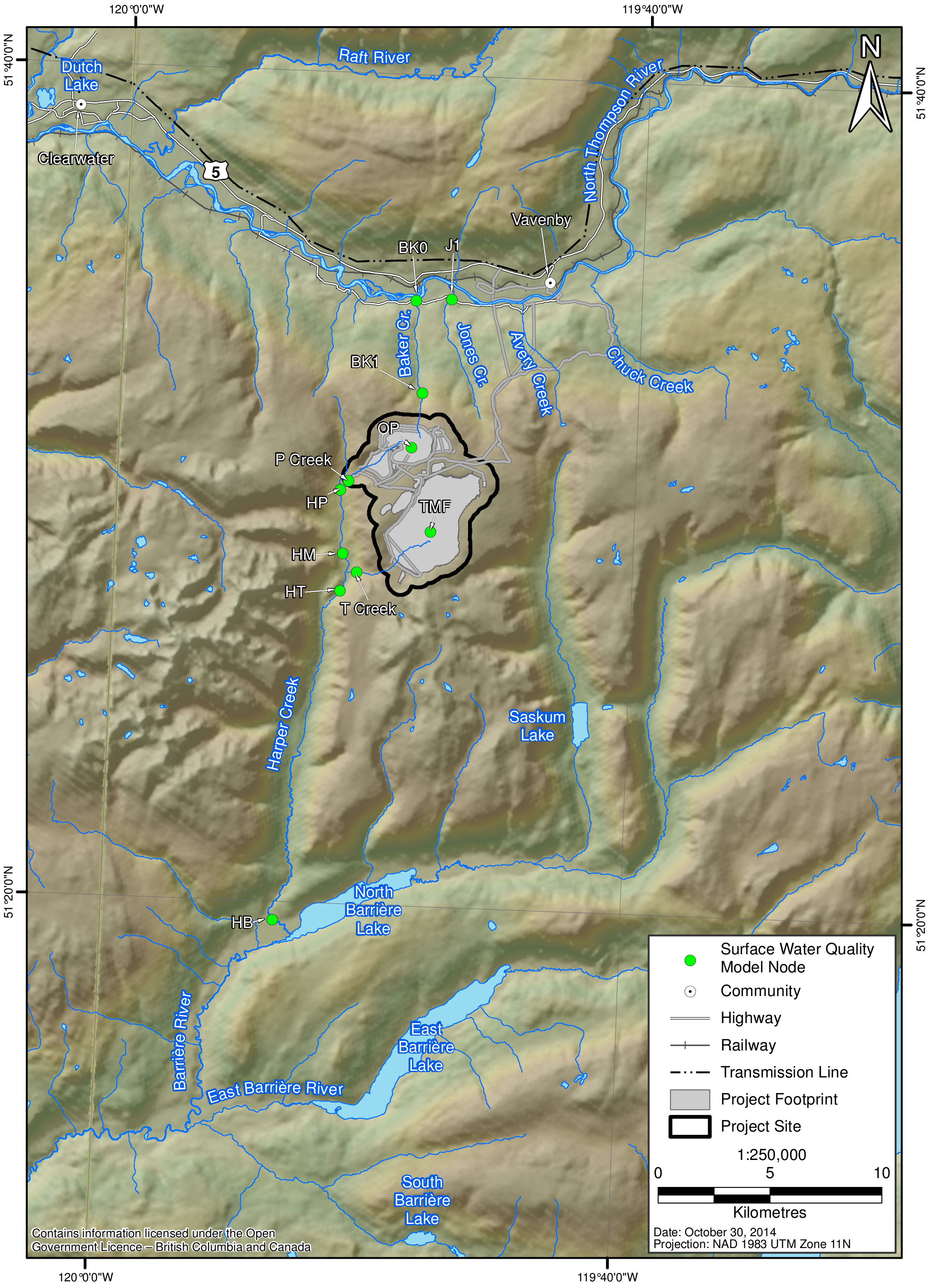
In support of the environmental assessment, quantitative modelling was completed to predict key effects on surface water quality (Chapter 13, Appendix 13-C). The primary objective of the water quality modelling for the Project was to predict the concentrations of total and dissolved metals, nutrients, and anions within the Project footprint and in the surrounding surface waters that will receive seepage from the Project components and or direct effluent discharge from the TMF.

To assess chemical loadings to the receiving environment, Knight Piésold developed water quality predictions for the Project using GoldSim. A summary of the model approach, assumptions, and sensitivity analyses are provided in Section 13.5.3. Full details are provided in Appendix 13-C, Harper Creek Project: Water Quality Predictions (KP 2014). Modelling node locations are provided in Figure 14.5-8.

The water quality model is based on monthly time steps and contains both contact and non-contact water that reports to T, P, Harper, Baker and Jones creeks, either directly or via a tributary. Results of water quality predictions include management and mitigation measures; that is, results indicating a change in water quality represent a residual effect to the surface water VC (see Section 13.5.3). For the purposes of the effects assessment, the expected case (for all modelling nodes) and the unrecovered seepage sensitivity case (for P Creek, HP, and HM modelling nodes only) of the water quality predictions were used (Appendix 13-C).

Figure 14.5-8

Surface Water Quality Modelling Nodes



Methodology for Selecting Contaminants of Potential Concern

A change in surface water quality parameters (i.e., metals or anions, excluding nutrients) was assessed through the consideration of locations where there was the potential for interactions between a VC (e.g., sediment quality, aquatic resources, and fish) and Project-related water. Project-related effects associated with the TMF and open pit are restricted to potential effects to wildlife (Chapter 16), as fish and aquatic resources were assumed to not have interaction with this infrastructure within the Project Site. For the purposes of residual effects assessment, it was assumed that any change in water quality would also lead to a change in sediment quality; however the extent of the change to sediment quality (i.e., quantification or sediment quality predictions) was not determined.

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 or fish (Environment Canada 2012b). HQs are 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 selecting contaminants of potential concern (COPCs) was illustrated in Figure 13.5-2 (Chapter 13, Surface Water Quality Effects Assessment). 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 (hereafter referred to as BC WQGs).

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 BC WQG. Note that the BC WQG used for cadmium was the draft cadmium guideline (Sinclair et al. 2014) and is subject to change when the guideline is finalized. Water quality parameters with an 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 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 for those parameters. Water quality parameters with an 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.

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 the receiving environment (Appendix 13-D). 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 above guideline are not a Project-related effect and should not be considered in the effects assessment as 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 COPC and retained for further assessment in the following sections. 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.

Contaminants of Potential Concern

Based on the selection procedure described in the preceding section and the COPCs identified in Chapter 13 (Section 13.5.3), Table 14.5-12 summarizes the COPCs for fish and aquatic resources. The COPCs listed in Table 14.5-12 have concentrations that are predicted to be greater than both the BC WQG and background conditions during the specific phase of the Project at the node indicated. It was assumed that sediment quality at the nodes where water quality is affected may also be changed; however, the potential change in sediment quality was not quantified. The residual effects to the fish VC are assumed to be due to a combination of changes in water quality and changes in sediment quality.

Table 14.5-12. Contaminants of Potential Concern for Fish and Aquatic Resources

COPCs Based on the Expected Case Water Quality Model Results					
Model Node	**Construction**	**Operations 1**	**Operations 2**	**Closure**	**Post-Closure**
BK0	-	Cr*	Cr*	Cr*	Cr*
BK1	-	-	-	-	-
J1	-	-	-	-	-
P Creek	-	-	-	-	-
HP	-	-	-	-	-
HM	-	Se*	Se*	-	-
T Creek	-	-	-	**Cd-d, Cu, Se, SO_4**	**Cd-d, Cu, Se, SO_4, Zn**
HT	**Cu**	**Cu, Se**	**Cu, Se**	**Cd-d, Cu, Se**	**Cd-d, Cu, Se**
HB	-	-	-	**Cd-d, Cu, Se**	**Cd-d, Cu, Se**
COPCs Based on the Unrecovered Seepage Sensitivity Case Water Quality Model Results					
Model Node	**Construction**	**Operations 1**	**Operations 2**	**Closure**	**Post-Closure**
P Creek	NO_2*	NO_2*, **Se**	**Se**		
HP	-	NO_2*, **Se**	**Se**		
HM		NO_2*, Se*	Se*		

Notes:
Cd-d = dissolved cadmium, Cr = chromium, Cu = copper, NO2 = nitrite, Se = selenium, SO4 = sulphate, Zn = zinc
Parameters shown in bold were carried through to the Characterization of Residual Effects Sections (Section 14.5.3.2 for fish and Section 14.5.3.4 for aquatic resources).
(*) means that although the parameter was identified as a COPC based on the screening procedure it was not carried into the residual characterization section (see rationale provided in text for each modelling node).
(-) means that no COPCs were identified at that modelling node during that phase of the Project.

Based on the expected case and unrecovered seepage sensitivity case water quality model results (Appendix 13-A), no COPCs were identified during any of the Project phases at the BK1 modelling node in Baker Creek or the J1 modelling node in Jones Creek. No residual effects due to changes in water quality would be expected in these locations during the various Project phases.

The following sections discuss the details of when and where concentrations are predicted to be greater than guidelines at the various modelling nodes. This information is useful for identifying the correct significance descriptors for magnitude, duration, and frequency of residual effects.

BK0 Modelling Node (Lower Baker Creek)

The BK0 modelling node is located in lower Baker Creek, upstream of the confluence with the North Thompson River (Figure 14.5-8). Based on the expected case water quality model results (Appendix 13-C), chromium was identified as a COPC in the Operations, Closure, and Post-Closure phases.

Chromium

Chromium is predicted to be greater than the maximum BC WQG by up to 0.6% and greater than baseline concentrations in May of each year from Year 1 to 99. The guideline for chromium incorporates a safety factor of 10 (i.e., effects would not be expected until concentrations are 10 times higher than the guideline; CCME 1999), and the predicted concentration (even if it was correct) is only 0.6% higher than the guideline. Therefore, chromium is not considered a COPC at the BK0 site and no further consideration is warranted.

P Creek Modelling Node (P Creek)

The P Creek modelling node is located in lower P Creek, upstream of the confluence with Harper Creek (Figure 14.5-8). Based on results of the Unrecovered Seepage Sensitivity Analysis (Appendix 13-C), nitrite (Construction and Operations 1 phases) and selenium (Operations 1 and 2 phases) were identified as COPCs for further consideration at this modelling node (Table 14.5-12).

Nitrite

The potential for toxicity due to nitrite is dependent on chloride, which is reflected in the chloride-dependent formula for determining the appropriate guideline concentration. The most conservative guideline (0.02 mg/L) was used as the BC WQG at this site.

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, nitrite was excluded from further consideration at the P Creek Modelling Node.

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 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 the Operations 1 and 2 phases, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in P Creek.

HP Modelling Node (Harper Creek Downstream of P Creek)

The HP modelling node is located in upper Harper Creek, just downstream of the confluence of P Creek and Harper Creek (Figure 14.5-8). Based on results of the Unrecovered Seepage Sensitivity Analysis (Appendix 13-C), nitrite (Construction and Operations 1 phases) and selenium (Operations 1 and 2 phases) were identified as COPCs for further consideration at this modelling node (Table 14.5-12).

Nitrite

The potential for toxicity due to nitrite is dependent on chloride, which is reflected in the chloride-dependent formula for determining the appropriate guideline concentration. The most conservative guideline (0.02 mg/L) was used as the BC WQG at this site.

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 phase 1); and
- January to March of Year (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, nitrite was excluded from further consideration at the HP Modelling Node.

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:

- 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 the Operations 1 and 2 phases, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in upper Harper Creek downstream of P Creek.

HM Modelling Node (Harper Creek between P and T Creeks)

The HM Modelling Node is located between P and T Creeks on Harper Creek (Figure 14.5-8). Based on the expected case of the water quality model (Appendix 13-C), only selenium was identified as a COPC for further consideration at this modelling node (Table 14.5-12). Based on the unrecovered seepage sensitivity case of the water quality model (Appendix 13-C), nitrite, and selenium were identified as COPCs.

Expected Case: Selenium

Selenium is predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) by up to 1.3 fold in the Operations 1 phase and 1.4 fold in the Operations 2 phase. Concentrations are predicted to be greater than the BC WQG 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 WQGs in all other months and in all other phases. Based on the timing of the elevated selenium concentrations (winter, low flow), it is unlikely that the selenium will be taken up into the aquatic food chain since there is limited productivity in the lower trophic levels during the winter. The concentration of selenium is only marginally greater than the BC WQG and, based on a literature search conducted to support the Selenium Management Plan (see Section 24.12), it is unlikely that a concentration of 2.8 µg/L occurring during the non-growing season in a lotic (fast flowing) aquatic environment would have adverse effects on either aquatic resources or fish. Therefore, the predicted elevation of selenium concentrations at the HM modelling node is not considered further.

Unrecovered Seepage Sensitivity Case: Nitrite, and Selenium

The potential for toxicity due to nitrite is dependent on chloride, which is reflected in the chloride-dependent formula for determining the appropriate guideline concentration. The most conservative guideline (0.02 mg/L) was used as the BC WQG at this site. Nitrite concentrations in water are predicted to be greater than the BC WQG and greater than background concentrations in February and March of Year 3 (Operations 1 phase), with concentrations of 0.023 and 0.025 mg/L, respectively. Since the predicted concentrations are only marginally higher than guidelines and occur for only two months out of the entire modelled period, nitrite was excluded from further consideration at the HM Modelling Node.

Selenium is predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) by up to 1.06 fold and greater than background concentrations during March of Years 15, 16, 20, 21, 23, 27, and 28 of the Operations 1 and 2 phases.

The maximum concentration predicted during these years is 2.1 µg/L. Selenium is predicted to be below the BC WQGs in all other months and in all other phases. Based on the timing of the elevated selenium concentrations (winter, low flow), it is unlikely that the selenium will be taken up into the aquatic food chain since there is limited productivity in the lower trophic levels during the winter. The concentration of selenium is only marginally greater than the BC WQG and, based on a literature search conducted to support the Selenium Management Plan (see Section 24.12), it is unlikely that a concentration of 2.1 µg/L occurring during the non-growing season in a lotic (fast flowing) aquatic environment would have adverse effects on either aquatic resources or fish. Therefore, the predicted elevation of selenium concentrations at the HM modelling node is not considered further.

T Creek Modelling Node (T Creek)

The T Creek modelling node is located near the end of T Creek, just upstream from the confluence with Harper Creek (Figure 14.5-8).

Based on the results of the expected case water quality model (Appendix 13-C), during the Construction and Operations phases, no COPCs were identified in T Creek. However, once discharge from the TMF begins during the Closure phase, the following COPCs were identified: dissolved cadmium (Cd), total copper, total selenium, sulphate (SO_4), and total zinc (Zn; Post-Closure phase only; Table 14.5-12).

Dissolved Cadmium

The potential for toxicity due to dissolved cadmium is hardness dependent, which is reflected in the hardness-dependent formula for determining the appropriate guideline concentration. Baseline mean hardness was used in calculating the appropriate draft BC WQG for dissolved cadmium.

Predicted water concentrations of dissolved cadmium are greater than the 30-day average draft BC WQG and greater than baseline concentrations throughout all months of the Closure and Post-Closure phases. Concentrations are predicted to be up to 3.7 fold greater than the 30-day average draft BC WQG in the Closure phase, and up to 8.7 fold greater than the draft BC WQG in the Post-Closure phase.

Dissolved cadmium is also predicted to be greater than the maximum draft BC WQG by up to 1.6 fold in the Closure phase and 3.8 fold in the Post-Closure phase. Concentrations of dissolved cadmium are predicted to be greater than the maximum draft BC WQG 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in T Creek.

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. Baseline mean hardness for the T Creek site was used in calculating the appropriate BC WQG for copper.

Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L) and greater than baseline concentrations throughout all months of the Closure and Post-Closure phases. Concentrations are predicted to be up to 2.6 fold greater than the 30-day average BC WQG in the Closure phase and up to 2.5 fold greater in the Post-Closure phase.

Total copper is also predicted to be greater than the maximum BC WQG by up 1.4 fold in the Closure phase and 1.3 fold in the Post-Closure phase. Concentrations are predicted to be greater than the BC WQG 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); and
- 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in T Creek.

Selenium

Starting in June of Year 31, selenium concentrations in water 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. 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in T Creek.

Sulphate

The potential for toxicity due to sulphate is hardness dependent, which is reflected in the hardness-dependent formula for determining the appropriate guideline concentration. Baseline mean hardness was used in calculating the appropriate BC WQG for sulphate.

Predicted water concentrations of sulphate are greater than the 30-day average BC WQG (128 mg/L) by up to 1.8 fold in the Closure phase and 1.7 fold in the Post-Closure phase. Concentrations are predicted to be greater than the BC WQG 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in T Creek.

Zinc

The potential for toxicity due to total zinc is dependent on hardness, which is reflected in the hardness-dependent formula for determining the appropriate guideline concentration. Baseline mean hardness was used in calculating the appropriate BC WQG for zinc.

Predicted water concentrations of total zinc 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in T Creek.

HT Modelling Node (Harper Creek Downstream of T Creek)

The HT modelling node is located on Harper Creek, just downstream of the confluence with T Creek (Figure 14.5-8). Based on the results of the expected case water quality modelling results, dissolved cadmium, total copper, and total selenium were identified as COPCs for further consideration at this modelling node (Table 14.5-12).

Dissolved Cadmium

The potential for toxicity due to dissolved cadmium is dependent on hardness, which is reflected in the hardness-dependent formula for determining the appropriate guideline concentration. Baseline mean hardness for the HT site was used in calculating the appropriate draft BC WQG for dissolved cadmium.

Predicted water concentrations of dissolved cadmium are greater than the 30-day average draft BC WQG by up to 1.2 fold in the Closure phase and 2.3 fold in the Post-Closure phase. Concentrations are predicted to be greater than the draft BC WQG 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 phase).

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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in Harper Creek at the HT modelling node.

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. Baseline mean hardness for the HT site was used in calculating the appropriate BC WQG for copper.

Predicted water concentrations of total copper are greater than the 30-day average BC WQG (0.002 mg/L) by up to 1.2 fold in the Construction and Operations phases, 1.6 fold in the Closure phase, and 1.6 fold in the Post-Closure phase. Concentrations are predicted to be greater than the BC WQG 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 phase).

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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in Harper Creek at the HT modelling node.

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 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 phase); 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. 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in Harper Creek at the HT site.

HB Modelling Node (Harper Creek Upstream of North Barrière Lake)

The HB modelling node is located in lower Harper Creek, upstream of the confluence of Harper Creek with North Barrière Lake (Figure 14.5-8). Cadmium, copper, and selenium were identified as COPCs for further consideration at this modelling node (Table 14.5-12).

Cadmium

The potential for toxicity due to dissolved cadmium is dependent on hardness, which is reflected in the hardness-dependent formula for determining the appropriate guideline concentration. Baseline mean hardness for the HB site was used in calculating the appropriate draft BC WQG for dissolved cadmium.

Predicted water concentrations of dissolved cadmium are greater than the 30-day average draft BC WQG by up to 1.1 fold in the Closure phase and up to 1.7 fold in the Post-Closure phase. Concentrations are predicted to be greater than the 30-day average draft BC WQG 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in Harper Creek at the HB modelling node.

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. Baseline mean hardness for the HB site was used in calculating the appropriate BC WQG for 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 1.1 fold in both the Closure and Post-Closure phases. Concentrations are predicted to be greater than the 30-day average BC WQG 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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in Harper Creek at the HB modelling node.

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, between 2.04 and 3.2 µg/L); and
- March of Years 42 to 72 (Post-Closure phase, between 2.02 and 2.7 µg/L).

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, this COPC will be assessed for potential for effects to fish (Section 14.5.3.1 and 14.5.3.2) and aquatic resources (Section 14.5.3.3 and 14.5.3.4) in Harper Creek at the HB site.

14.5.3.2 Characterization of Residual Effects on Fish and Fish Habitat Valued Components

Changes in Water Quantity

For the purposes of assessing the residual effects to fish and fish habitat VCs as a result of changes in water quantity, the residual effects for stream reaches that did not pass the screening criteria (Section 14.5.3.1) are characterized in this section. These stream reaches include: Harper Creek between P and T creeks, T Creek, and P Creek.

The predicted changes in water quantity in upper Harper Creek between P and T creeks, T Creek, and P Creek, may have adverse effects on fish (Bull Trout) and fish habitat (Section 14.5.3.1 and Table 14.4-3; Section 12.5.3.1, Hydrology Effects Assessment). These sections of stream are likely to experience prolonged periods of decreased water quantity (through Post-Closure), below established threshold and pre-mine levels, resulting in the potential to decrease fish habitat area and reduce Bull Trout population size.

Based on the screening assessment and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to fish (Bull Trout) and fish habitat due to changes in water quantity in Harper Creek between P and T creeks, T Creek, and P Creek is described as follows.

- Magnitude: The predicted reductions in discharge yield predictions of **medium** effects in upper Harper Creek between P and T creeks, and **high** effects in T Creek and P Creek. When assessed from a watershed perspective, within the whole of Harper Creek the effects identified above are considered to be **of medium magnitude**.
- Extent: **Local**. The effects of water quantity reductions on fish (Bull Trout) and fish habitat are limited to the upper reach and associated tributaries of upper Harper Creek.

- Duration: The effect is predicted to extend to the **far future** because of the long-term alterations in flows through Post-Closure in these streams.
- Frequency: Residual effects are predicted to be **continuous**, throughout the year during the mine life**.**
- Reversibility: **Partially-reversible**. The predicted effects have the potential to be partially reversible if restoration of natural drainage systems is established. However, reversibility is unlikely under the current mine plan. A return to baseline conditions may not be probable because of the predicted changes in Post-Closure.
- Resiliency: **Low**. The fish and fish habitat of concern in upper Harper, P, and T creeks is Bull Trout, which are particularly sensitive to environmental change due to narrow habitat requirements and demonstrated declines in disturbed habitats (COSEWIC 2012a).

Potential for Toxicity due to Changes in Water Quality

For the purposes of assessing the residual effects to fish as a result of changes in water quality, the affected waterways were divided into several areas: P Creek (based on data from the P Creek modelling node), T Creek (based on data from the T Creek modelling node), upper Harper Creek (based on data from the HP and HT modelling nodes), and lower Harper Creek (based on data from the HB modelling node). Table 14.5-13 summarizes the COPCs that will be assessed at each modelling node.

Table 14.5-13. Contaminants of Potential Concern for Fish

Model Node	Construction	Operations 1	Operations 2	Closure	Post-Closure
P Creek	-	Se	Se	-	-
T Creek	-	-	-	Cd-d, Cu, Se, SO_4	Cd-d, Cu, Se, SO_4, Zn
HP	-	Se	Se	-	-
HT	Cu	Cu, Se	Cu, Se	Cd-d, Cu, Se	Cd-d, Cu, Se
HB	-	-	-	Cd-d, Cu, Se	Cd-d, Cu, Se

Cd-d = dissolved cadmium, Cr = chromium, Cu = copper, NO_2 = nitrite, Se = selenium, SO_4 = sulphate, Zn = zinc
(-) means that no COPCs were identified at that modelling node during that phase of the Project

The following sections describe the potential fish receptors that may be present at the modelling nodes where water concentrations of various parameters are predicted to be greater than guidelines. These sections define a toxicity threshold, based on the receptors that may be present, at each modelling node to determine whether or not the predicted concentrations are greater than toxicity thresholds. This information is useful for defining the magnitude of the residual effect.

P Creek (Based on the P Creek Modelling Node)

Bull Trout are the only species of fish that were found in the lower 469 m of P Creek upstream of the confluence with Harper Creek during baseline studies. No fish were found above the fish barrier located 469 m upstream of the confluence with Harper Creek, and this area has been determined to be non-fish-bearing (Section 14.4.3.2 and Appendix 14-A).

Bull Trout, predominantly juveniles, may be present in the fish-bearing portion of P Creek during the late spring, summer, and early fall since the lower 469 m of P Creek offers rearing habitat. Adult Bull Trout may also move in and out of P Creek during these same times. Mature, spawning adults were not observed during fish community surveys of P Creek (Section 14.4.3.2 and Appendix 14-A). There is limited or no overwintering habitat in the lower 469 m of T Creek, and limited spawning habitat. Thus, exposure of any life stages of Bull Trout during the winter is unlikely, and exposure of eggs during the incubation period is possible, but unlikely.

Selenium

Selenium during the Operations 1 and 2 phases was the only COPC retained for consideration at the P Creek modelling node (Section 14.5.3.1 and Table 14.5-13).

Selenium taken up via the diet is deposited in the egg (i.e., maternal transfer), which can then lead to developmental abnormalities and mortality in the early life stages (e.g., yolk-sac fry, alevin). It may also be possible for toxicity to occur in juveniles via uptake of selenium through the diet, but this endpoint is not well defined. It is difficult to establish a toxicity threshold for selenium in water because the primary route of uptake of selenium by fish is through the diet (P. M. Chapman et al. 2009).

Selenium bioaccumulates in the aquatic food chain and the greatest degree of bioaccumulation occurs at the primary producer level (P. M. Chapman et al. 2009). The rate of bioaccumulation is site-specific and can be influenced by a number of factors including speciation (selenate, selenite, organo-selenium compounds), type of habitat (lentic versus lotic), and composition of the food chain. Individual species of fish may also have different sensitivity to selenium, and some fish of the *Salvelinus* genus (e.g., Dolly Varden) have been shown to tolerate higher body (or egg) burdens without experiencing toxicity (McDonald et al. 2010).

Bioaccumulation models can be developed that correlate the concentration of selenium in water with the concentration of selenium in fish tissues (either muscle or egg). Bioaccumulation models enable the back-calculation of a “safe” water concentration based on a toxicity threshold in tissue. A bioaccumulation model specific for the Project was attempted; however, the model had a poor fit and poor explanatory value, likely because the range in baseline water concentrations of selenium was very small. Therefore, a bioaccumulation model (for lotic environments) developed for another project in BC was used as an interim measure to enable assessment of potential effects to fish (Section 24.12). It is anticipated that a Project-specific bioaccumulation model will be developed over time, as monitoring data are collected and analyzed (Section 24. 12, Selenium Management Plan).

There is no publicly available bioaccumulation model for Bull Trout. However, studies conducted at several other active or proposed mine sites in BC have found that selenium bioaccumulation by Bull Trout is lower than that in other fish species (e.g., Slimy Sculpin) found in the same environments (Golder Associates Ltd. 2012). A bioaccumulation model for Slimy Sculpin is available (Golder Associates Ltd. 2012), and the use of this model will likely over-estimate the potential for bioaccumulation in Bull Trout (i.e., is likely to be protective of Bull Trout). This model was used to back-calculate a water concentration of selenium that is expected to be protective of fish, using a toxicity threshold derived by DeForest et al. (2012; 20 µg selenium/g dry weight in fish egg) based on Canadian fish species (Section 24.12). A concentration of 10 µg/L of selenium was calculated to be the 'safe' target for selenium in lotic environments such as P Creek (Section 24.12.6).

The maximum predicted concentration of selenium at the P Creek modelling node peaks at 6.2 µg/L in August of Year 28. Since this is below the concentration that is expected to be protective of fish health (10 µg/L) in a lotic environment, it is unlikely that effects to Bull Trout will occur. Monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12, as a follow-up program) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Characterization of Residual Effects to Bull Trout in P Creek (P Creek Modelling Node)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to the fish VC due to changes in water quality in the fish-bearing portion of P Creek is described as:

- Magnitude: **Medium**. Selenium concentrations in water are predicted to be between two to five times higher than the 30-day average BC WQG during the Operations 1 and Operations 2 phases. Predicted concentrations of selenium are predicted to be lower than toxicity thresholds for fish (as defined by the target concentration for selenium of 10 µg/L from the Selenium Management Plan, Section 24.12) throughout the phases of the Project in P Creek.
- Extent: **Local**. The change in water quality is limited to P Creek, within the LSA.
- Duration: **Medium-term**. The potential for effects to fish due to change in water quality at P Creek is predicted to occur only during some of the Operations 1 and Operations 2 phases (duration between 2 and 30 years).
- Frequency: **Sporadic**. Concentrations of selenium at the P Creek modelling node are predicted to be greater than the 30-day average BC WQG only in August between Years 3 and 28.
- Reversibility: **Reversible**: Concentrations of selenium are predicted to be greater than the 30-day average BC WQG only during the Operations 1 and 2 phases, and are predicted to be below the 30-day average BC WQG after Year 29. The potential for effects to fish will diminish or disappear once the selenium concentrations return to baseline levels.
- Resiliency: **Low**. Fish are considered to be sensitive to changes in water quality and Bull Trout are considered to be particularly sensitive to environmental change due to narrow habitat requirements and demonstrated declines in disturbed habitats (COSEWIC 2012a).

T Creek (Based on the T Creek Modelling Node)

Bull Trout are the only species of fish that were found in the lower 336 m of T Creek upstream of the confluence with Harper Creek during baseline studies. No fish were found above the fish barrier located 336 m upstream of the confluence with Harper Creek, and this area has been determined to be non-fish bearing (Section 14.4.3.2 and Appendix 14-A).

Bull Trout, predominantly juveniles, may be present in the fish-bearing portion of T Creek during the late spring, summer, and early fall since the lower 336 m of T Creek offers rearing habitat. Adult

Bull Trout may also move in and out of T Creek during these same times. There is no overwintering habitat in the lower 336 m of T Creek, and limited spawning habitat. Thus, exposure of any life stages of Bull Trout during the winter is unlikely, and exposure of eggs during the incubation period is possible, but unlikely.

Potential for Acute Toxicity (Lethality) to Bull Trout

Concentrations of dissolved cadmium and total copper in water are predicted to be greater than the maximum BC WQG at the T Creek modelling node during the Closure and Post-Closure phases, suggesting that the potential for acute lethality to fish (specifically Bull Trout) needs to be considered at this location.

A literature search was conducted to determine what the toxicity threshold is for acute toxicity due to cadmium or copper, with emphasis on any available information on Bull Trout specifically. When data for Bull Trout was not available, toxicity data for related species were used instead, with preference for data from other fish of the *Salvelinus* genus or salmonids of the *Oncorhynchus* genus. The literature search considered existing technical summaries used for development of guidelines (e.g., BC WQG or CCME WQGs), data summaries reported in the ECOTOX database (US EPA 2014), and published peer-reviewed studies. The 96-hour LC_{50} value (i.e., the concentration that causes lethality in 50% of the test organisms following 96 hours of exposure) was used, if available, to define the toxicity threshold.

The toxicity of cadmium and copper are hardness-dependent, so consideration of the hardness reported in the toxicity studies is important to ensuring that the selection of toxicity thresholds for comparison to predicted cadmium and copper concentrations (and baseline mean hardness) is as representative as possible.

Although the draft BC WQG for cadmium is for the dissolved fraction, many toxicity studies report toxicity on the basis of total cadmium. Therefore, to be conservative when considering the potential for effects, both the toxicity threshold and the predicted concentrations used were for total cadmium.

Cadmium

For total cadmium, the factsheet for the derivation of the CCME short-term WQG reported a geometric mean of comparable acute toxicity values of 0.00197 mg/L (adjusted to a hardness of 50 mg/L) in Bull Trout, based on a study by Hansen, Welsh, Lipton, Cacela, et al. (2002). The original Hansen, Welsh, Lipton, Cacela, et al. (2002) study reported a LC_{50} of 0.00083 mg/L, with a water hardness of approximately 30 mg/L. A 96-hour LC_{50} value of 0.00091 mg/L (hardness of approximately 30 mg/L) for Bull Trout fry was also reported in the ECOTOX database (US EPA 2014), based on a study by Stratus Consulting Inc. (1999). The lower value of 0.00083 mg/L from the Hansen, Welsh, Lipton, Cacela, et al. (2002) study was used as the cadmium toxicity threshold for Bull Trout in the comparison to predicted total cadmium concentrations.

The maximum concentration of total cadmium at the T Creek modelling node is predicted to be 0.00011 mg/L, occurring in several winter months in Years 49 to 52, where hardness ranges from 17 to 23 mg/L (Table 13.4-5 and Appendices 13-A and 13-B). The predicted total cadmium concentration is more than seven times lower than the Bull Trout acute toxicity threshold for total cadmium. Therefore, it is considered unlikely that acute toxicity would occur in Bull Trout due to exposure to cadmium.

Copper

There is one study available that considered the comparative acute toxicity of copper to Bull Trout and Rainbow Trout (Hansen, Lipton, and Welsh 2002), finding similar sensitivity between the species. The lowest 96-hour LC_{50} (at 100 mg/L hardness) determined in this study was 0.050 mg Cu/L for Bull Trout, and 0.035 mg Cu/L for Rainbow Trout. Other studies at lower water hardness are reported in the ECOTOX database for Rainbow Trout (US EPA 2014). The lowest LC_{50} value reported for copper at a water hardness 20 mg/L was 0.0057 mg/L (Cacela et al. 1996), while multiple other studies of Rainbow Trout in waters of low hardness suggested that the toxicity threshold is higher (i.e., 0.015 to 0.031 mg/L with water hardness between 20 and 30 mg/L; G. A. Chapman 1978; Chakoumakos, Russo, and Thurston 1979; Marr et al. 1998). Based on this information, an acute toxicity threshold of 0.015 mg/L total copper (at approximately 20 mg/L water hardness) was used to determine the potential for acute lethality in Bull Trout.

The maximum concentration of total copper at the T Creek modelling node is predicted to be 0.0052 mg/L in October of Year 31, where October has a baseline mean hardness of 18 mg/L. Concentrations of copper are predicted to decrease with time from this maximum level. Although this is similar to the LC_{50} reported by Cacela et al. (1996) for Rainbow Trout, it is below the LC_{50} reported in multiple other studies at similar water hardness as the baseline mean hardness in T Creek (i.e., approximately 20 mg/L; Table 13.4-5 and Appendices 13-A and 13-B). Therefore, it is considered unlikely that acute toxicity would occur in Bull Trout due to exposure to copper.

Based on the analysis presented above, it is considered unlikely that acute toxicity would occur in Bull Trout in the lower 336 m of T Creek in Closure or Post-Closure phases due to exposure to cadmium or copper.

Potential for Chronic, Sub-lethal Toxicity to Bull Trout

Concentrations of dissolved cadmium, total copper, total selenium, sulphate, and zinc (Post-Closure phase only) in water are predicted to be greater than the 30-day average BC WQG at the T Creek modelling node during the Closure and Post-Closure phases, suggesting that the potential for chronic toxicity (either lethality or sub-lethal effects) to fish needs to be considered at this location.

Similar to the approach used for determining toxicity thresholds for acute effects, a literature search was conducted, with emphasis on any available studies on Bull Trout. When data for Bull Trout was not available, toxicity data for related species was used instead, with preference for data from other fish of the *Salvelinus* genus or salmonids of the *Oncorhynchus* genus. The toxicological endpoints considered were those that have been demonstrated to be ecologically-relevant (e.g., reproduction, growth, development and survival of various life stages), consistent with guidance from BC MOE (BC MOE 2012a). The literature search considered existing technical summaries used for development of guidelines (e.g., BC WQG or CCME WQGs), data summaries reported in the ECOTOX database (US EPA 2014), and published peer-reviewed studies. Wherever possible, the EC_{10} or EC_{20} value (i.e., the effects concentration required to cause a 10 to 20% decrease or change in the endpoint) was used to define the toxicity threshold. The following sections consider the potential for toxicity to Bull Trout due to each of the COPCs.

Cadmium

A study of Bull Trout by Hansen, Welsh, Lipton and Suedkamp (2002) reported a no-observed-effects-concentration (NOEC; i.e., concentration at which effects do not occur) for growth and mortality of 0.00037 mg Cd/L (at approximately 30 mg/L water hardness) after 55 days of exposure. The same study reported a lowest-observed-effects-concentration (LOEC; i.e., the lowest tested concentration at which effects are statistically measureable) for mortality and growth endpoints of 0.00079 mg Cd/L. No other studies of Bull Trout could be located. Studies with other fish of the *Salvelinus* genus (e.g., *S. fontinalis*, Brook Trout or *S. namaycush*, Lake Trout) found that effects on biomass, growth, or survival began to occur at concentrations greater than 0.003 to 0.012 mg Cd/L (reported as LOECs, water hardness of 37 to 45 mg/L; Sinclair et al. 2014). To be conservative, the NOEC reported by Hansen, Welsh, Lipton and Suedkamp (2002) for Bull Trout was used as the chronic toxicity threshold, even though this threshold is likely to be higher (i.e., between 0.00037 and 0.00079 mg/L).

The maximum concentration of total cadmium at the T Creek modelling node is predicted to be 0.00011 mg/L, occurring in several winter months in Years 49 to 52, where hardness ranges from 17 to 23 mg/L (Table 13.4-5 and Appendices 13-A and 13-B; reasonably similar to the hardness used in the toxicity study by Hansen, Welsh, Lipton and Suedkamp 2002). The predicted total cadmium concentration is more than three times lower than the Bull Trout chronic toxicity threshold for total cadmium. Therefore, chronic effects to Bull Trout due to cadmium exposure are unlikely.

Copper

Only one study of the chronic toxicity of copper to Bull Trout could be located. (Hansen, Welsh, Lipton and Cacela 2002) reported that, following a 60-day exposure to copper in hard water, only minor effects on mortality occurred at 0.179 mg Cu/L and no effects on growth were noted. However, given that the hardness used in this study (220 mg/L) is substantially higher than what occurs naturally in T Creek (approximately 20 mg/L) and increased hardness decreases copper toxicity, this study was not used in determining a toxicity threshold for Bull Trout for copper.

Studies with other fish of the *Salvelinus* genus (e.g., Brook Trout) found that effects due to copper may occur at lower concentrations, depending on the life stage of fish (egg stage appears to be most sensitive). Effects exposure to copper on the development from the egg to fry stage of fish were noted in Brook Trout following exposure to copper at 0.005 mg/L (growth, 60 days of exposure) or 0.013 mg/L (percent to hatch, 30 days of exposure) with a water hardness of 32 to 51 mg/L (reported as LOECs; Sauter et al. 1977). In contrast, effects of copper exposure on growth and mortality of juvenile Brook Trout (8 month old fish) were not noted until concentrations reached approximately 0.16 mg/L (reported as a LOEC, water hardness of approximately 20 mg/L; Jop, Askew, and Foster 1995), with a NOEC of 0.075 to 0.080 mg/L. McKim and Benoit (1971) reported that growth and survival of Brook Trout alevins and juveniles was affected by copper concentrations of 0.017 mg/L, with a NOEC of 0.0095 mg/L; effects in adults were not noted until copper concentrations reached 0.032 mg/L (hardness of approximately 45 mg/L). Toxicity studies in other salmonids (e.g., members of the *Oncorhynchus* genus such as Rainbow Trout and Coho Salmon) suggest that copper may begin to cause effects on reproduction, growth, or survival at concentrations between 0.005 and 0.100 mg/L or more, with toxicity decreasing as water hardness increases (US EPA 2014).

Since different life stages appear to exhibit different sensitivity to copper, different toxicity thresholds were used. For the egg life stage, a toxicity threshold of 0.005 mg/L was selected (Sauter et al. 1977) and for juveniles the NOEC of 0.075 mg/L reported by Jop, Askew, and Foster (1995) was used as the toxicity threshold for copper.

The maximum concentration of total copper at the T Creek modelling node is predicted to be 0.0052 mg/L in October of Year 31, where October has a baseline mean hardness of 18 mg/L. Concentrations of copper are predicted to decrease with time from this maximum level. Although this is similar to the LOEC reported by Sauter et al. (1977) for Brook Trout eggs, it is unlikely that Bull Trout would spawn in T Creek since good spawning habitat is limited. Therefore, the potential for exposure of eggs to copper in T Creek is low, and the potential for effects to Bull Trout is also low.

The maximum predicted concentration of copper (0.0057 mg/L) is below the toxicity threshold reported for exposure of juveniles (NOEC of 0.075 mg/L). Concentrations of copper in water are predicted to be lower in the high flow season, which is when juveniles would be expected to be present in T Creek (there is no overwintering habitat in T Creek). Therefore, it is considered unlikely that chronic toxicity would occur in Bull Trout due to exposure to copper.

Selenium

A maximum target concentration of 10 µg/L for selenium has been determined based on a fish bioaccumulation model and back-calculation using a conservative toxicity threshold (see preceding section (P Creek [Based on the P Creek Modelling Node]) and the Selenium Management Plan in Section 24.12).

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. 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 predicted concentrations of selenium are greater than or near to the target concentration of 10 µg/L, it is possible that toxicity may occur. However, there are several factors that may influence the potential for toxicity to Bull Trout including:

- Bull Trout would not be expected to overwinter in T Creek, since there is little overwintering habitat available (Section 14.4.3.4). Fish would move out of T Creek to overwinter in pool habitats of Harper Creek, and would therefore not be present during the time in which selenium concentrations are predicted to be highest.
- Selenium concentrations are predicted to be below the target of 10 µg/L during May, June, and July; this is the time of year when aquatic productivity is likely to be greatest, and the bioaccumulation of selenium through the food chain is most likely to occur.

- T Creek is a low-order lotic waterway, with relatively low abundance of aquatic resources. In addition, during the Construction and Operations phases, diminished water quantity in T Creek will decrease the abundance of aquatic resources, which will take time to recover (see Section 14.5.3.3). The decreased or low productivity will decrease the amount of selenium taken up into the aquatic food chain, decreasing the potential for exposure of fish through the food chain.
- Downstream drift of benthic invertebrates will be relatively low since the abundance of these organisms in T Creek is relatively low, particularly in the early years of the Closure phase when selenium concentrations are predicted to be highest. The drift of benthic invertebrates (i.e., potential fish food) from upper T Creek where selenium concentrations may be higher is not likely to be a significant contributor to the diet of fish in lower T Creek or in upper Harper Creek.

Monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12, as a follow up program) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Sulphate

The BC WQG for sulphate was updated in 2013 and provides an up-to-date literature review of the limited studies available for sulphate toxicity following chronic exposures (Meays and Nordin 2013). Studies done to support guideline development included a Rainbow Trout embryo toxicity test, which measures mortality following exposure during the egg to alevin developmental stages. In very soft water (6 mg/L), the LC_{10} (concentration of sulphate required to cause mortality in 10% of the exposed eggs) was 176 mg/L, while in soft water (50 mg/L), the LC_{10} for sulphate was 315 mg/L. Elphick et al. (2011) reported that the EC_{10} for normal development was 941 mg sulphate/L for Chinook Salmon (10-day embryo exposure test) and 356 mg sulphate/L for Rainbow Trout (31-day embryo to alevin exposure test) at 15 mg/L water hardness. No data are available for Bull Trout sensitivity to sulphate toxicity or for toxicity to different endpoints (e.g., biomass or growth). Since the water hardness (15 mg/L) used in the tests conducted by Elphick et al. (2011) for Rainbow Trout are most similar to the baseline mean hardness for T Creek (around 20 mg/L), 356 mg sulphate/L was used as the toxicity threshold for the purposes of effects assessment.

Sulphate concentrations are typically predicted to be highest during the low flow periods and lowest in the high flow periods, with concentrations decreasing over time throughout the Closure and Post-Closure phases. The maximum concentration of sulphate predicted at the T Creek modelling node is 224 mg/L between October of Year 30 and January of Year 31. The maximum predicted concentration of sulphate in T Creek (224 mg/L) is lower than the toxicity threshold (356 mg/L), so it is unlikely that effects to Bull Trout would occur due to sulphate exposure.

Zinc

No studies on chronic zinc exposure in Bull Trout could be located. A study done with Brook Trout found that embryo and larval survival was affected at zinc concentrations of 1.36 mg/L (reported as a LOEC, NOEC was 0.530 mg/L, water hardness of 45 mg/L; Holcombe, Benoit, and Leonard 1979). Mebane, Hennessy, and Dillon (2008) conducted a study with Rainbow Trout, finding that mortality occurred after 69 days of exposure at 0.088 mg zinc/L (reported as an EC_{10}, water hardness of

20 mg/L). G. A. Chapman (1982) reported that the EC_{10} for survival of early life stages of Chinook Salmon was decreased after 120 days of exposure at 0.407 mg zinc/L with water hardness of 25 mg/L and 0.732 mg zinc/L with water hardness of 50 mg/L. G. A. Chapman (1978) found that the EC_{10} for survival following 200 hours of zinc exposure varied depending on the life stage (swim-up stage most sensitive, alevin least sensitive) and fish species (Steelhead more sensitive than Chinook Salmon). The EC_{10} reported in this study for survival ranged from 0.054 to 0.256 mg/L in Steelhead (*O. mykiss*) and 0.068 to 0.661 mg/L in Chinook Salmon, with water hardness of 23 mg/L.

Based on this data, to be conservative, 0.054 mg/L (the lowest value reported by G. A. Chapman 1978) was selected as toxicity threshold for zinc for Bull Trout. Water hardness used in the G. A. Chapman (1978) study (23 mg/L) is similar to the natural baseline hardness in T Creek (approximately 20 mg/L, Table 13.4-5 and Appendices 13-A and 13-B).

The maximum concentration of zinc predicted at the T Creek modelling node is 0.012 mg/L in several months during the low flow period (October to March) between Years 46 and 59. The maximum predicted concentration of zinc is more than four times lower than the toxicity threshold for fish, so it is unlikely that effects to Bull Trout would occur due to zinc exposure.

Characterization of Residual Effects to Bull Trout in T Creek (T Creek Modelling Node)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to Bull Trout due to changes in water quality in the fish-bearing portion of T Creek is described as follows.

- Magnitude: **High**. A number of parameters are greater than the BC WQG, and selenium is predicted to be more than five times higher than BC WQGs during Closure and the early Post-Closure phase, with concentrations decreasing with time. Predicted concentrations of selenium may be greater than toxicity thresholds for fish (as defined by the target concentration for selenium of 10 µg/L from the Selenium Management Plan, Section 24.12) for a short period during Closure and Post-Closure.
- Extent: **Local**. The change in water quality is limited to T Creek, within the LSA.
- Duration: **Far-future**. The potential for effects due to change in water quality at T Creek is predicted to extend through the Closure and Post-Closure phases and beyond.
- Frequency: **Continuous**. Predicted concentrations for several of the COPCs at T Creek modelling node (e.g., cadmium, copper, and selenium) are greater than BC WQGs throughout all time steps during the Closure and Post-Closure phases.
- Reversibility: **Partially reversible**: Concentrations of the COPCs are predicted to decrease over time, and will eventually decrease to concentrations below the BC WQG.
- Resiliency: **Low**. Fish are considered to be sensitive to changes in water quality and Bull Trout are considered to be particularly sensitive to environmental change due to narrow habitat requirements and demonstrated declines in disturbed habitats (COSEWIC 2012a).

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.

Upper Harper Creek (Based on the HP and HT Modelling Nodes)

Concentrations of dissolved cadmium, total copper, and total selenium in water are predicted to be greater than the 30-day average BC WQG at the HT modelling node in Harper Creek (expected case water quality model results), and total selenium concentrations are predicted to be greater than the 30-day average BC WQG at the HP modelling node (unrecovered seepage sensitivity case water quality model results; Section 13.5.3.1 and Appendices 13-C and 13-D), suggesting that the potential for chronic toxicity to fish needs to be considered for upper Harper Creek. Predicted concentrations are less than the maximum BC WQGs, so acute toxicity would not be expected.

Bull Trout are the only species of fish that may be found in this area of Harper Creek. There is a partial (seasonal) fish barrier present at km 18.5 of Harper Creek, which is the dividing line between upper and lower Harper Creek; only Bull Trout have been found upstream of this barrier. Bull Trout at various life stages may be expected to be present throughout the year since the upper Harper Creek offers spawning, overwintering, and rearing habitat.

The methodology for assessing the potential for effects to Bull Trout was described in the preceding section (T Creek [Based on the T Creek Modelling Node]), and the same approach was used here. Toxicity thresholds for Bull Trout determined in the preceding section are also used here.

Cadmium

The NOEC of 0.00037 mg/L reported by Hansen, Welsh, Lipton, Cacela, et al. (2002) for Bull Trout was used as the chronic toxicity threshold, even though this threshold is likely to be higher (see preceding section (T Creek [Based on the T Creek Modelling Node]).

The maximum concentration of total cadmium at the HT modelling node is predicted to be 0.000065 mg/L in March of Years 51 to 53, where March has a baseline mean hardness of 37 mg/L (Table 13.4-5 and Appendices 13-A and 13-B; reasonably similar to the hardness used in the toxicity study by Hansen, Welsh, Lipton and Suedkamp 2002). The predicted total cadmium concentration is more than seven times lower than the Bull Trout chronic toxicity threshold for total cadmium. Therefore, chronic effects to Bull Trout due to cadmium exposure are unlikely.

Copper

Since different life stages appear to exhibit different sensitivity to copper, different toxicity thresholds were used (see preceding section for T Creek [Based on the T Creek Modelling Node]). For the egg life stage, a toxicity threshold of 0.005 mg/L was selected (Sauter et al. 1977) and for juveniles the NOEC of 0.075 mg/L reported by Jop, Askew, and Foster (1995) was used as the toxicity threshold for copper.

The maximum concentration of total copper at the HT modelling node is predicted to be 0.0033 mg/L in June of Year 31, and 32 where June has a baseline mean hardness of 16 mg/L (Table 13.4-5 and Appendices 13-A and 13-B; similar to the 20 mg/L hardness used in the toxicity study by Jop, Askew, and Foster 1995). The predicted total copper concentration is below the toxicity threshold for the egg life stage, and is more than twenty times lower than the toxicity threshold for juvenile fish for total copper. Therefore, chronic effects to Bull Trout due to copper exposure are unlikely.

Selenium

A maximum target concentration of 10 µg/L for selenium has been determined based on a fish bioaccumulation model and back-calculation using a conservative toxicity threshold (see preceding section for P Creek (Based on the P Creek Modelling Node) and the Selenium Management Plan in Section 24.12).

Based on the expected case water quality modelling results, the maximum predicted concentration of selenium at the HT modelling node is 5.9 µg/L, occurring in March of Year 36, with concentrations decreasing annually with time. Based on the unrecovered seepage sensitivity case water quality modelling results, the maximum predicted concentration of selenium at the HP modelling node is 6.0 µg/L, occurring in March of Years 27 and 28. Since the predicted selenium concentrations at both of these modelling nodes are below the concentration that is expected to be protective of fish health (10 µg/L) in a lotic environment, it is unlikely that toxicity to Bull Trout will occur in upper Harper Creek. A follow-up monitoring program will be implemented under the Selenium Management Plan to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed (Section 24.12).

Characterization of Residual Effects to Bull Trout in Upper Harper Creek (HP and HT Modelling Nodes)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to Bull Trout due to changes in water quality in upper Harper Creek is described as follows.

- Magnitude: **Medium**. Although predicted concentrations of cadmium, copper, and selenium are greater than the 30-day average BC WQG (but within five fold of the guideline), predicted concentrations are below toxicity thresholds for fish.
- Extent: **Local**. The change in water quality is limited to some portions of upper Harper Creek (i.e., downstream of the confluence with P or T creeks), within the LSA.
- Duration: **Far-future**. The potential for effects due to change in water quality (concentrations greater than BC WQG) in some parts of upper Harper Creek is predicted to extend through the Operations phase (in the vicinity of the HP modelling node) or Closure and Post-Closure phases (downstream of the confluence with T Creek).
- Frequency: **Regular**. Predicted concentrations for several of the COPCs at the HT modelling node are greater than BC WQGs regularly during Closure phase and the early portion of Post-Closure phase, but the frequency decreases with time and becomes more sporadic towards the end of Post-Closure phase.
- Reversibility: **Partially reversible**: Concentrations of the COPCs are predicted to decrease over time, and will eventually decrease to concentrations below the BC WQG.
- Resiliency: **Low**. Fish are considered to be sensitive to changes in water quality and Bull Trout are considered to be particularly sensitive to environmental change due to narrow habitat requirements and demonstrated declines in disturbed habitats (COSEWIC 2012a).

Lower Harper Creek (Based on the HB Modelling Node)

Concentrations of dissolved cadmium, total copper, and total selenium in water are predicted to be greater than the 30-day average BC WQG at the HB Creek modelling node in lower Harper Creek, suggesting that the potential for chronic toxicity to fish (Bull Trout, Rainbow Trout, Coho Salmon) needs to be considered at this location. Multiple species of fish were identified during baseline studies in this area of Harper Creek including Bull Trout, Coho Salmon, Sockeye Salmon, Rainbow Trout, Mountain Whitefish, Longnose Dace, and Torrent Sculpin (Appendix 14-A). Fish at various life stages may be expected to be present throughout the year since lower Harper Creek offers spawning, overwintering, and rearing habitat, and is directly connected to North Barrière Lake.

The methodology for assessing the potential for effects to selected fish VCs was described in the preceding section (T Creek [Based on the T Creek Modelling Node]), and the same approach was used here. Although additional toxicity data was considered (beyond data for fish of the *Salvelinus* genus or *Oncorhynchus* genus) to ensure that the toxicity threshold used was for the most sensitive fish species that could be present in lower Harper Creek, the focus of the assessment was on the representative fish species (i.e., Bull Trout, Rainbow Trout, and Coho Salmon).

Cadmium

The toxicity threshold for Bull Trout was based on a NOEC of 0.00037 mg/L reported by Hansen, Welsh, Lipton, Cacela, et al. (2002). Additional examination of available literature for toxicity thresholds for fish species other than Bull Trout found a study showing that Rainbow Trout are slightly more sensitive to the effects of cadmium than Bull Trout or other Pacific salmon species (e.g., Chinook or Coho Salmon). Mebane, Hennessy, and Dillon (2008) calculated an EC_{10} of 0.00015 mg/L (hardness of 29 mg/L) based on change in biomass following a 62-day exposure of early life stages of Rainbow Trout to cadmium. This lower EC_{10} value was used as the toxicity threshold for fish in lower Harper Creek.

The maximum concentration of total cadmium at the HB modelling node is predicted to be 0.000040 mg/L in March of Years 43 to 65, where March has a baseline mean hardness of 26 mg/L (Table 13.4-5 and Appendices 13-A and 13-B). The predicted total cadmium concentration is almost four times lower than the fish chronic toxicity threshold for the most sensitive species (0.00015 mg/L) for total cadmium. Therefore, chronic effects to fish due to cadmium exposure are unlikely.

Copper

Different fish life stages appear to exhibit different sensitivity to copper (see preceding section for T Creek [Based on the T Creek Modelling Node]). Since multiple fish species and life stages would be present in lower Harper Creek, the lowest toxicity threshold of 0.005 mg/L was used (based on a study by Sauter et al. (1977) with Brook Trout eggs). Toxicity studies with other salmonids (e.g., members of the *Oncorhynchus* genus such as Rainbow Trout and Coho Salmon) suggest that copper may begin to cause effects on reproduction, growth, or survival at concentrations between 0.005 and 0.100 mg/L or more, with toxicity decreasing as water hardness increases (US EPA 2014).

The maximum concentration of total copper at the HB modelling node is predicted to be 0.0021 mg/L in June of Years 31 to 61, where June has a baseline mean hardness of 11 mg/L (Table 13.4-5 and Appendices 13-A and 13-B). The predicted total copper concentration is only marginally higher than the 30-day BC WQG (0.002 µg/L) and is more than two times lower than the toxicity threshold for the most sensitive fish species. Therefore, chronic effects to fish VCs due to copper exposure are unlikely.

Selenium

A maximum target concentration of 10 µg/L for selenium has been determined based on a fish bioaccumulation model and back-calculation using a conservative toxicity threshold (see preceding section for P Creek [Based on the P Creek Modelling Node] and the Selenium Management Plan in Section 24.12).

The maximum predicted concentration of selenium at the HB modelling node is 3.2 µg/L, occurring in March of Year 36, with concentrations decreasing annually with time. Predicted concentrations of selenium at the HB modelling node are only greater than the 30-day average BC WQG during March of Year 32 (Operations 2 phase) and during February and March for some of the Post-Closure phase (up to Year 71). During the more critical 'growing' season (i.e., when water temperatures and aquatic productivity increases in the late spring, summer, and early fall), concentrations of selenium are predicted to be below the BC WQG, thereby decreasing the potential for selenium bioaccumulation during this time. Since predicted concentrations are below the concentration (10 µg/L) that is expected to be protective of fish health in a lotic environment, it is unlikely that effects to fish VCs will occur.

Follow-up monitoring will be required to ensure that selenium is not accumulating in sediments or the food chain in this location. Monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Characterization of Residual Effects to Fish Valued Components in Lower Harper Creek (HB Creek Modelling Node)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to fish VCs (Bull Trout, Rainbow Trout, Coho Salmon) due to changes in water quality in upper Harper Creek is described as:

- Magnitude: **Low**. Predicted concentrations of cadmium, copper, and selenium are marginally greater than the 30-day average BC WQG (within two fold of the guideline), and predicted concentrations are below toxicity thresholds for fish.
- Extent: **Regional**. The change in water quality occurs throughout Harper Creek and may extend into the outlet area of North Barrière Lake or into Barrière Creek, but is predicted to remain within the RSA (Chapter 13, Section 13.5.3).
- Duration: **Far future**. The potential for effects due to change in water quality (predicted concentrations greater than BC WQG) in lower Harper Creek is predicted to extend through the Closure and Post-Closure phases for some parameters (i.e., cadmium).

- Frequency: **Regular to Sporadic**. Predicted concentrations for cadmium, copper, and selenium at the HB modelling node are greater than BC WQGs regularly during the Closure phase and early parts of the Post-Closure phase, but the frequency decreases with time.
- Reversibility: **Partially reversible**: Concentrations of the COPCs are predicted to decrease over time, and will eventually decrease to concentrations below the BC WQG (e.g., copper will be below BC WQGs by mid-Year 71, selenium by early in Year 72).
- Resiliency: **Low**. Fish are considered to be sensitive to changes in water quality and Bull Trout are considered to be particularly sensitive to environmental change due to narrow habitat requirements and demonstrated declines in disturbed habitats (COSEWIC 2012a).

14.5.3.3 Residual Effects on Aquatic Resources Valued Components

Following mitigation, changes in water quantity and water quality due to Project activities have the potential to affect aquatic resources in the LSA. These residual effects resulting from the changes are assessed below.

Changes in Water Quantity

The predicted changes in water quantity in P Creek, T Creek, Baker Creek, Jones Creek, and upper Harper Creek may have effects on aquatic resources (Section 14.5.3.1 and Tables 14.5-5 to 14.5-11; Section 12.5.3.1, Hydrology Effects Assessment). Decreases in mean monthly discharges are predicted for P Creek, T Creek, Baker Creek, Jones Creek, and upper Harper Creek, with predicted periods of no or very little flow in P Creek, T Creek, and Jones Creek. The primary and secondary producer communities in headwater and low-order streams are sensitive to changes in flow regimes (Gomi, Sidle, and Richardson 2002; Halwas, Church, and Richardson 2005), and these predicted changes in hydrology have the potential to decrease the available habitat area, decrease the biomass of aquatic communities, and change the structure of these communities. There is the potential for residual effects to the primary and secondary producer communities in P Creek, T Creek, and Jones Creek as a result of these changes in water quantity, and this will be assessed in more detail in Section 14.5.3.4,Characterization of Residual Effects on Aquatic Resources VC, Changes in Water Quantity). The lower magnitude of predicted changes in water quantity in lower Harper Creek is within the range of natural variation, and is therefore not expected to have substantial Project-related effects on primary and secondary producers. Temperature effects from changes water quantity are predicted to be negligible (<0.1°C) and not considered further for aquatic resources (Section 14.5.3.1).

The predicted changes in water quantity in P Creek, T Creek, Baker Creek, and Harper Creek may also have effects on sediment quality (Tables 14.5-5 to 14.5-11; Section 12.5.3.1, Hydrology Effects Assessment). The deposition and scouring of stream sediments, as well as the accumulation of particle-associated metals, will be affected by changes in flow. The predicted decreases in peak flows (up to 100% in T Creek, up to 36% in P Creek, and up to 21% in Harper Creek) will result in less scouring and downstream advection of sediment and will likely cause increases in the deposition and accumulation of sediments. The magnitude of the changes in sediment composition will depend not only on water flow, but also micro- and reach-scale features in the streams. This enhanced accumulation of sediments will be offset by the predicted cessation of low flows in P Creek, T Creek, and Baker Creek; little sediment would be expected to be transported into and within streams in the absence of stream flow. Residual effects on sediment quality from changes in water quantity are assessed in Section 14.5.3.4.

Changes in Water Quality

To assess chemical loadings to the receiving environment, Knight Piésold developed water quality predictions for the Project using GoldSim. A summary of the model approach, assumptions, and sensitivity analyses are provided in Section 13.5.3. Full details are provided in Appendix 13-C, Harper Creek Project: Water Quality Predictions (KP 2014). Modelling node locations are provided in Figure 14.5-8.

The water quality model is based on monthly time steps and contains both contact and non-contact water that reports to T, P, Harper, Baker and Jones creeks, either directly or via a tributary. Results of water quality predictions include management and mitigation measures; that is, results indicating a change in water quality represent a residual effect to the surface water VC (see Section 13.5.3). For the purposes of the effects assessment, the expected case (for all modelling nodes) and the unrecovered seepage sensitivity case (for P Creek, HP, and HM modelling nodes only) of the water quality predictions were used (Appendix 13-C, Water Quality Predictive Model).

Methodology for Selecting Contaminants of Potential Concern

The methodology for selecting metals and anions to assess the potential for residual effects due to toxicity to the aquatic resources VC was the same as that described for fish in Section 14.5.3.1 (under *Changes in Water Quality*). This is because the BC WQGs used for selecting COPCs for the fish VC also apply to the aquatic resources VC. For the purposes of residual effects assessment, it was assumed that any change in water quality would also lead to a change in sediment quality; however the extent of the change to sediment quality (i.e., quantification or sediment quality predictions) was not determined. Additional description and summary of results of the COPC selection process can be found in Chapter 13 (Surface Water Quality Effects Assessment) and Appendix 13-D (Comparison of Predicted Water Quality to Water Quality Guidelines).

In addition to the potential for toxicity due to changes in water quality, nutrients (phosphorus and nitrogen-containing compounds such as ammonia, nitrate, and nitrite) can affect aquatic resources by altering productivity. The analysis of potential nutrient loading effects on aquatic resources focused on five representative months: January, May, June, August, and October. January, August, and October represent the periods during the winter, summer, and fall when surface water flows are generally driven by groundwater discharge and represent a baseflow condition. May represents the freshet period whereas June is the period of peak discharge.

To determine whether nitrogenous nutrients have the potential to cause residual effects to aquatic resources, the secondary screening step described previously to identify Project-related changes to water quality (i.e., comparison of predicted water concentrations of ammonia, nitrate, and nitrite to baseline water concentrations) was carried out for P Creek, T Creek, Harper Creek, Jones Creek, and Baker Creek. These areas are most likely to experience changes in nutrient loading as a result of Project activities. The threshold for determining the magnitude of change in nutrient concentrations was set to be 30%, which reflects the threshold between moderate and high magnitude ratings in the effects assessment methodology (Table 14.5-3).

The assessment of the potential effects from phosphorus on the aquatic resources follows the framework for phosphorus management published by Environment Canada (2004) and is supported by information from the baseline sampling program. The phosphorus guidance framework consists of using reference or baseline phosphorus concentrations to describe the current or unaffected status of the ecosystem in terms of trigger ranges of total phosphorus. These trigger ranges are associated with categories of natural ecosystem function that are termed trophic levels—these trophic levels range from low biomass, low productivity oligotrophic ecosystems to rich, high-biomass eutrophic ecosystems. Once the current or baseline trigger range is established, the predicted concentration of phosphorus is assessed against the maximum acceptable concentration within the baseline trigger range. If the upper limit of the baseline trigger range is predicted to be surpassed, then there is a potential risk of effects on the aquatic ecosystem. The guidelines recommend that total phosphorus should not: 1) be greater than predefined “trigger ranges;” or 2) increase more than 50% over baseline reference levels (CCME 2004; Environment Canada 2004).

Although total phosphorus is considered the most appropriate parameter for analyzing the effects of changes in phosphorus supply on primary producers (Dodds, Smith, and Lohman 2002; Dodds 2003; Environment Canada 2004), the water quality model was not designed to effectively model the concentrations of total phosphorus at a sufficient resolution for this analysis. Baseline conditions were used to assess the general nutrient status of the waterbodies in the assessment in terms of total phosphorus, as directed by the *Canadian Guidance Framework for Management of Phosphorus in Freshwater Systems* (Environment Canada 2004). The modelling results for orthophosphate (dissolved inorganic phosphate) were used to estimate the direction of the predicted changes in phosphorus concentration relative to baseline conditions.

Contaminants of Potential Concern – Potential for Toxicity

The metals and anion (except nutrients) COPCs selected are the same as what was described for the fish VC in Section 14.5.3.2 (under *Potential for Toxicity due to Changes in Water Quality*) and shown in Table 14.5-14.

Table 14.5-14. Contaminants of Potential Concern for the Aquatic Resources Valued Components

Model Node	Construction	Operations 1	Operations 2	Closure	Post-Closure
P Creek	-	Se	Se	-	-
T Creek	-	-	-	Cd-d, Cu, Se, SO_4	Cd-d, Cu, Se, SO_4, Zn
HP	-	Se	Se	-	-
HT	Cu	Cu, Se	Cu, Se	Cd-d, Cu, Se	Cd-d, Cu, Se
HB	-	-	-	Cd-d, Cu, Se	Cd-d, Cu, Se

Contaminants of Potential Concern – Nutrient Loading

Tables 14.5-15 to 14.5-21 present summaries of predicted nutrient concentrations in P Creek, T Creek, upper Harper Creek (HM and HT modelling nodes), lower Harper Creek (HB modelling node), Jones Creek (J1 modelling node), and Baker Creek (B0 modelling node) throughout the life of the

Project. Predictions for nutrient concentrations were taken from the expected case for all locations, and from the unrecovered seepage sensitivity case for P Creek and upper Harper Creek (HM node). The water quality model predicts that all forms of nitrogenous compounds (i.e., ammonia, nitrate, and nitrite) will be below BC WQGs during all the years modelled, with the exception of the concentration of ammonia in P Creek, which is naturally greater than the BC WQG in August in the baseline program (Tables 14.5-15 to 14.5-21; Appendix 13-C).

Table 14.5-15. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for P Creek

Nutrient	Project Phase	Month	Baseline Conc. (mean, mg/L)	Guideline[a]	Predicted Conc. (Expected Case, mean, mg/L)	Direction of Change[b]	Predicted Conc. (Seepage Case, mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.005	1.23	0.005	↔	0.033	↑
		May	0.005	2.03	0.005	↔	0.011	↑
		June	0.007	1.69	0.007	↔	0.014	↑
		August	1.3	1.15	1.3	↔	1.31	↔
		October	0.009	1.41	0.009	↔	0.068	↑
	Operations 1	January	0.005	1.23	0.005	↔	0.005	↔
		May	0.005	2.03	0.005	↔	0.016	↑
		June	0.007	1.69	0.007	↔	0.017	↑
		August	1.3	1.15	1.3	↔	1.31	↔
		October	0.009	1.41	0.009	↔	0.009	↔
	Operations 2, Closure and Post-Closure	January	0.005	1.23	0.005	↔	0.005	↔
		May	0.005	2.03	0.005	↔	0.005	↔
		June	0.007	1.69	0.007	↔	0.006	↔
		August	1.3	1.15	1.3	↔	1.25	↔
		October	0.009	1.41	0.009	↔	0.009	↔
Nitrite	Construction	January	0.001	0.02	0.001	↔	0.006	↑
		May	0.001	0.02	0.001	↔	0.002	↑
		June	0.001	0.02	0.001	↔	0.002	↑
		August	0.001	0.02	0.001	↔	0.004	↑
		October	0.002	0.02	0.002	↔	0.013	↑
	Operations 1	January	0.001	0.02	0.001	↔	0.001	↔
		May	0.001	0.02	0.001	↔	0.003	↑
		June	0.001	0.02	0.001	↔	0.003	↑
		August	0.001	0.02	0.001	↔	0.011	↑
		October	0.002	0.02	0.002	↔	0.002	↔
	Operations 2, Closure and Post-Closure	January	0.001	0.02	0.001	↔	0.001	↔

(continued)

Table 14.5-15. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for P Creek (completed)

Nutrient	Project Phase	Month	Baseline Conc. (mean, mg/L)	Guideline[a]	Predicted Conc. (Expected Case, mean, mg/L)	Direction of Change[b]	Predicted Conc. (Seepage Case, mean, mg/L)	Direction of Change[b]
	Operations 2, Closure and Post-Closure *(cont'd)*	May	0.001	0.02	0.001	↔	0.001	↔
		June	0.001	0.02	0.001	↔	0.001	↔
		August	0.001	0.02	0.001	↔	0.001	↔
		October	0.002	0.02	0.002	↔	0.002	↔
Nitrate	Construction	January	0.31	3	0.31	↔	0.52	↑
		May	0.54	3	0.54	↔	0.59	↔
		June	0.14	3	0.14	↔	0.2	↑
		August	0.13	3	0.13	↔	0.27	↑
		October	0.17	3	0.17	↔	0.63	↑
	Operations 1	January	0.31	3	0.31	↔	0.31	↔
		May	0.54	3	0.54	↔	0.63	↔
		June	0.14	3	0.14	↔	0.23	↑
		August	0.13	3	0.13	↔	0.57	↑
		October	0.17	3	0.17	↔	0.17	↔
	Operations 2, Closure and Post-Closure	January	0.31	3	0.31	↔	0.31	↔
		May	0.54	3	0.54	↔	0.54	↔
		June	0.14	3	0.14	↔	0.14	↔
		August	0.13	3	0.13	↔	0.13	↔
		October	0.17	3	0.17	↔	0.17	↔
Ortho-phosphate	Construction	January	0.001	N/A	0.001	↔	0.001	↔
		May	0.001		0.001	↔	0.001	↔
		June	0.001		0.001	↔	0.001	↔
		August	0.0017		0.0017	↔	0.0017	↔
		October	0.0023		0.0023	↔	0.0023	↔
	Operations[c], Closure and Post-Closure	January	0.001		0.001	↔	0.001	↔
		May	0.001		0.001	↔	0.001	↔
		June	0.001		0.001	↔	0.001	↔
		August	0.0017		0.0017	↔	0.0016	↔
		October	0.0023		0.0023	↔	0.0023	↔

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

[c] *Modelling results were the same for both Operations 1 and Operations 2 phases (Years 1 to 24).*

Concentrations of nitrogenous nutrients in P Creek are expected to remain the same or nearly the same as during baseline studies under the expected case, but are expected to increase under the unrecovered seepage case (Table 14.5-15). The concentrations of ammonia, nitrate, and nitrite are predicted to be at least 30% greater than baseline concentrations in T Creek, Jones Creek, Baker Creek, upper Harper Creek, and lower Harper Creek during some or all phases of the Project (Tables 14.5-16 to 14.5-21; increases identified by "↑"). There is potential that the change in nitrogenous nutrient concentrations may affect aquatic resources, and this will be carried forward for more detailed analysis in Section 14.5.3.4.

Total phosphorus concentrations were not modelled, but orthophosphate concentrations were included and were used to estimate the overall phosphorus changes in the receiving environment (Tables 14.5-15 to 14.5-21). The water quality modelling predicted phosphorus concentrations in P Creek and lower Harper Creek to be unchanged relative to baseline through all Project phases (Tables 14.5-15 and 14.5-19); residual effects due to phosphorus would not be expected in these locations. Phosphorus concentrations in Jones Creek were predicted to decrease in January and October relative to baseline concentrations (Table 14.5-19).

Table 14.5-16. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HM Modelling Node)

Nutrient	Project Phase	Month	Baseline Conc. (mean, mg/L)	Guideline[a]	Predicted Conc. (Expected Case, mean, mg/L)	Direction of Change[b]	Predicted Conc. (Seepage Case, mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.019	1.75	0.018	↔	0.035	↑
		May	0.010	2.00	0.010	↔	0.011	↔
		June	0.010	1.95	0.010	↔	0.036	↑
		August	0.83	1.87	0.61	↔	0.900	↔
		October	0.011	1.97	0.015	↑	0.028	↑
	Operations 1	January	0.019	1.75	0.023	↔	0.045	↑
		May	0.010	2.00	0.010	↔	0.011	↔
		June	0.010	1.95	0.011	↔	0.011	↔
		August	0.83	1.87	0.34	↓	0.874	↔
		October	0.011	1.97	0.022	↑	0.031	↑
	Operations 2, Closure, and Post-Closure	January	0.019	1.75	0.019	↔	0.018	↔
		May	0.010	2.00	0.010	↔	0.010	↔
		June	0.010	1.95	0.010	↔	0.009	↔
		August	0.83	1.87	0.34	↓	0.086	↔
		October	0.011	1.97	0.019	↑	0.011	↔
Nitrite	Construction	January	0.003	0.020	0.004	↔	0.006	↑
		May	0.001	0.020	0.001	↔	0.001	↔
		June	0.002	0.020	0.002	↔	0.002	↔

(continued)

Table 14.5-16. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HM Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Conc. (mean, mg/L)	Guideline[a]	Predicted Conc. (Expected Case, mean, mg/L)	Direction of Change[b]	Predicted Conc. (Seepage Case, mean, mg/L)	Direction of Change[b]
Nitrite *(cont'd)*	Construction *(cont'd)*	August	0.001	0.020	0.002	↑	0.003	↑
		October	0.002	0.020	0.003	↑	0.005	↑
	Operations[c], Closure, and Post-Closure	January	0.003	0.020	0.005	↑	0.003	↔
		May	0.001	0.020	0.001	↔	0.001	↔
		June	0.002	0.020	0.002	↔	0.002	↔
		August	0.001	0.020	0.004	↑	0.001	↔
		October	0.002	0.020	0.005	↑	0.002	↔
Nitrate	Construction	January	0.20	3.0	0.21	↔	0.45	↑
		May	0.30	3.0	0.33	↔	0.36	↔
		June	0.17	3.0	0.17	↔	0.18	↔
		August	0.08	3.0	0.13	↔	0.15	↑
		October	0.12	3.0	0.16	↑	0.26	↑
Nitrate *(cont'd)*	Operations 1	January	0.20	3.0	0.25	↔	0.42	↑
		May	0.30	3.0	0.36	↔	0.34	↔
		June	0.17	3.0	0.17	↔	0.18	↔
		August	0.08	3.0	0.20	↑	0.17	↑
		October	0.12	3.0	0.22	↑	0.28	↑
	Operations 2	January	0.20	3.0	0.21	↔	0.21	↔
		May	0.30	3.0	0.35	↔	0.33	↔
		June	0.17	3.0	0.17	↔	0.17	↔
		August	0.08	3.0	0.17	↑	0.09	↔
		October	0.12	3.0	0.20	↑	0.12	↔
	Closure, and Post-Closure	January	0.20	3.0	0.21	↔	0.21	↔
		May	0.30	3.0	0.36	↔	0.33	↔
		June	0.17	3.0	0.17	↔	0.17	↔
		August	0.08	3.0	0.17	↑	0.09	↔
		October	0.12	3.0	0.20	↑	0.12	↔
Ortho-phosphate	Construction	January	0.003	N/A	0.004	↑	0.002	↔
		May	0.001		0.001	↔	0.001	↔
		June	0.001		0.001	↔	0.001	↔
		August	0.002		0.003	↑	0.002	↔
		October	0.002		0.003	↑	0.002	↔

(continued)

Table 14.5-16. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HM Modelling Node; completed)

Nutrient	Project Phase	Month	Baseline Conc. (mean, mg/L)	Guideline[a]	Predicted Conc. (Expected Case, mean, mg/L)	Direction of Change[b]	Predicted Conc. (Seepage Case, mean, mg/L)	Direction of Change[b]
	Operations[c], Closure, and Post-Closure	January	0.003		0.005	↑	0.003	↔
		May	0.001		0.001	↔	0.001	↔
		June	0.001		0.001	↔	0.001	↔
		August	0.002		0.004	↑	0.002	↔
		October	0.002		0.005	↑	0.002	↔

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

[c] *Modelling results were the same for both Operations 1 and Operations 2 phases (Years 1 to 24).*

Table 14.5-17. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for T Creek

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.027	2.09	0.027	↔
		May	0.017	1.97	0.017	↔
		June	0.011	1.95	0.011	↔
		August	0.78	1.84	0.78	↔
		October	0.010	1.97	0.007	↔
	Operations[c]	January	0.027	2.09	0.027	↔
		May	0.017	1.97	0.017	↔
		June	0.011	1.95	0.011	↔
		August	0.78	1.84	0.78	↔
		October	0.010	1.97	0.010	↔
	Closure	January	0.027	2.09	0.099	↑
		May	0.017	1.97	0.071	↑
		June	0.011	1.95	0.084	↑
		August	0.78	1.84	0.45	↓
		October	0.010	1.97	0.11	↑
	Post-Closure	January	0.027	2.09	0.038	↑
		May	0.017	1.97	0.031	↑
		June	0.011	1.95	0.029	↑
		August	0.78	1.84	0.16	↓
		October	0.010	1.97	0.034	↑
Nitrite	Construction and Operations[c]	January	0.003	0.020	0.003	↔
		May	0.001	0.020	0.001	↔
		June	0.001	0.020	0.001	↔
		August	0.001	0.020	0.001	↔
		October	0.002	0.020	0.001	↔
	Closure	January	0.003	0.040	0.017	↑
		May	0.001	0.040	0.011	↑
		June	0.001	0.040	0.014	↑
		August	0.001	0.040	0.014	↑
		October	0.002	0.040	0.019	↑
	Post-Closure	January	0.003	0.040	0.006	↑
		May	0.001	0.040	0.004	↑
		June	0.001	0.040	0.004	↑
		August	0.001	0.040	0.005	↑
		October	0.002	0.040	0.005	↑

(continued)

Table 14.5-17. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for T Creek (continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Nitrate	Construction	January	0.088	3.0	0.088	↔
		May	0.007	3.0	0.007	↔
		June	0.006	3.0	0.006	↔
		August	0.040	3.0	0.040	↔
		October	0.022	3.0	0.014	↓
	Operations[c]	January	0.088	3.0	0.088	↔
		May	0.007	3.0	0.007	↔
		June	0.006	3.0	0.006	↔
		August	0.040	3.0	0.040	↔
		October	0.022	3.0	0.021	↔
	Closure	January	0.088	3.0	0.70	↑
		May	0.007	3.0	0.47	↑
		June	0.006	3.0	0.60	↑
		August	0.040	3.0	0.61	↑
		October	0.022	3.0	0.81	↑
	Post-Closure	January	0.088	3.0	0.25	↑
		May	0.007	3.0	0.17	↑
		June	0.006	3.0	0.17	↑
		August	0.040	3.0	0.20	↑
		October	0.022	3.0	0.23	↑
Ortho-phosphate	Construction	January	0.0034	N/A	0.003	↔
		May	0.0011		0.001	↔
		June	0.0011		0.001	↔
		August	0.0020		0.0017	↔
		October	0.0024		0.0013	↓
	Operations[c]	January	0.0034		0.003	↔
		May	0.0011		0.001	↔
		June	0.0011		0.001	↔
		August	0.0020		0.0017	↔
		October	0.0024		0.0019	↔
	Closure	January	0.0034		0.0028	↔
		May	0.0011		0.0017	↑
		June	0.0011		0.0019	↑
		August	0.0020		0.0022	↔
		October	0.0024		0.0024	↔

(continued)

Table 14.5-17. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for T Creek (completed)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ortho-phosphate *(cont'd)*	Post-Closure	January	0.0034		0.0039	↔
		May	0.0011		0.0030	↑
		June	0.0011		0.0030	↑
		August	0.0020		0.0035	↑
		October	0.0024		0.0037	↑

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

[c] *Modelling results were the same for both Operations 1 and Operations 2 phases (Years 1 to 24).*

Table 14.5-18. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HT Modelling Node)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.020	1.75	0.018	↔
		May	0.012	2.00	0.011	↔
		June	0.010	1.95	0.009	↔
		August	0.82	1.87	0.69	↔
		October	0.011	1.97	0.016	↑
	Operations 1	January	0.020	1.75	0.023	↔
		May	0.012	2.00	0.011	↔
		June	0.010	1.95	0.011	↔
		August	0.82	1.87	0.36	↓
		October	0.011	1.97	0.022	↑
	Operations 2	January	0.020	1.75	0.019	↔
		May	0.012	2.00	0.011	↔
		June	0.010	1.95	0.010	↔
		August	0.82	1.87	0.36	↓
		October	0.011	1.97	0.019	↑
	Closure	January	0.020	1.75	0.039	↑
		May	0.012	2.00	0.033	↑
		June	0.010	1.95	0.044	↑
		August	0.82	1.87	0.35	↓
		October	0.011	1.97	0.051	↑

(continued)

Table 14.5-18. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HT Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia *(cont'd)*	Post-Closure	January	0.020	1.75	0.024	↔
		May	0.012	2.00	0.018	↑
		June	0.010	1.95	0.019	↑
		August	0.82	1.87	0.31	↓
		October	0.011	1.97	0.025	↑
Nitrite	Construction	January	0.0030	0.020	0.0033	↔
		May	0.0010	0.020	0.0011	↔
		June	0.0017	0.020	0.0017	↔
		August	0.0013	0.020	0.0025	↑
		October	0.0023	0.020	0.0037	↑
	Operations 1	January	0.0030	0.020	0.0053	↑
		May	0.0010	0.020	0.0013	↔
		June	0.0017	0.020	0.0021	↔
		August	0.0013	0.020	0.0043	↑
		October	0.0023	0.020	0.0052	↑
	Operations 2	January	0.0030	0.020	0.0046	↑
		May	0.0010	0.020	0.0013	↔
		June	0.0017	0.020	0.0020	↔
		August	0.0013	0.020	0.0036	↑
		October	0.0023	0.020	0.0047	↑
	Closure	January	0.0030	0.020	0.0079	↑
		May	0.0010	0.020	0.0052	↑
		June	0.0017	0.020	0.0087	↑
		August	0.0013	0.020	0.0051	↑
		October	0.0023	0.020	0.0080	↑
	Post-Closure	January	0.0030	0.020	0.0049	↑
		May	0.0010	0.020	0.0025	↑
		June	0.0017	0.020	0.0032	↑
		August	0.0013	0.020	0.0040	↑
		October	0.0023	0.020	0.0049	↑
Nitrate	Construction	January	0.16	3.0	0.18	↔
		May	0.18	3.0	0.25	↑
		June	0.09	3.0	0.11	↔
		August	0.09	3.0	0.12	↑
		October	0.12	3.0	0.16	↔

(continued)

Table 14.5-18. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HT Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Nitrate *(cont'd)*	Operations 1	January	0.16	3.0	0.25	↑
		May	0.18	3.0	0.31	↑
		June	0.09	3.0	0.14	↑
		August	0.09	3.0	0.19	↑
		October	0.12	3.0	0.22	↑
	Operations 2	January	0.16	3.0	0.21	↑
		May	0.18	3.0	0.30	↑
		June	0.09	3.0	0.14	↑
		August	0.09	3.0	0.16	↑
		October	0.12	3.0	0.20	↑
	Closure	January	0.16	3.0	0.35	↑
		May	0.18	3.0	0.43	↑
		June	0.09	3.0	0.38	↑
		August	0.09	3.0	0.23	↑
		October	0.12	3.0	0.43	↑
	Post-Closure	January	0.16	3.0	0.23	↑
		May	0.18	3.0	0.28	↑
		June	0.09	3.0	0.17	↑
		August	0.09	3.0	0.18	↑
		October	0.12	3.0	0.21	↑
Ortho-phosphate	Construction	January	0.0025	N/A	0.0033	↑
		May	0.0009		0.0011	↔
		June	0.0009		0.0015	↑
		August	0.0023		0.0030	↔
		October	0.0028		0.0034	↔
	Operations[c]	January	0.0025		0.0047	↑
		May	0.0009		0.0013	↑
		June	0.0009		0.0014	↑
		August	0.0023		0.0039	↑
		October	0.0028		0.0047	↑
	Closure	January	0.0025		0.0043	↑
		May	0.0009		0.0015	↑
		June	0.0009		0.0017	↑
		August	0.0023		0.0038	↑
		October	0.0028		0.0042	↑

(continued)

Table 14.5-18. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Upper Harper Creek (HT Modelling Node; completed)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ortho-phosphate	Post-Closure	January	0.0025		0.0044	↑
		May	0.0009		0.0020	↑
		June	0.0009		0.0022	↑
		August	0.0023		0.0039	↑
		October	0.0028		0.0044	↑

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

[c] *Modelling results were the same for both Operations 1 and Operations 2 phases (Years 1 to 24).*

Table 14.5-19. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Lower Harper Creek (HB Modelling Node)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.019	2.05	0.019	↔
		May	0.014	1.92	0.013	↔
		June	0.012	1.90	0.011	↔
		August	0.11	1.82	0.16	↑
		October	0.008	1.95	0.010	↔
	Operations 1	January	0.019	2.05	0.020	↔
		May	0.014	1.92	0.013	↔
		June	0.012	1.90	0.011	↔
		August	0.11	1.82	0.19	↑
		October	0.008	1.95	0.012	↑
	Operations 2	January	0.019	2.05	0.019	↔
		May	0.014	1.92	0.013	↔
		June	0.012	1.90	0.011	↔
		August	0.11	1.82	0.19	↑
		October	0.008	1.95	0.011	↔
	Closure	January	0.019	2.05	0.027	↑
		May	0.014	1.92	0.021	↑
		June	0.012	1.90	0.025	↑
		August	0.11	1.82	0.19	↑
		October	0.008	1.95	0.022	↑

(continued)

Table 14.5-19. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Lower Harper Creek (HB Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia *(cont'd)*	Post-Closure	January	0.019	2.05	0.021	↔
		May	0.014	1.92	0.016	↔
		June	0.012	1.90	0.015	↔
		August	0.11	1.82	0.19	↑
		October	0.008	1.95	0.014	↑
Nitrite	Construction	January	0.0030	0.020	0.0032	↔
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0012	↔
		August	0.0013	0.020	0.0017	↔
		October	0.0023	0.020	0.0026	↔
	Operations 1	January	0.0030	0.020	0.0038	↔
		May	0.0010	0.020	0.0011	↔
		June	0.0010	0.020	0.0014	↑
		August	0.0013	0.020	0.0023	↑
		October	0.0023	0.020	0.0030	↑
	Operations 2	January	0.0030	0.020	0.0035	↔
		May	0.0010	0.020	0.0011	↔
		June	0.0010	0.020	0.0013	↔
		August	0.0013	0.020	0.0021	↑
		October	0.0023	0.020	0.0028	↔
	Closure	January	0.0030	0.020	0.0050	↑
		May	0.0010	0.020	0.0026	↑
		June	0.0010	0.020	0.0037	↑
		August	0.0013	0.020	0.0027	↑
		October	0.0023	0.020	0.0048	↑
	Post-Closure	January	0.0030	0.020	0.0038	↔
		May	0.0010	0.020	0.0016	↑
		June	0.0010	0.020	0.0019	↑
		August	0.0013	0.020	0.0023	↑
		October	0.0023	0.020	0.0031	↑
Nitrate	Construction	January	0.12	3.0	0.14	↔
		May	0.14	3.0	0.17	↔
		June	0.03	3.0	0.05	↑
		August	0.03	3.0	0.05	↑
		October	0.04	3.0	0.06	↑

(continued)

Table 14.5-19. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Lower Harper Creek (HB Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Nitrate *(cont'd)*	Operations 1	January	0.12	3.0	0.16	↑
		May	0.14	3.0	0.19	↑
		June	0.03	3.0	0.07	↑
		August	0.03	3.0	0.08	↑
		October	0.04	3.0	0.08	↑
	Operations 2	January	0.12	3.0	0.15	↑
		May	0.14	3.0	0.19	↑
		June	0.03	3.0	0.07	↑
		August	0.03	3.0	0.08	↑
		October	0.04	3.0	0.08	↑
	Closure	January	0.12	3.0	0.21	↑
		May	0.14	3.0	0.25	↑
		June	0.03	3.0	0.17	↑
		August	0.03	3.0	0.10	↑
		October	0.04	3.0	0.16	↑
	Post-Closure	January	0.12	3.0	0.16	↑
		May	0.14	3.0	0.20	↑
		June	0.03	3.0	0.09	↑
		August	0.03	3.0	0.09	↑
		October	0.04	3.0	0.09	↑
Ortho-phosphate	Construction	January	0.0029	N/A	0.0032	↔
		May	0.0010		0.0010	↔
		June	0.0010		0.0011	↔
		August	0.0018		0.0020	↔
		October	0.0022		0.0023	↔
	Operations[c]	January	0.0029		0.0035	↔
		May	0.0010		0.0011	↔
		June	0.0010		0.0011	↔
		August	0.0018		0.0024	↔
		October	0.0022		0.0027	↔
	Closure	January	0.0029		0.0035	↔
		May	0.0010		0.0012	↔
		June	0.0010		0.0013	↔
		August	0.0018		0.0024	↔
		October	0.0022		0.0027	↔

(continued)

Table 14.5-19. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Lower Harper Creek (HB Modelling Node; completed)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ortho-phosphate *(cont'd)*	Post-Closure	January	0.0029		0.0036	↔
		May	0.0010		0.0014	↔
		June	0.0010		0.0015	↔
		August	0.0018		0.0025	↔
		October	0.0022		0.0028	↔

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

[c] *Modelling results were the same for both Operations 1 and Operations 2 phases (Years 1 to 24).*

Table 14.5-20. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Jones Creek (J1 Modelling Node)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.016	2.05	0.009	↓
		May	0.011	1.92	0.011	↔
		June	0.007	1.90	0.008	↔
		August	0.011	1.82	0.013	↔
		October	0.009	1.95	0.009	↔
	Operations[c]	January	0.016	2.05	0.009	↓
		May	0.011	1.92	0.010	↔
		June	0.007	1.90	0.007	↔
		August	0.011	1.82	0.013	↔
		October	0.009	1.95	0.009	↔
	Closure and Post-Closure	January	0.016	2.05	0.009	↓
		May	0.011	1.92	0.011	↔
		June	0.007	1.90	0.008	↔
		August	0.011	1.82	0.014	↔
		October	0.009	1.95	0.009	↔
Nitrite	Construction	January	0.0030	0.020	0.0010	↓
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0010	↔
		August	0.0010	0.020	0.0010	↔
		October	0.0023	0.020	0.0016	↔

(continued)

Table 14.5-20. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Jones Creek (J1 Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Nitrite *(cont'd)*	Operations 1	January	0.0030	0.020	0.0011	↓
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0010	↔
		August	0.0010	0.020	0.0010	↔
		October	0.0023	0.020	0.0016	↔
	Operations 2	January	0.0030	0.020	0.0010	↓
		May	0.0010	0.020	0.0013	↔
		June	0.0010	0.020	0.0010	↔
		August	0.0010	0.020	0.0010	↔
		October	0.0023	0.020	0.0016	↔
	Closure	January	0.0030	0.020	0.0012	↓
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0010	↔
		August	0.0010	0.020	0.0011	↔
		October	0.0023	0.020	0.0017	↔
	Post-Closure	January	0.0030	0.020	0.0011	↓
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0010	↔
		August	0.0010	0.020	0.0010	↔
		October	0.0023	0.020	0.0016	↔
Nitrate	Construction	January	0.067	3.0	0.028	↓
		May	0.041	3.0	0.039	↔
		June	0.006	3.0	0.008	↔
		August	0.013	3.0	0.022	↑
		October	0.009	3.0	0.020	↑
	Operations 1	January	0.067	3.0	0.028	↓
		May	0.041	3.0	0.039	↔
		June	0.006	3.0	0.007	↔
		August	0.013	3.0	0.021	↑
		October	0.009	3.0	0.019	↑
	Operations 2	January	0.067	3.0	0.028	↓
		May	0.041	3.0	0.038	↔
		June	0.006	3.0	0.007	↔
		August	0.013	3.0	0.021	↑
		October	0.009	3.0	0.019	↑

(continued)

Table 14.5-20. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Jones Creek (J1 Modelling Node; completed)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Nitrate *(cont'd)*	Closure	January	0.067	3.0	0.033	↓
		May	0.041	3.0	0.039	↔
		June	0.006	3.0	0.008	↔
		August	0.013	3.0	0.023	↑
		October	0.009	3.0	0.021	↑
	Post-Closure	January	0.067	3.0	0.030	↓
		May	0.041	3.0	0.039	↔
		June	0.006	3.0	0.007	↔
		August	0.013	3.0	0.022	↑
		October	0.009	3.0	0.020	↑
Ortho-phosphate	Construction	January	0.0030	N/A	0.0012	↓
		May	0.0025		0.0023	↔
		June	0.0010		0.0010	↔
		August	0.0018		0.0014	↔
		October	0.0045		0.0026	↓
	Operations[c], Closure, and Post-Closure	January	0.0030		0.0012	↓
		May	0.0025		0.0023	↔
		June	0.0010		0.0010	↔
		August	0.0018		0.0014	↔
		October	0.0045		0.0027	↓

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

[c] *Modelling results were the same for both Operations 1 and Operations 2 phases (Years 1 to 24).*

Phosphorus concentrations are predicted to increase in T Creek and in upper Harper Creek during the Closure and Post-Closure phases (Tables 14.5-16 and 14.5-18). The increases are predicted to occur during freshet, summer, and fall, which are the periods of potential overland flow. The predicted increases are relatively modest (i.e., generally less than a 2-fold increase in orthophosphate concentration). If total phosphorus is assumed to change linearly with orthophosphate, then the maximum expected change in total phosphorus is 2-fold. Mean total phosphorus values for T Creek and Harper Creek are approximately 0.004 mg/L in the baseline sampling program (Chapter 13 and Appendices 13-A and 13-B). If total phosphorus concentrations doubled, as predicted from the model change in orthophosphate concentrations, then total phosphorus concentrations in T Creek and Harper Creek would be expected to remain less than 0.010 mg/L. Based on the guidance framework for phosphorus, this greater than 50% increase in phosphorus during the Closure and Post-Closure phases in T Creek and Harper Creek has the potential to have residual effects on the growth and community structure of the primary producer community.

Table 14.5-21. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Baker Creek (B0 Modelling Node)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ammonia	Construction	January	0.017	2.05	0.022	↔
		May	0.013	1.92	0.017	↔
		June	0.009	1.90	0.009	↔
		August	0.010	1.82	0.060	↑
		October	0.012	1.95	0.014	↔
	Operations 1	January	0.017	2.05	0.017	↔
		May	0.013	1.92	0.017	↔
		June	0.009	1.90	0.009	↔
		August	0.010	1.82	0.069	↑
		October	0.012	1.95	0.012	↔
	Operations 2	January	0.017	2.05	0.016	↔
		May	0.013	1.92	0.017	↔
		June	0.009	1.90	0.009	↔
		August	0.010	1.82	0.070	↑
		October	0.012	1.95	0.012	↔
	Closure and Post-Closure	January	0.017	2.05	0.016	↔
		May	0.013	1.92	0.017	↔
		June	0.009	1.90	0.009	↔
		August	0.010	1.82	0.069	↑
		October	0.012	1.95	0.012	↔
Nitrite	Construction	January	0.0030	0.020	0.0049	↑
		May	0.0010	0.020	0.0011	↔
		June	0.0010	0.020	0.0011	↔
		August	0.0013	0.020	0.0024	↑
		October	0.0023	0.020	0.0030	↔
	Operations 1	January	0.0030	0.020	0.0039	↑
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0011	↔
		August	0.0013	0.020	0.0018	↔
		October	0.0023	0.020	0.0026	↔
	Operations 2	January	0.0030	0.020	0.0037	↑
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0011	↔
		August	0.0013	0.020	0.0018	↔
		October	0.0023	0.020	0.0026	↔

(continued)

Table 14.5-21. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Baker Creek (B0 Modelling Node; continued)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Nitrite *(cont'd)*	Closure and Post-Closure	January	0.0030	0.020	0.0038	↑
		May	0.0010	0.020	0.0010	↔
		June	0.0010	0.020	0.0011	↔
		August	0.0013	0.020	0.0018	↔
		October	0.0023	0.020	0.0026	↔
Nitrate	Construction	January	0.046	3.0	0.062	↑
		May	0.009	3.0	0.025	↑
		June	0.005	3.0	0.008	↑
		August	0.020	3.0	0.047	↑
		October	0.022	3.0	0.043	↑
	Operations 1	January	0.046	3.0	0.071	↑
		May	0.009	3.0	0.024	↑
		June	0.005	3.0	0.006	↑
		August	0.020	3.0	0.042	↑
		October	0.022	3.0	0.037	↑
	Operations 2	January	0.046	3.0	0.073	↑
		May	0.009	3.0	0.024	↑
		June	0.005	3.0	0.006	↑
		August	0.020	3.0	0.041	↑
		October	0.022	3.0	0.036	↑
	Closure and Post-Closure	January	0.046	3.0	0.072	↑
		May	0.009	3.0	0.024	↑
		June	0.005	3.0	0.006	↑
		August	0.020	3.0	0.042	↑
		October	0.022	3.0	0.036	↑
Ortho-phosphate	Construction	January	0.0030	N/A	0.0048	↑
		May	0.0010		0.0035	↑
		June	0.0010		0.0011	↔
		August	0.0013		0.0022	↑
		October	0.0021		0.0028	↑
	Operations 1	January	0.0030		0.0036	↔
		May	0.0010		0.0034	↑
		June	0.0010		0.0011	↔
		August	0.0013		0.0016	↔
		October	0.0021		0.0023	↔

(continued)

Table 14.5-21. Summary of Nutrient Concentrations from the Predictive Water Quality Modelling for Baker Creek (B0 Modelling Node; completed)

Nutrient	Project Phase	Month	Baseline Concentration (mean, mg/L)	Guideline[a]	Predicted Concentration (mean, mg/L)	Direction of Change[b]
Ortho-phosphate	Operations 2	January	0.0030		0.0035	↔
		May	0.0010		0.0034	↑
		June	0.0010		0.0011	↔
		August	0.0013		0.0016	↔
		October	0.0021		0.0023	↔
	Closure	January	0.0030		0.0036	↔
		May	0.0010		0.0034	↑
		June	0.0010		0.0011	↔
		August	0.0013		0.0017	↔
		October	0.0021		0.0023	↔
	Post-Closure	January	0.0030		0.0035	↔
		May	0.0010		0.0034	↑
		June	0.0010		0.0011	↔
		August	0.0013		0.0017	↔
		October	0.0021		0.0023	↔

[a] *BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2014d); guideline for nitrite is chloride-dependent and guideline for ammonia is pH- and temperature-dependent, shown are the guidelines calculated from mean values of those modifying parameters.*

[b] *Direction of change determine relative to baseline ±30%.*

In Baker Creek, phosphorus concentrations were predicted to increase during freshet (May) across all phases of the Project, as well as increase in all seasons during the Construction Phase (Table 14.5-21). The maximum relative increase in orthophosphate concentrations was approximately 3-fold. If a 3-fold increase in total phosphorus concentrations is predicted, then total phosphorus concentrations in Baker Creek would be expected to be approximately 0.009 mg/L (baseline values approximately 0.003 mg/L, Chapter 13 and Appendices 13-A and 13-B). However, like the predicted increase in phosphorus concentrations in T Creek and Harper Creek, this increase in Baker Creek would be greater than 50% of baseline and therefore has the potential for residual effects on the primary producer community.

14.5.3.4 *Characterization of Residual Effects on Aquatic Resources Valued Component*

The residual effects on aquatic resources described in Section 14.5.3.5 are classified using the criteria defined in Table 14.5-3. Each summary refers to the discussion and analysis presented in Section 14.5.3.5 to determine the value of each criterion.

Changes in Water Quantity

The predicted cessation of flow in P and T creeks will have substantial effects on the primary and secondary producers. Although stream aquatic organisms are adapted to these naturally variable environments, ephemeral environments support different communities (Reece and Richardson 2000).

The predicted cessation of flows in P and T creeks represent a change towards these ephemeral systems, which would be accompanied by substantial changes to the primary and secondary producer communities. Furthermore, the deposition and transport of sediments would also be altered, and is predicted to result in changes to sediment quality and the distribution of deposition environments.

The predicted decreases in flows in Jones Creek are predicted to occur generally during winter (February and March) and then again in summer (August and September; Table 14.5-11). Similarly, the predicted decreases in flows in Baker Creek occur in summer (August and September; Table 14.5-10). The effects on aquatic resources in Jones Creek are predicted to be smaller. The largest predicted decreases, in winter, would occur during periods of naturally low baseflow, which also coincide with a period of minimal biological activity because of the low temperatures and light-limited conditions. Aquatic organisms would likely be acclimatized to these conditions and may be more resilient to Project-related decreases in flow. The predicted summer decreases in flow, in contrast, are smaller in magnitude (40 to 55% for Jones and 30 to 50% for Baker Creek). The decreases in flows are predicted to decrease the available habitat for aquatic organisms, and this is predicted to be generally proportional to the decrease in flow. As a result, the predicted effects on aquatic resources from the decreases in flows in Baker and Jones creeks would be greater than the range of natural variation.

Hydrologic changes to Harper Creek are predicted to be smaller in magnitude than the changes in the headwater P and T creeks, and are expected to have the largest relative effect in upper Harper Creek (Table 14.5-6). The largest predicted decrease in upper Harper Creek is 33% during the Operations Phase, which may be sufficient to change the distribution of habitat and composition of sediments. In addition to these in-stream changes, the decreases in flows from P Creek and T Creek would also reduce the input of drifting invertebrates and organic matter (Gomi, Sidle, and Richardson 2002; Wipfli, Richardson, and Naiman 2007). Stream productivity is partially dependent on allochthonous inputs of organic matter and prey organisms, and the aquatic organisms in low-order streams like Harper Creek may rely on the inputs from headwater creeks, which may contribute between 4 and 45% of the total secondary production (Wipfli and Gregovich 2002). For upper Harper Creek, stream productivity is therefore predicted to decrease as a result of the reduction in in-stream habitat and changes in sediment quality through the deposition of sediments due to decreases in water quantity combined with the loss of subsidies from P and T Creek. The abundance and composition of the secondary producer community is predicted to change as a result relative to baseline conditions, and is expected to be greatest during the Operations phase when the greatest decreases in annual flows in P, T, and upper Harper creeks are predicted to occur.

The effects of changes in water quantity further downstream from the Project Site in lower Harper Creek are predicted to be relatively small compared to upper Harper Creek. The predicted overall reductions in flow are smaller (only 2-fold greater than the expected error in the model). Furthermore, the indirect effects from the decrease in headwater stream subsidies will be reduced by the decreased contribution of the P Creek and T Creek watersheds to the overall catchment area (and the subsidies of organic matter and prey organisms). The watershed areal contribution from P Creek and T Creek is less than 15% at the outflow of Harper Creek. Therefore, the changes to aquatic resources from decreases in water quantity in lower Harper Creek are predicted to more moderate than the predicted changes higher in the watershed and more likely to be within the range of natural variation. This attenuation of the effect with distance is expected to restrict any indirect effects to Harper Creek.

The recovery of stream primary producer and secondary producer communities depends on recruitment of new individuals from other populations or propagules from “seed banks” in sediments (Hughes 2007). Upstream movement by swimming organisms is likely limited to the reach scale (Hughes 2007), but organisms with flying adult forms, such as the benthic invertebrates dominant in Harper Creek and its tributaries in the baseline program, can establish new populations at substantial distances (>10 km; Bunn and Hughes 1997; Malmqvist 2002; Hughes 2007). However, these colonization events are often caused by the immigration of only a few individual adults, and can vary significantly because of differences in the flight capabilities, life histories, and environmental conditions (Bunn and Hughes 1997; Hughes 2007). As a result of this susceptibility to stochastic processes, the resiliency of the community—to return to its previous composition and abundance after a disturbance—in headwater systems is reduced. Disturbance is a feature of headwater systems, and organisms present in headwater streams like T Creek and Harper Creek are adapted to stochastic ecosystem processes like mass wasting events or wildfires (Lamberti et al. 1991; Gomi, Sidle, and Richardson 2002; Malmqvist 2002). However, the composition and abundance of the aquatic organisms may differ after recovery from the disturbance. In the context of the predicted decrease in aquatic habitat in T Creek, and consequent decreases in the abundance and diversity of aquatic organisms, the recovery after the restoration of near-baseline streamflows will likely occur. The composition of the post-disturbance communities, however, may be significantly different from the baseline communities.

The recovery of sediment quality will depend on the restoration of flow regimes. Low order streams, like the streams in the LSA, are stochastic and sensitive to random natural events such as mass wasting or tree falls, which alter the distribution of depositional areas within a stream (Gomi, Sidle, and Richardson 2002). Although the locations and composition of sediment depositional areas in the LSA may be different after Closure, on a stream scale it is expected that sediment quality will be broadly similar to baseline conditions.

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to aquatic resources due to a change in water quantity is described as:

- Magnitude: **low** for lower Harper Creek, **medium** for upper Harper Creek, and **high** for P Creek, T Creek, Jones Creek, and Baker Creek.
- Extent: **local** because no changes in water quantity (flow) are predicted outside of the LSA (Section 12.5.3, Hydrology Effects Assessment).
- Duration: the effect is predicted to extend to the **far future** because of the long-term alterations in flows.
- Frequency: residual effects are predicted to be **continuous**
- Reversibility: **Partially-reversible**, with restoration of natural drainage systems and re-colonization of affected habitat from downstream and nearby populations. Complete return to baseline conditions may not be probable because of the predicted changes in Post-Closure.
- Resiliency: **Neutral**, aquatic resources in headwater and low-order streams are naturally adapted to disturbances but the return to pre-disturbance state is affected by stochastic processes related to re-colonization.

Potential for Toxicity due to Changes in Water Quality

The following sections describe the potential primary and secondary producer receptors that may be present at the modelling nodes where water concentrations of various parameters are predicted to be greater than guidelines. It was assumed that sediment quality at the nodes where water quality is affected may also be changed; however, the potential change in sediment quality was not quantified. The residual effects to aquatic resources (i.e., primary and secondary producers) are assumed to be due to a combination of changes in water quality and changes in sediment quality.

These sections define a toxicity threshold, based on the receptors that may be present, at each modelling node to determine whether or not the predicted concentrations are greater than toxicity thresholds. This information is useful for defining the magnitude of the residual effect.

P Creek (Based on the P Creek Modelling Node)

Selenium during the Operations 1 and 2 phases was the only COPC retained for consideration at the P Creek modelling node (Section 14.5.3.1 and Table 14.5-13).

Baseline studies found that the periphyton community in P Creek (OP-10 site) was dominated by organisms from Myxophyceae (cyanobacteria) and Bacillariophyceae (diatoms), while the benthic invertebrate community was dominated by organisms from the order Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies; Section 14.4.3.3; Appendix 14-A). Since these organisms make up the majority of the primary and secondary producer community in P Creek (74 to >90%), they were considered when determining toxicity thresholds for potential effects due to changes in water quality.

Selenium

Most aquatic resources are thought to be less sensitive to toxicity due to selenium than fish or other egg-laying vertebrates (P. M. Chapman et al. 2009). Generally, the concentration of selenium required to cause adverse effects in aquatic resources is greater than 40 µg/L (reviewed in DeBruyn and Chapman 2007). However, DeBruyn and Chapman (2007) suggest that some species of aquatic resources may be equally or more sensitive, when considered based on tissue residues rather than water concentrations. For example, while Swift (2002) found that long term (three years) of exposure to 10 µg selenium/L had no significant effects on macroinvertebrate abundance, diversity, and richness in general, *Caecidotea* (isopod) and *Tubifex* (tubificid worm) abundance did significantly decrease. These more sensitive species were not identified in aquatic resources baseline studies in T Creek; however, a concentration of 10 µg/L of selenium was calculated to be the "safe" target for selenium for fish, and, based on professional judgement and the available scientific literature, this was also used as the toxicity threshold for aquatic resources (Section 24.12).

Selenium concentrations in water are predicted to be greater than the BC WQG (0.002 mg/L or 2 µg/L) in August of Years 3 to 28 (Operations 1 and Operations 2 phases). The concentration 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 this is below the concentration that is expected to be protective of aquatic resources (10 µg/L) in a lotic environment, it is unlikely that effects to primary or secondary producers will occur. Monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Characterization of Residual Effects to the Aquatic Resources Valued Component in P Creek (P Creek Modelling Node)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to the aquatic resources VC due to changes in water quality in P Creek (based on the unrecovered seepage sensitivity case of the water quality model; Section 14.5.3.3, Table 14.5-14, and Appendices 13-C and 13-D) is described as follows.

- Magnitude: **Medium**. Selenium concentrations in water are predicted to be between two and five times higher than the BC WQG during the Operations 1 and Operations 2 phases. Predicted concentrations of selenium are predicted to be lower than toxicity thresholds for fish (as defined by the target concentration for selenium of 10 µg/L from the Selenium Management Plan, Section 24.12) throughout the phases of the Project in P Creek. Sediment quality is also likely to change as a result of increased selenium concentrations in water.
- Extent: **Local**. The change in water quality that could affect aquatic resources is limited to P Creek, within the LSA.
- Duration: **Medium-term**. The potential for effects to aquatic resources due to change in water quality at P Creek is predicted to occur only during some of the Operations 1 and Operations 2 phases (duration between 2 and 30 years).
- Frequency: **Sporadic**. Concentrations of selenium at the P Creek modelling node are predicted to be greater than the 30-day average BC WQG only in August between Years 3 and 28.
- Reversibility: **Reversible**: Concentrations of selenium are predicted to be greater than the 30-day average BC WQG only during the Operations 1 and 2 phases, and are predicted to be below the 30-day average BC WQG after Year 29. The potential for effects to aquatic resources will diminish or disappear once the selenium concentrations return to baseline levels.
- Resiliency: **Neutral**. Aquatic resources are somewhat resilient to effects of changes in water quality since they are adapted to living in a constantly changing environment (e.g., due to annual floods, temperature fluctuations, changes in nutrient availability, etc.). Some aquatic resources are also able to adapt to higher concentrations of metals within a short period of time.

T Creek (Based on the T Creek Modelling Node)

Baseline studies found that the periphyton community in T Creek (TMF-10 and TMF-20 sites) was dominated by organisms from Myxophyceae (cyanobacteria) and Bacillariophyceae (diatoms), while the benthic invertebrate community was dominated by organisms from the order Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies; Section 14.4.3.3; Appendix 14-A). Since these organisms make up the majority of the primary and secondary producer community in T Creek (74 to >90%), they were considered when determining toxicity thresholds for potential effects due to changes in water quality.

Potential for Acute Toxicity (Lethality) to the Aquatic Resources Valued Component

Concentrations of dissolved cadmium and total copper in water are predicted to be greater than the maximum BC WQG at the T Creek modelling node during the Closure and Post-Closure phases, suggesting that the potential for acute lethality to aquatic resources needs to be considered at this location.

A literature search was conducted to determine what the toxicity threshold is for acute toxicity due to cadmium or copper, with emphasis on any available information on the primary and secondary producers that were most commonly identified during baseline studies (Section 14.4.3.3; Appendix 14-A). The toxicity threshold for the most sensitive species (for which data exists) was used to define the toxicity threshold for aquatic resources.

The literature search considered existing technical summaries used for development of guidelines (e.g., BC WQG or CCME WQGs), data summaries reported in the ECOTOX database (US EPA 2014), and published peer-reviewed studies. The LC_{50} value (i.e., the concentration that causes lethality in 50% of the test organisms) was used, if available, to define the acute toxicity threshold.

Cadmium

Although the draft BC WQG for cadmium is for the dissolved fraction, many toxicity studies report toxicity on the basis of total cadmium. Therefore, when considering the potential for effects, both the toxicity threshold and the predicted concentrations used were for total cadmium.

The acute toxicity threshold for the most sensitive invertebrate species included in the recently updated CCME cadmium guideline WQG were *Hyalella azteca*, with a reported 96-hour LC_{50} value of 0.00084 mg/L, and *Daphnia magna*, with a reported 72-hour LC_{50} of 0.00091 mg/L (CCME 2014b). However, no amphipods identified in T Creek during baseline studies, and it is possible they could be present. No cladocerans were found during baseline studies, but they would not be expected to be present in lotic (stream) environments since they are very susceptible to changes in flow.

Mebane, Dillon, and Hennessy (2012) found the larvae of the mayfly *Baetis tricaudatus* had a 96-hour LC_{50} of 0.016 mg/L (water hardness of 59 mg/L) or 0.074 mg/L (water hardness of 21 mg/L). This study was conducted using field-collected stream water as the test water, so it is possible that other contaminants that were not measured may have influenced the toxicity reported in the study. However, since mayflies were among the most common aquatic invertebrates identified during baseline studies in T Creek, the acute toxicity threshold for aquatic resources for cadmium at T Creek was based on this study.

The maximum concentration of total cadmium at the T Creek modelling node is predicted to be 0.00011 mg/L, occurring in several winter months in Years 49 to 52. The predicted total cadmium concentration is more than one hundred times lower than the acute toxicity threshold for aquatic resources for total cadmium. Even if the more sensitive amphipod species was considered (*H. azteca*), the maximum cadmium concentration is still more than seven times lower than the toxicity threshold for aquatic resources. Therefore, it is considered unlikely that acute toxicity would occur in aquatic resources due to exposure to cadmium.

Copper

The maximum BC WQG for copper (Singleton 1987) includes reference to the acute toxicity thresholds for several invertebrates species such as *D. magna* (cladoceran, LC_{50} of 0.0065 mg/L) and *Physa heterotropha* (pond snail, LC_{50} of 0.013 mg/L); however, neither of these organisms would be expected to be present in T Creek due to habitat preferences. Relevant acute toxicity thresholds for various aquatic invertebrates that could be found in T Creek start at about 0.030 mg/L for *Chironomous* sp. (diptera), from 0.055 mg/L for mayflies, and 0.038 mg/L for caddisflies (US EPA 2014).

The toxicity thresholds for primary producers are higher than those reported for secondary producers. NOECs of 0.015 mg copper/L has been reported for multiple species belonging to Bacillariophyceae (diatoms) (US EPA 2014); however toxicity thresholds are generally greater than 0.100 mg/L. Secondary producers are likely to be more sensitive to copper than primary producers.

Based on this information, an acute toxicity threshold of 0.030 mg/L total copper based on *Chironomous* sp. was used to determine the potential for acute lethality in aquatic resources.

The maximum concentration of total copper at the T Creek modelling node is predicted to be 0.0052 mg/L in October of Year 31. Concentrations of copper are predicted to decrease with time from this maximum level. The predicted copper concentrations are close to six times lower than the acute toxicity threshold for aquatic resources for copper. Even if the more sensitive cladoceran species was considered (*D. magna*, LC50 of 0.0065 mg/L), the maximum copper concentration is still lower than the toxicity threshold for aquatic resources Therefore, it is considered unlikely that acute toxicity would occur in aquatic resources due to exposure to copper.

Potential for Chronic, Sub-lethal Toxicity to the Aquatic Resources Valued Component

Concentrations of dissolved cadmium, total copper, selenium, sulphate, and zinc (Post-Closure phase only) in water are predicted to be greater than the 30-day average BC WQG at the T Creek modelling node during the Closure and Post-Closure phases, suggesting that the potential for chronic toxicity (either lethality or sub-lethal effects) to aquatic resources needs to be considered at this location.

Similar to the approach used for determining toxicity thresholds for acute effects, a literature search was conducted, with emphasis on any available studies on the primary and secondary producers that were most commonly identified during baseline studies (Section 14.4.3.3; Appendix 14-A). The toxicity threshold for the most sensitive species (for which data exists) was used to define the toxicity threshold for aquatic resources.

The toxicological endpoints considered were those that have been demonstrated to be ecologically-relevant (e.g., reproduction, growth, development and survival of various life stages, changes in abundance or community composition), consistent with guidance from BC MOE (2012a). The literature search considered existing technical summaries used for development of guidelines (e.g., BC WQG or CCME WQGs), data summaries reported in the ECOTOX database (US EPA 2014), and published peer-reviewed studies. Wherever possible, the EC_{10} or EC_{20} value (i.e., the effects concentration required to cause a 10 to 20% decrease or change in the endpoint) was used to define the toxicity threshold. The following sections consider the potential for toxicity to aquatic resources due to each of the COPCs.

Cadmium

The most sensitive primary or secondary producers for chronic toxicity due to cadmium are cladocerans (e.g., *D. magna*) or amphipods (e.g., *H. azteca*; CCME 2014b; Sinclair et al. 2014). Concentrations at which effects have been observed in these organisms are reported to be at or near 0.0001 mg cadmium/L. The most sensitive species are reported to be *D. magna*, with an EC_{10} for feeding inhibition of 0.000045 mg/L, *Ceriodaphnia dubia*, with effects on reproduction noted at 0.00012 mg/L, and *H. azteca*, with an EC_{25} of 0.00012 mg/L for effects on biomass. However, these organisms are unlikely to be found in a fast flowing (lotic) environment, such as would be found in T Creek, since their preferred habitats are in lentic environments with slow-moving or standing water (cladocerans), or in depositional environments (amphipods).

Chironomous tentans, a midge (dipteran) species may be found in T Creek, and has a reported EC_{25} value of 0.00096 mg/L based on effects on hatching success (CCME 2014b). Other effects to survival, weight or biomass, number of eggs, and percent emergence of *C. tentans* have been reported to occur at concentrations from 0.0011 to more than 0.0061 mg cadmium/L. However, other studies have found that *C. tentans* is much less sensitive to cadmium, with effects (e.g., to growth or survival) occurring only when concentrations of cadmium were greater than 0.18 mg/L (Suedel, Rodgers Jr., and Deaver 1997).

Based on this information, the toxicity threshold of 0.00096 mg/L for *C. tentans* reported by CCME (2014b) and used in the derivation of the CCME cadmium guideline was used for aquatic resources as the chronic toxicity threshold.

The maximum concentration of total cadmium at the T Creek modelling node is predicted to be 0.00011 mg/L, occurring in several winter months in Years 49 to 52. While the maximum predicted concentration is in the range of toxicity thresholds for the most sensitive species, these organisms (i.e., cladocerans and amphipods) are unlikely to be present in T Creek. The predicted total cadmium concentration is more than eight times lower than the aquatic resources chronic toxicity threshold for total cadmium. Therefore, chronic effects to aquatic resources that are likely to be present in T Creek due to cadmium exposure are unlikely.

Copper

Among primary producers of the phylum Bacillariophyceae (diatoms), the toxicity threshold (LOEC) for *Epithemia* sp., although not found during baseline studies, occurs at 0.020 mg/L of copper, with a NOEC value of 5 µg/L (Roussel et al. 2007). *Fragilaria capucina* has a toxicity threshold of 0.021 mg copper/L based on effects to population abundance. Toxicity thresholds for other diatoms and cyanophytes are considerably higher (US EPA 2014).

The BC WQG technical appendix (1987) notes that *Hydra* sp. are sensitive to copper exposures at concentrations greater than 0.010 mg/L, with no effects observed at concentrations of up to 0.005 µg/L. Other sensitive species, such as *Gammarus* sp. (amphipod) or *Campeloma* sp. (mollusk), with toxicity thresholds in the 0.002 to 0.003 mg/L range were not found during baseline studies (Appendix 14-A) and are unlikely to be present in T Creek since they prefer different habitats than those present in a lotic environment.

Among the secondary producers that could reside in T Creek, a mayfly species (*Ephemerella infrequens*) is the most sensitive, with a reported toxicity threshold of 0.006 mg/L, based on survival (Leland et al. 1989). The toxicity threshold for survival or developmental abnormalities for other organisms, such as two species of midge (*C. tentans* and *Tanytarsus dissimilis*), is slightly higher ranging from 0.0089 to 0.016 mg/L (Anderson, Walbridge, and Fiandt 1980; Suedel, Deaver, and Rodgers Jr. 1996; Janssens de Bisthoven, Vermeulen, and Ollevier 1998). Other studies have found toxicity thresholds ranging from 0.02 mg/L up to 0.3 mg/L, depending on the species, duration of study, and water hardness (US EPA 2014).

There have been several studies of the effects of copper on aquatic resource communities, with endpoints based on changes in abundance of different organisms or community structure and diversity. Reduced species richness and diversity has been noted during mesocosm or field studies where copper concentrations were measured to be less than 0.005 mg/L (reviewed in Brix, DeForest, and Adams 2011). Several studies found that in stream environments, sensitive species among primary and secondary producers can be affected by copper exposures at concentrations in the range of 0.003 and 0.006 mg/L, and that community structure can be altered at concentrations of 0.005 mg/L (Leland and Carter 1984, 1985; Leland et al. 1989).

Based on the data available, a toxicity threshold for copper of 0.005 mg/L was used for the purposes of effects assessment.

The maximum concentration of total copper at the T Creek modelling node is predicted to be 0.0052 mg/L in October of Year 31. Concentrations of copper are predicted to decrease with time from this maximum level. The predicted maximum copper concentration is in the range in which effects to aquatic resources might occur (0.005 mg/L). The following factors might influence the potential for toxicity in aquatic resources.

- Copper concentrations are predicted to be greater than 0.005 mg/L (i.e., the toxicity threshold) during only some winter months in Years 41 to 48 of the Post-Closure phase. During these winter months, aquatic resources are not very active and may be better able to withstand exposure to copper during these times.
- T Creek is a low-order lotic waterway, with relatively low abundance of aquatic resources. In addition, during the Construction and Operations phases, diminished water quantity in T Creek will decrease the abundance of aquatic resources, which will take time to recover (see Section 14.5.3.3, Changes in Water Quantity). The naturally and flow-induced low productivity and abundance of primary and secondary producers in T Creek will decrease the magnitude of the potential change to the aquatic resources communities.

Since the concentrations of copper are predicted to be near the toxicity threshold for aquatic resources during the winter months for eight years during the Post-Closure phase, there is some potential that changes to the aquatic community in T Creek will occur as a result of exposure to copper.

Selenium

A maximum target concentration of 10 µg/L for selenium has been determined based on a fish bioaccumulation model and back-calculation using a conservative toxicity threshold (see preceding

Sections 14.5.3.2 and 14.5.3.4, P Creek – Based on the P Creek Modelling Node*)* and the Selenium Management Plan in Section 24.12).

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. 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). Selenium is predicted to be greater than the target concentration of 10 µg/L during the lower flow periods of the Closure phase, but is predicted to be below the target concentration in all months after April of Year 36.

Since predicted concentrations of selenium are greater than or near to the target concentration, it is possible that toxicity may occur in sensitive species. However, sensitive species, such as the isopods or tubificid worms in the study by Swift (2002), were not identified in T Creek during baseline studies and most other aquatic resources (where data are available) are less sensitive. In addition, selenium concentrations are predicted to be below the target of 10 µg/L during May, June, and July; this is the time of year when aquatic productivity is likely to be greatest, when the bioaccumulation of selenium through the food chain and subsequent toxicity is most likely to occur.

Follow-up monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Sulphate

The BC WQG for sulphate was updated in 2013 and provides an up-to-date literature review of the limited studies available for sulphate toxicity following chronic exposures (Meays and Nordin 2012).

There is limited toxicity data available for effects to aquatic resources due to sulphate. Based on the data summarized by Meays and Nordin (2013), in low hardness water (50 mg/L), the most sensitive primary or secondary producer is *C. dubia*, with effects on reproduction occurring at sulphate concentrations of 158 mg/L (reported as an EC_{10}; Elphick et al. 2011)). Effects on *H. azteca* have been reported at concentrations ranging from 205 to 1430 mg/L (Meays and Nordin 2012). However, as noted previously, cladocerans and amphipods are not likely to be found in T Creek, due to habitat preferences for lentic, rather than lotic, environments.

Effects on other aquatic resources due to sulphate exposure were noted at concentrations of 441 mg/L for algae (*Pseudokircheriella subcapitata*), 327 mg/L for a mayfly (*Centroptilum triangulifer*) and greater than 14,000 mg/L for *C. tentans* (midge; Meays and Nordin 2013). Since mayflies were found in T Creek during baseline studies (Appendix 14-A), the toxicity threshold for sulphate in T Creek was 327 mg/L.

The maximum concentration of sulphate predicted at the T Creek modelling node is 224 mg/L between October of Year 30 and January of Year 31. The maximum predicted concentration of sulphate in T Creek (224 mg/L) is lower than the toxicity threshold (327 mg/L), so it is unlikely that effects to aquatic resources would occur due to sulphate exposure. The predicted concentrations are greater than the toxicity threshold for some of the more sensitive aquatic resources, but these organisms are not expected to be present in T Creek.

Zinc

Most studies of the effects of zinc on aquatic resources found that primary and secondary producers are relatively insensitive to zinc toxicity, with toxicity thresholds typically measured in grams per litre (US EPA 2014). However, several studies have suggested that some aquatic resources may be particularly sensitive to zinc. Hatakeyama (1989) found that mayfly larvae (*Epeorus latifolium*) experienced decreased growth and larval survival at concentrations of 0.019 mg zinc/L. (Anderson, Walbridge, and Fiandt 1980) found that a survival of species of midge (*T. dissimilis*) was affected at concentrations of 0.037 mg zinc/L. Based on this data, to be conservative, 0.019 mg/L was selected as a toxicity threshold for zinc for aquatic resources.

The maximum concentration of zinc predicted at the T Creek modelling node is 0.012 mg/L in several months during the low flow period (October to March) between Years 46 and 59. The maximum predicted concentration of zinc is lower than the toxicity threshold for aquatic resources, so it is unlikely that effects to aquatic resources would occur due to zinc exposure.

Characterization of Residual Effects to the Aquatic Resources Valued Component in T Creek (T Creek Modelling Node)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to the aquatic resources VC due to changes in water quality in T Creek is described as follows.

- Magnitude: **High**. A number of parameters are greater than the BC WQG. Selenium is predicted to be more than five times higher than BC WQGs during Closure and the early Post-Closure phase. Predicted concentrations of copper may be at or near toxicity thresholds for some aquatic resources during some winter months for eight years in the Post-Closure phase. Sediment quality is also likely to change as a result of increased concentrations of cadmium, copper, selenium, and zinc in water.
- Extent: **Local**. The change in water quality is limited to T Creek, within the LSA.
- Duration: **Far future**. The potential for effects due to change in water quality at T Creek is predicted to extend through the Closure and Post-Closure phases.
- Frequency: **Continuous**. Predicted concentrations for several of the COPCs at T Creek modelling node (e.g., cadmium, copper, and selenium) are greater than BC WQGs throughout all time steps during the Closure and Post-Closure phases.
- Reversibility: **Partially reversible**: Concentrations of the COPCs are predicted to decrease over time, and will eventually decrease to concentrations below the BC WQG.
- Resiliency: **Neutral**. Aquatic resources are somewhat resilient to effects of changes in water quality since they are adapted to living in a constantly changing environment (e.g., due to annual floods, temperature fluctuations, changes in nutrient availability, etc.). Some aquatic resources are also able to adapt to higher concentrations of metals within a short period of time.

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.

Upper Harper Creek (Based on the HP and HT Modelling Nodes)

Baseline studies found that the periphyton community in upper Harper Creek was dominated by organisms from Myxophyceae (cyanobacteria) and Bacillariophyceae (diatoms), while the benthic invertebrate community was dominated by organisms from the order Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies;; Section 14.4.3.3; Appendix 14-A). Since these organisms make up the majority of the primary and secondary producer community in upper Harper Creek (84 to >90%), they were considered when determining toxicity thresholds for potential effects due to changes in water quality.

Concentrations of dissolved cadmium, total copper, and total selenium in water are predicted to be greater than the 30-day average BC WQG at the HT modelling node in Harper Creek (expected case water quality model results), and total selenium concentrations are predicted to be greater than the 30-day average BC WQG at the HP modelling node (unrecovered seepage sensitivity case water quality model results), suggesting that the potential for chronic toxicity to aquatic resources needs to be considered for upper Harper Creek. Predicted concentrations are less than the maximum BC WQGs, so acute toxicity would not be expected.

The methodology for assessing the potential for effects to aquatic resources was described in the preceding section (T Creek – Based on the T Creek Modelling Node), and the same approach was used here. Toxicity thresholds for aquatic resources determined in the preceding section are also used here.

Cadmium

The toxicity threshold of 0.00096 mg/L for *C. tentans* reported by (CCME 2014b) and used in the derivation of the CCME cadmium guideline was used for aquatic resources as the chronic toxicity threshold.

The maximum concentration of total cadmium at the HT modelling node is predicted to be 0.000065 mg/L in March of Years 51 to 53. The predicted total cadmium concentration is 14 times lower than the aquatic resources chronic toxicity threshold for total cadmium. Therefore, chronic effects to aquatic resources due to cadmium exposure are unlikely.

Copper

Based on the data available, a toxicity threshold for copper of 0.005 mg/L was used for the purposes of effects assessment.

The maximum concentration of total copper at the HT modelling node is predicted to be 0.0033 mg/L in June of Year 31, and 32 where June has a baseline mean hardness of 16 mg/L. The predicted total copper concentration is lower than the toxicity threshold for aquatic resources for total copper. Therefore, chronic effects to aquatic resources due to copper exposure are unlikely.

Selenium

A maximum target concentration of 10 µg/L for selenium has been determined based on a fish bioaccumulation model and back-calculation using a conservative toxicity threshold (see preceding

Sections 14.5.3.2 and 14.5.3.4, P Creek – Based on the P Creek Modelling Node*)* and the Selenium Management Plan in Section 24.12).

Based on the expected case water quality modelling results, the maximum predicted concentration of selenium at the HT modelling node is 5.9 µg/L, occurring in March of Year 36. Based on the unrecovered seepage sensitivity case water quality modelling results, the maximum predicted concentration of selenium at the HP modelling node is 6.0 µg/L, occurring in March of Years 27 and 28. Since the predicted concentrations of selenium are below the concentration (10 µg/L) that is expected to be protective of aquatic resources in a lotic environment, it is unlikely that effects to aquatic resources will occur. Monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Characterization of Residual Effects to the Aquatic Resources Valued Component in Upper Harper Creek (HP and HT Modelling Nodes)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to the aquatic resources VC due to changes in water quality in upper Harper Creek is described as follows.

- Magnitude: **Medium**. Although predicted concentrations of cadmium, copper, and selenium are greater than the 30-day average BC WQG (within two to five fold of the guideline), predicted concentrations are below toxicity thresholds for aquatic resources. Sediment quality is also likely to change as a result of increased concentrations of cadmium, copper, and selenium in water.
- Extent: **Local**. The change in water quality is limited to some portions of upper Harper Creek (i.e., downstream of the confluence with T Creek, down to the seasonal fish barrier at km 18.5), within the LSA.
- Duration: **Far future**. The potential for effects due to change in water quality (concentrations greater than BC WQG) in some parts of upper Harper Creek is predicted to extend through the Operations phase (in the vicinity of the HP modelling node) or Closure and Post-Closure phases (downstream of the confluence with T Creek).
- Frequency: **Regular**. Predicted concentrations for several of the COPCs at the HT modelling node are greater than BC WQGs regularly during Closure phase and the early portion of Post-Closure phase, but the frequency decreases with time and becomes more sporadic towards the end of Post-Closure phase.
- Reversibility: **Partially reversible**. Concentrations of the COPCs are predicted to decrease over time, and will eventually decrease to concentrations below the BC WQG.
- Resiliency: **Neutral**. Aquatic resources are somewhat resilient to effects of changes in water quality since they are adapted to living in a constantly changing environment (e.g., due to annual floods, temperature fluctuations, changes in nutrient availability, etc.). Some aquatic resources are also able to adapt to higher concentrations of metals within a short period of time.

Lower Harper Creek (Based on the HB Modelling Node)

Baseline studies found that the periphyton community in lower Harper Creek (HC-10 site) was dominated by organisms from the Myxophyceae (cyanobacteria) and Bacillariophyceae (diatoms) phyla, while the benthic invertebrate community was dominated by organisms from the order Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies; Section 14.4.3.3; Appendix 14-A). Since these organisms made up the majority of the primary and secondary producer community in lower Harper Creek (56 to >90%), they were considered when determining toxicity thresholds for potential effects due to changes in water quality.

Concentrations of dissolved cadmium, total copper, and total selenium in water are predicted to be greater than the 30-day average BC WQG at the HB Creek modelling node in lower Harper Creek, suggesting that the potential for chronic toxicity to aquatic resources needs to be considered at this location.

The methodology for assessing the potential for effects to aquatic resources was described in the preceding section (T Creek – Based on the T Creek Modelling Node), and the same approach was used here. Toxicity thresholds for aquatic resources determined in the preceding section are also used here.

Cadmium

The toxicity threshold of 0.00096 mg/L for *C. tentans* reported by (CCME 2014b) and used in the derivation of the CCME cadmium guideline was used for aquatic resources as the chronic toxicity threshold.

The maximum concentration of total cadmium at the HB modelling node is predicted to be 0.000040 mg/L in March of Years 43 to 65, where March has a baseline mean hardness of 26 mg/L. The predicted total cadmium concentration is 24 times lower than the aquatic resources chronic toxicity threshold for aquatic resources for total cadmium. Therefore, chronic effects to aquatic resources due to cadmium exposure are unlikely.

Copper

Based on the data available, a toxicity threshold for copper of 0.005 mg/L was used for the purposes of effects assessment.

The maximum concentration of total copper at the HB modelling node is predicted to be 0.0021 mg/L in June of Years 31 to 61, where June has a baseline mean hardness of 11 mg/L. The predicted total copper concentration is only marginally higher than the 30-day BC WQG and is more than two times lower than the toxicity threshold for aquatic resources. Therefore, chronic effects to aquatic resources due to copper exposure are unlikely.

Selenium

A maximum target concentration of 10 µg/L for selenium has been determined based on a fish bioaccumulation model and back-calculation using a conservative toxicity threshold (see preceding Sections 14.5.3.2 and 14.5.3.4, P Creek – Based on the P Creek Modelling Node*)* and the Selenium Management Plan in Section 24.12).

The maximum predicted concentration of selenium at the HB modelling node is 3.2 µg/L, occurring in March of Year 36, with concentrations decreasing annually with time. Predicted concentrations of selenium at the HB modelling node are only greater than the 30-day average BC WQG during March of Year 32 (Operations 2 phase) and during February and March for some of the Post-Closure phase (up to Year 71). During the more critical "growing" season (i.e., when water temperatures and aquatic productivity increases in the late spring, summer, and early fall), concentrations of selenium are predicted to be below the BC WQG, thereby decreasing the potential for selenium bioaccumulation during this time. Since the predicted concentrations of selenium are below the target concentration (10 µg/L) that is expected to be protective of aquatic organisms in a lotic environment, it is unlikely that effects to aquatic resources will occur.

A follow-up monitoring program will be required to ensure that selenium is not accumulating in sediments or the food chain in this location. Monitoring will be implemented under the Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12) to ensure that potential effects in the aquatic environment are identified and adaptively managed as needed.

Characterization of Residual Effects to the Aquatic Resources Valued Component in Lower Harper Creek (HB Modelling Node)

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effect to the aquatic resources VC due to changes in water quality in lower Harper Creek is described as follows.

- Magnitude: **Low**. Predicted concentrations of cadmium, copper, and selenium are marginally greater than the 30-day average BC WQG (within two fold of the guideline), and predicted concentrations are below toxicity thresholds for aquatic resources. Sediment quality is also likely to change as a result of increased concentrations of cadmium, copper, and selenium in water.
- Extent: **Regional**. The change in water quality occurs throughout Harper Creek and may extend into the outlet area of North Barrière Lake, but is predicted to remain within the RSA (Chapter 13, Section 13.5.3).
- Duration: **Far future**. The potential for effects due to change in water quality (predicted concentrations greater than BC WQG) in lower Harper Creek is predicted to extend through the Closure and Post-Closure phases for some parameters (e.g., cadmium).
- Frequency: **Regular to Sporadic**. Predicted concentrations for cadmium, copper, and selenium at the HB modelling node are greater than BC WQGs regularly during the Closure phase and early parts of the Post-Closure phase, but the frequency decreases with time.
- Reversibility: **Partially reversible**: Concentrations of the COPCs are predicted to decrease over time, and will eventually decrease to concentrations below the BC WQG (e.g., copper will be below BC WQGs by mid-Year 71, selenium by early in Year 72).
- Resiliency: **Neutral**. Aquatic resources are somewhat resilient to effects of changes in water quality since they are adapted to living in a constantly changing environment (e.g., due to annual

floods, temperature fluctuations, changes in nutrient availability). Some aquatic resources are also able to adapt to higher concentrations of metals within a short period of time.

Potential for Effects due to Nutrient Loading

Both nitrogen and phosphorus are required nutrients for the growth and productivity of primary producers, and Project activities have the potential for increasing the loading of both elements into the freshwater environment. Residual effects from nutrient loading can involve the stimulation of primary production, with subsequent increases in primary producer biomass, alterations in community structure, and changes to trophic dynamics and secondary producer communities (Section 14.5.1.3).

The baseline phosphorus data for P Creek, T Creek, Baker Creek, Jones Creek, and Harper Creek shows total phosphorus concentrations to fall in the oligotrophic trigger range between 0.004 and 0.010 mg/L (Chapter 13 and Appendices 13-A and 13-B). Consistent with this low input of phosphorus, primary producer biomass and abundance was generally low during baseline sampling (Section 14.4.3.5).

Environmental effects of nitrogen and phosphorus are inter-related because both phosphorus and nitrogen are required nutrients for the growth of primary producers. Significant accumulation of primary producer biomass generally occurs at dissolved inorganic nitrogen (the sum of nitrate, nitrite, and ammonia) concentrations greater than 0.04 mg/L and total phosphorus concentrations greater than 0.03 mg/L (Dodds, Smith, and Lohman 2002). The baseline sampling program indicated that nitrogenous nutrients in the P Creek, T Creek, Baker Creek, Jones Creek, and Harper Creek, primarily nitrate, are generally available and the concentration of dissolved inorganic nitrogen was greater than this 0.03 mg/L threshold (Tables 14.5-15 to 14.5-21). Dissolved inorganic nitrogen concentrations are predicted to increase in Closure and Post-Closure phases in T Creek, Baker Creek, Jones Creek, and Harper Creek.

Primary producer biomass is controlled not only by the supply of phosphorus, but also by light availability, the interval between high flow conditions, grazing by herbivores, or by the supply of other nutrients like nitrogen (Feminella and Hawkins 1995; Biggs 2000; Stelzer and Lamberti 2001). Although the peak flows are predicted to decrease (up to approximately 45% in T Creek, up to 27% in Harper Creek; Section 12.5.1, Hydrology Effects Assessment), the timing of peak flows is not predicted to change. The period between high flows during the Project, which can scour and displace primary producers, is predicted to remain similar to the natural flow regime and exert the same controlling effects on primary producer biomass (Chapter 12; Biggs 2000). There are no direct effects of nitrogen on the secondary producer community (all predicted nitrogen concentrations are predicted to be below applicable water quality guidelines); therefore, grazing pressure is expected to be similar to baseline conditions.

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

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

The increase in biomass is not predicted to be greater than the BC water quality criteria (10 µg/cm^2; BC MOE 2001) because baseline primary producer biomass was generally less than 2 µg chl a/cm^2 (Section 14.4.3.5) and the factors discussed above will likely mitigate increases in biomass to be substantially less than a 5-fold increase.

Changes in primary producer community structure are not expected. Substantial variation in the relative abundance of different periphyton groups was observed in the baseline program; diatoms and cyanobacteria are natural components of the primary producer community in Harper Creek and throughout the LSA. The expected increase in loading of nitrogenous compounds (Tables 14.5-15 to 14.5-21) relative to phosphorus would be predicted to favour diatoms over cyanobacteria, but other factors including the interval between high flow events and grazing also exert significant controls over community structure (Feminella and Hawkins 1995; Biggs 2000). Furthermore, nutrient ratios are not necessarily the best predictors for changes in periphyton community structure (Francoeur et al. 1999; Stelzer and Lamberti 2001); rather, specific data on the nutrients limiting growth are the best predictors of changes in community structure. Lastly, these limiting-nutrient conditions shift with changes in the environment, including flow regime and temperature.

Based on the forgoing and the definitions of residual effects characterization terms in Table 14.5-3, the residual effects to aquatic resources due to a change in water quality associated with nutrient loading is described as follows.

- Magnitude: **Negligible** for P Creek, and **medium** for T Creek, upper Harper Creek and lower Harper Creek.
- Extent: **Local** because no changes in water quality are predicted outside of the LSA (Section 13.5.3, Surface Water Quality Effects Assessment).
- Duration: The effect is predicted to extend to the **far future** because of the long-term changes in water quality due to discharge from the TMF.
- Frequency: Residual effects are predicted to be **continuous**.
- Reversibility: **Partially reversible**, with management of water quality in the TMF discharge and re-colonization of affected habitat from downstream and nearby populations.
- Resiliency: **Neutral**, aquatic resources in headwater and low-order streams are naturally adapted to disturbances but the return to pre-disturbance state is affected by stochastic processes related to re-colonization.

14.5.3.5 Likelihood of Residual Effects on Fish, Fish Habitat, and Aquatic Resources Valued Components

Changes in Water Quantity

The likelihood of residual effects to fish, fish habitat, and aquatic resources from changes in water quantity is rated to be **high**. The quantitative hydrology modelling showed changes in flows were of high magnitude, but moderate effect in upper Harper Creek, T Creek, and P Creek (Section 12.5.3, Hydrology Effects Assessment).

Potential for Toxicity due to Changes in Water Quality

Quantitative water quality modelling conducted by Knight Piésold (Appendix 13-C) predicts that water quality will change in P Creek, T Creek, and throughout Harper Creek. Although the assessment is based on quantitative modelling, the likelihood of residual effects to fish and aquatic resources from changes in water quality is rated to be **moderate** in T and upper Harper creeks. The predicted increases in COPC concentrations due to the discharge from the TMF during Closure and Post-Closure phases may have effects on aquatic organisms in the downstream environment since predicted concentrations are greater than guidelines and closer to toxicity thresholds than in other areas. However, the potential for effects may be altered by factors not considered in the effects assessment such as changes in water hardness that could affect the potential for toxicity (i.e., water hardness is predicted to increase compared to background levels which should decrease the potential for toxicity, but this was not accounted for in the assessment).

The likelihood that toxicity will occur in P creek is low since concentrations of selenium are only predicted to be elevated in one of the two model cases considered in the assessment (i.e., unrecovered seepage sensitivity case but not in the expected case; Chapter 13 and Appendix 13-C). The predicted concentrations of selenium in the unrecovered seepage sensitivity case water quality model are below toxicity thresholds and are only sporadically greater than guidelines. This suggests that toxicity is less likely to occur in biological receptors in this area, particularly because P creek is a lotic environment (i.e., the risk of toxicity due to selenium is lower in lotic environments).

The likelihood that toxicity will occur also decreases with distance from the source (e.g., TMF discharge or seepage), and the likelihood of the potential for toxicity due to changes in water quality is **low** in lower Harper Creek. Predicted concentrations in lower Harper Creek at the HB modelling node are only marginally greater than guidelines and well below toxicity thresholds; effects to biological receptors (i.e., fish and aquatic resources) is unlikely to occur.

Potential for Effects due to Nutrient Loading

The assessment of residual effects due to nutrient loading is supported by the quantitative water quality modelling (Appendix 13-C). The likelihood of effects on primary producers due to the predicted increases in nitrogenous and phosphorus nutrients is rated to be **high**. The predicted changes in nutrient concentrations are sufficiently large to have effects on primary production, but the effects are expected to be restricted to the LSA.

14.5.3.6 *Summary of Residual Effects on Fish and Aquatic Resources*

The residual effects to fish, fish habitat, and aquatic resources are summarized in Table 14.5-22. These are the residual effects predicted to occur after the implementation of the mitigation and management measures outlined in Section 14.5.2.

Table 14.5-22. Summary of Residual Effects on Fish, Fish Habitat, and Aquatic Resources Valued Components

Valued Component	Project Phase (Timing of Effect)	Cause-Effect [1]	Mitigation Measure(s)	Residual Effect
Fish and Fish Habitat	Construction, Operations, Closure, Post-Closure	Changes in Water Quantity	Diverting non-contact and contact water; maintaining natural networks; reusing contact water to minimize the use of freshwater. Implementing the sedimentation and erosion control plan to avoid morphologic changes. Implementation of Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Site Water Management Plan (Section 24.13); Sediment and Erosion Control Plan (Section 24.11); Fish Habitat Offsetting Plan (Appendix 14-E)	Potential for effects to fish (Bull Trout) and loss of fish habitat due to changes in water quantity in upper Harper Creek between P and T Creeks, T Creek and P Creek.
Fish	Construction, Operations, Closure, Post-Closure	Potential for Toxicity due to Changes in Water Quality	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Potential for toxicity in fish in P Creek (Bull Trout), T Creek (Bull Trout), upper Harper (Bull Trout), and lower Harper Creek (Bull Trout, Rainbow Trout, and Coho Salmon) affecting fish abundance or health.
Aquatic Resources	Construction, Operations, Closure, Post-Closure	Changes in Water Quantity	Diverting non-contact and contact water; maintaining natural networks; reusing contact water to minimize the use of freshwater. Implementing the sedimentation and erosion control plan to avoid morphologic changes; Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Site Water Management Plan (Section 24.13)	Decreases in habitat for primary and secondary producers and alteration of sediment quality in upper Harper Creek, T Creek, P Creek, Jones Creek, and Baker Creek.

(continued)

Table 14.5-22. Summary of Residual Effects on Fish, Fish Habitat, and Aquatic Resources Valued Components (completed)

Valued Component	Project Phase (Timing of Effect)	Cause-Effect [1]	Mitigation Measure(s)	Residual Effect
Aquatic Resources	Construction, Operations, Closure, Post-Closure	Potential for Toxicity due to Changes in Water Quality	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Change in sediment quality and potential for toxicity to aquatic resources, affecting community abundance, structure or composition.
Aquatic Resources	Construction, Operations, Closure, Post-Closure	Potential for Effects due to Nutrient Loading	Explosives Handling Plan (Section 24.5); Diverting contact and mine water to TMF.	Acute effects to aquatic organisms during Closure Phase. Increases in primary production and potential changes to composition of primary producer community

14.5.4 Significance of Residual Effects

The significance determination follows a two-step process; first the severity of residual effects is ranked according to a minor, moderate and major scale (see Chapter 8, Figure 8.6-1). Then, a consideration of whether minor, moderate, or major effects are significant is made, following the process in the Effects Assessment Methodology Chapter (Section 8.6.5), using the following definitions:

- **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.
- **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.

14.5.4.1 Water Quantity

Changes in water quantity are predicted to have **not significant** (**moderate)** effects to fish, fish habitat, and aquatic resources. The residual effects to these VCs, although high in magnitude in some cases, are restricted to the LSA and no effects are predicted to extend to a regional scale. Residual effects predicted for fish and fish habitat will be incorporated into a Fish Habitat Offsetting Plan (Appendix 14-E) to mitigate potential effects. Therefore, the residual effects to fish, fish habitat, and aquatic resources from changes in water quantity are determined to be **not significant (moderate)**.

14.5.4.2 Potential for Toxicity due to Changes in Water Quality

P Creek (P Creek Modelling Node)

Residual effects in P Creek are assessed to be **not significant (minor)** for both fish (Bull Trout) and aquatic resources VCs. This is because the magnitude of the residual effects is medium (i.e., predicted concentrations are greater than guidelines but not more than five times higher, and predicted concentrations are below toxicity thresholds). The residual effects are confined to a localized area within the LSA and are predicted to occur only sporadically during the Operations 1 and 2 phases.

T Creek (T Creek Modelling Node)

Residual effects in T Creek are assessed to be **not significant (moderate)** for both fish (Bull Trout) and aquatic resources VCs. This is because the magnitude of the residual effect is high (i.e., predicted concentrations are greater than five times guideline levels and at or above toxicity thresholds for selenium), but the residual effects are confined to very localized area within the LSA, with limited fish presence (i.e., only provides good juvenile rearing habitat in the lower, fish-bearing portion) and limited aquatic productivity.

Upper Harper Creek (HP and HT Modelling Nodes)

Residual effects in upper Harper Creek are assessed to be **not significant (moderate)** for both fish (Bull Trout) and aquatic resources VCs. This is because the magnitude of the residual effect on fish or aquatic resources is medium (i.e., predicted concentrations are greater than guidelines but not more than five times higher, and predicted concentrations are below toxicity thresholds). The residual effects are confined to a localized area, but the residual effects are predicted to occur regularly and into the far-future (i.e., throughout the Operations, Closure, and Post-Closure phases).

Lower Harper Creek (HB Modelling Node)

Residual effects in lower Harper Creek are assessed to be **not significant (minor)** for both fish (Bull Trout, Rainbow Trout, and Coho Salmon) and aquatic resources VCs. This is because, although the extent is regional, the magnitude of the residual effect on fish or aquatic resources is low (i.e., predicted concentrations are marginally greater than guidelines, and predicted concentrations are below toxicity thresholds). The residual effects are predicted to taper off to a sporadic frequency with time during the Post-Closure phase.

14.5.4.3 Potential for Effects due to Nutrient Loading

The residual effects of changes in water quality due to nutrient loading on aquatic resources are predicted to be **not significant** (**moderate)**. The magnitude of the effects to primary and secondary producers from increases in nutrient loading are predicted to range from low to high, depending on location and timing, but all residual effects from nutrient loading are restricted to the LSA. Although some of the residual effects may affect individual organisms or sub-populations within a stream, the effects are geographically restricted and reversible. Therefore, the residual effects to fish, fish habitat, and aquatic resources from nutrient loading are rated to be **not significant**.

14.5.5 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.

The confidence in the predictions of residual effects on fish, fish habitat, and aquatic resources is rated to be **moderate**. The residual effect on aquatic resources from changes in water quantity is based on the hydrologic modelling, which is subject to uncertainty (Chapter 12 Section 12.5.5, Appendix 14-D). The cause-effect relationship between stream flows and aquatic VCs is well understood, but the uncertainty from the hydrologic and instream flow modelling is compounded by additional factors such as small-scale variation or stochastic events. Although the predictions from the assessment of effects from changes in water quantity are expected to be robust, some deviation from the predicted responses may occur.

The residual effects on aquatic resources from changes in water quality and nutrient loading are based on the quantitative water model, which is also subject to some uncertainty (Section 13.5.5 and Appendix 13-C). However, water quality modelling followed industry-standard techniques, incorporated reasonable conservatisms, and was developed using site-specific baseline and technical studies (Section 13.5.6). Furthermore, substantial variation exists in the response of different fish, primary producers, and secondary producers to changes in metal and nutrient concentrations, which can affect the confidence in predicting the effects of changes in water quality. Processes such as fish migration, competition, immigration, and nutrient cycling occur at the scale of reaches and riffles, and thus predicting the response of entire streams is subject to some uncertainty. The confidence in the significance prediction was rated as **moderate** for the residual effect of the Project on fish and aquatic resources VCs due to changes in water quality or nutrient loading.

The Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6) and the Selenium Management Plan (Section 24.12) are designed to provide the necessary information to address these uncertainties and allow for the adaptive management of these residual effects.

14.5.6 Summary of the Assessment of Residual Effects for Fish, Fish Habitat, and Aquatic Resources

The key residual effects on fish, fish habitat, and aquatic resources from the Project have two primary effect pathways: changes in water quantity and changes in water quality. The effect pathways are primarily driven by the alteration of natural draining networks by Project activities and infrastructure and by operation of the TMF. Table 14.5-23 summarizes the residual effects, the assessment criteria, and their significance ratings.

Table 14.5-23. Summary of Key Effects, Mitigation, Residual Effects, 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		Confidence *(High, Moderate, Low)*
				Scale *(Minor, Moderate, Major)*	Rating *(Not Significant; Significant)*	
Changes in Water Quantity (Fish, Fish Habitat, and Aquatic Resources VCs)	Diverting non-contact and contact water; maintaining natural networks; reusing contact water to minimize the use of freshwater. Implementing the sedimentation and erosion control plan to avoid morphologic changes. Implementation of Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Site Water Management Plan (Section 24.13); Sediment and Erosion Control Plan (Section 24.11) Fish Habitat Offsetting Plan (Appendix 14-E)	Magnitude: varies from **low** to **high** within the LSA Geographic Extent: **local** Duration: **far future** Frequency: **continuous** Reversibility: **partially reversible** Resiliency: **low** to **neutral**	**High**	**Moderate**	**Not significant**	Moderate
Potential for Toxicity due to Changes in Water Quality (Fish [Bull Trout] and Aquatic Resources VCs in P Creek)	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Magnitude: **medium** Geographic Extent: **local** Duration: **medium term** Frequency: **sporadic** Reversibility: **reversible** Resiliency: **low (for fish) or neutral (for aquatic resources)**	Low	**Minor**	**Not significant**	Moderate

(continued)

Table 14.5-23. Summary of Key Effects, Mitigation, Residual Effects, Likelihood, Significance, and Confidence (continued)

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)*
Potential for Toxicity due to Changes in Water Quality (Fish [Bull Trout] and Aquatic Resources VCs in T Creek)	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Magnitude: **high** Geographic Extent: **local** Duration: **far future** Frequency: **continuous** Reversibility: **partially reversible** Resiliency: **low (for fish) or neutral (for aquatic resources)**	Moderate	**Moderate**	**Not significant**	Moderate
Potential for Toxicity due to Changes in Water Quality (Fish [Bull Trout] and Aquatic Resources VCs in Upper Harper Creek)	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Magnitude: **medium** Geographic Extent: **local** Duration: **far future** Frequency: **regular** Reversibility: **partially reversible** Resiliency: **low (for fish) or neutral (for aquatic resources)**	Moderate	**Moderate**	**Not significant**	Moderate

(continued)

Table 14.5-23. Summary of Key Effects, Mitigation, Residual Effects, 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		Confidence *(High, Moderate, Low)*
				Scale *(Minor, Moderate, Major)*	Rating *(Not Significant; Significant)*	
Potential for Toxicity due to Changes in Water Quality (Fish[Bull Trout, Rainbow Trout, and Coho Salmon] and Aquatic Resources VCs in Lower Harper Creek)	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Magnitude: **low** Geographic Extent: **regional** Duration: **far future** Frequency: **regular, decreasing to sporadic over time** Reversibility: **partially reversible** Resiliency: **low (for fish) or neutral (for aquatic resources)**	Low	**Minor**	**Not significant**	Moderate
Potential for Effects due to Nutrient Loading in Harper Creek watershed, Baker Creek, and Jones Creek (Aquatic Resources VC)	Diverting contact and mine water to TMF; Explosives Handling Plan (Section 24.5);	Magnitude: varies from **low** to **high** within the LSA Geographic Extent: **local** Duration: **far future** Frequency: **continuous** Reversibility: **partially reversible** Resiliency: **neutral**	High	**Moderate**	**Not significant**	Moderate

14.6 CUMULATIVE EFFECTS ASSESSMENT

14.6.1 Scoping Cumulative Effects

14.6.1.1 Valued Components and Project-Related Residual Effects

Residual effects are predicted for fish, fish habitat, and aquatic resources VCs for changes in water quantity and quality (Section 14.5.6, Table 14.5-23). As a result, these residual effects are considered in the cumulative effects assessment, as described in Cumulative Effects Assessment Methodology in Section 8.7 of the Effects Assessment Methodology, Chapter 8.

14.6.1.2 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 fish, fish habitat, and aquatic resources are described below.

The temporal boundaries for the identification of physical projects and activities are 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 to take into account any far-future effects from past projects and activities.[1]
- **Present**: Active and inactive projects and activities.
- **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.

The first step in defining the cumulative assessment boundaries considers the other physical projects and activities for the assessment of cumulative effects that have been identified in the AIR as the Kamloops Land and Resource Management Plan boundary, and are illustrated in Figure 8.7-1. For the assessment of cumulative effects on fish, fish habitat, and aquatic resources, the spatial boundaries are restricted to areas hydrologically linked to the residual effects of the Project; in order for a cumulative effect to occur, a physical connection or overlap must be possible. Project residual effects are predicted to be restricted to the Harper Creek watershed and downstream to the northern branch of the Barrière River, as well as some effects to the headwater streams Jones Creek and Baker Creek. Therefore, the boundaries of the cumulative effects assessment area are the Barrière River watershed and the North Thompson River upstream from Clearwater (Figure 14.6-1).

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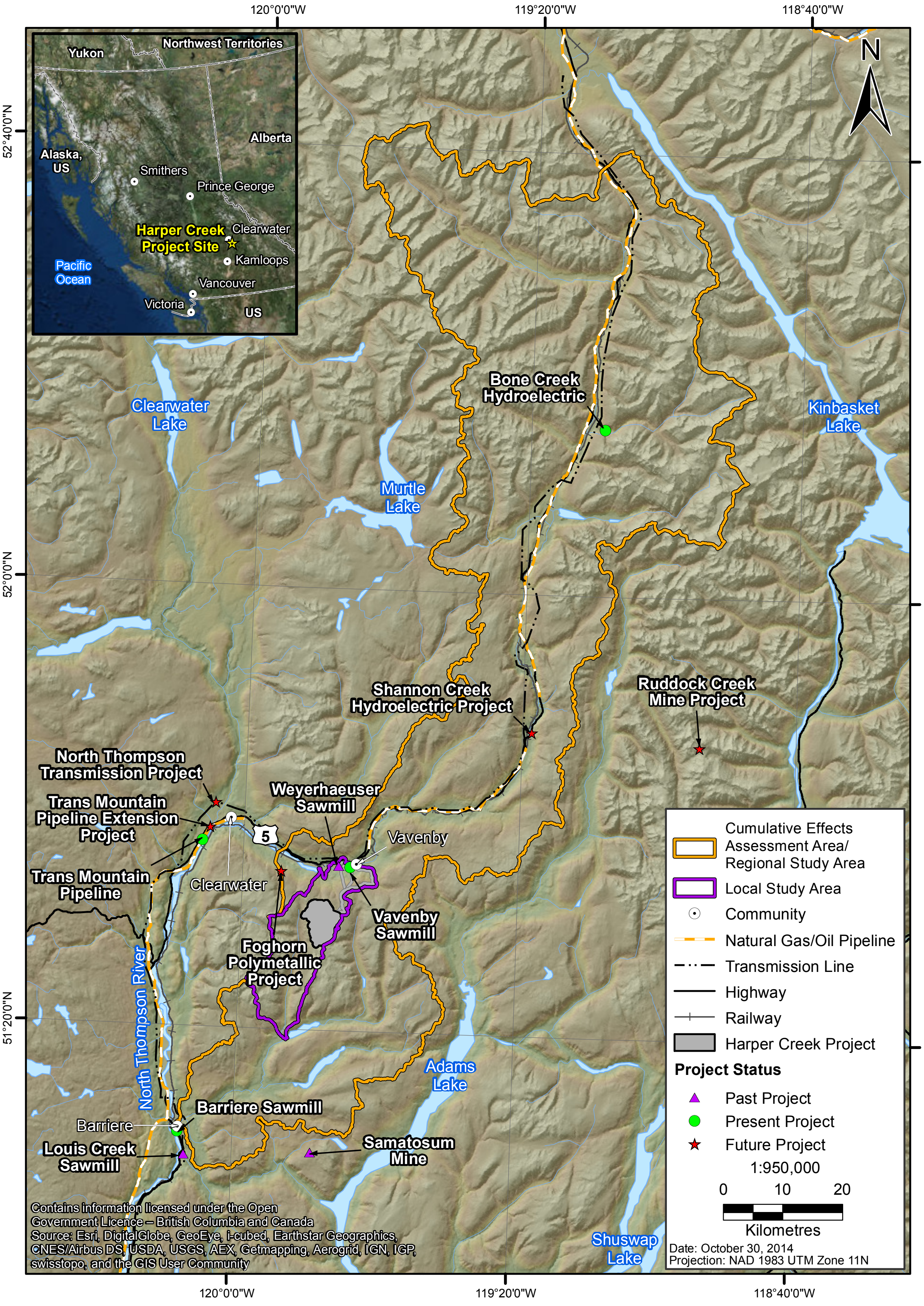
[1] Far-future effects are defined as effects that last more than 37 years, as per Table 8.6-2: Attributes for Characterization of Residual Effects.

Figure 14.6-1

Location of Past, Present, and Reasonably Foreseeable Future Projects for the Assessment of Cumulative Effects on Fish, Fish Habitat, and Aquatic Resources



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Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Date: October 30, 2014
Projection: NAD 1983 UTM Zone 11N

14.6.1.3 Projects and Activities Considered

Past, present, and reasonably foreseeable future projects (Figure 14.6-1) and activities (Figures 14.6-2 to 14.6-5) within the boundaries described above were considered in the cumulative effects assessment (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 (Chapter 8, Tables 8.7-1 and 8.7-2). Table 14.6-1 shows the screening matrix that identifies projects and activities within the fish, fish habitat, and aquatic resources CEA area.

In the impact matrix, the residual effect on fish, fish habitat, and aquatic resources (Table 14.5-23) were screened against all identified project and activities within the CEA area. The spatial and temporal extents of the Project-related residual effects were considered for this impact matrix.

14.6.1.4 Screening and Analyzing Cumulative Effects

No potential spatial interactions with past, present, and reasonably foreseeable future projects were identified for Project residual effects to fish, fish habitat, or aquatic resources in P, T, or Harper creeks, the outlet of North Barrière Lake, or Barrière River. The closest projects, the Weyerhauser and Vavenby sawmills, are not expected to interact with Baker and Jones creeks. Although a number of activities were identified to spatially overlap with Project residuals effects to fish, fish habitat, and aquatic resources (Figures 14.6-2 to 14.6-5), only aboriginal harvesting, fishing, and forestry are expected to interact with aquatic VCs. No aboriginal harvesting or recreation fishing has been reported for Harper Creek. Therefore, negligible risk of a cumulative effect from these activities is predicted. Minimal forestry activities were identified within the LSA (one cutblock at the south-western margin of the LSA; Figure 14.6-2), which would minimize the potential for interactions between forestry activities and the aquatic environment. The risk of cumulative effects on fish, fish habitat, and aquatic resources from forestry activities was determined to be negligible. The other activities, including recreation and agriculture, are not anticipated to interact substantively with fish, fish habitat, or aquatic resources.

Project residual effects are anticipated to be restricted to the LSA and there is limited spatial overlap with any past, present, or future projects or activities. In the case of activities that do spatially overlap with the residual effects, the risks of interactions resulting in cumulative effects were predicted to be minor. Therefore, no cumulative effects are predicted to occur because no past, present, or reasonably foreseeable future projects and activities have been identified with interactions with the Project-related residual effects due to water quantity (Section 12.6.2) or changes in water quality (Section 13.6.2).

14.7 CONCLUSIONS FOR FISH, FISH HABITAT, AND AQUATIC RESOURCES

The fish community in the Project area is composed of (in general order of abundance) Bull Trout, Coho Salmon, Rainbow Trout, Mountain Whitefish, Torrent Sculpin, and Longnose Dace. The distribution of fish in Project-area waterbodies is affected by the presence of natural barriers preventing many species from occupying the upstream reaches of creeks. In the Harper Creek watershed, Bull Trout are the most widely distributed, and were the only species found upstream of the 2-m waterfall at km 18.5 of upper Harper Creek, as well as in the lower fish-bearing reaches of

T and P creeks. All other fish species were observed only in the lower reaches of lower Harper Creek. Similarly, only the lower fish-bearing reaches of Jones and Baker creeks, which are North Thompson River tributaries, have populations of Rainbow Trout, Bull Trout, Coho Salmon, and Torrent Sculpin.

Aquatic resources in the Project area are characterized in the baseline program as low productivity communities of primary and secondary producers typical in headwater, high-relief streams.

The primary pathways of interaction between the Project and fish, fish habitat, and aquatic resources are:

- changes in water quantity, due to alteration of natural drainage networks and construction of infrastructure; and
- changes in water quality, due to discharge and seepage from the TMF or nutrient loading from explosives residues.

Other potential effects from direct mortality (fish VC only), erosion and sedimentation, and atmospheric deposition of dust are considered to be mitigated by Project design and the implementation of best practices and management plans. The assessment for potential residual effects on fish, fish habitat, and aquatic resources from changes in water quantity and water quality used a combination of quantitative modelling for hydrology and water quality and qualitative analysis to predict the magnitude and extent of residual effects.

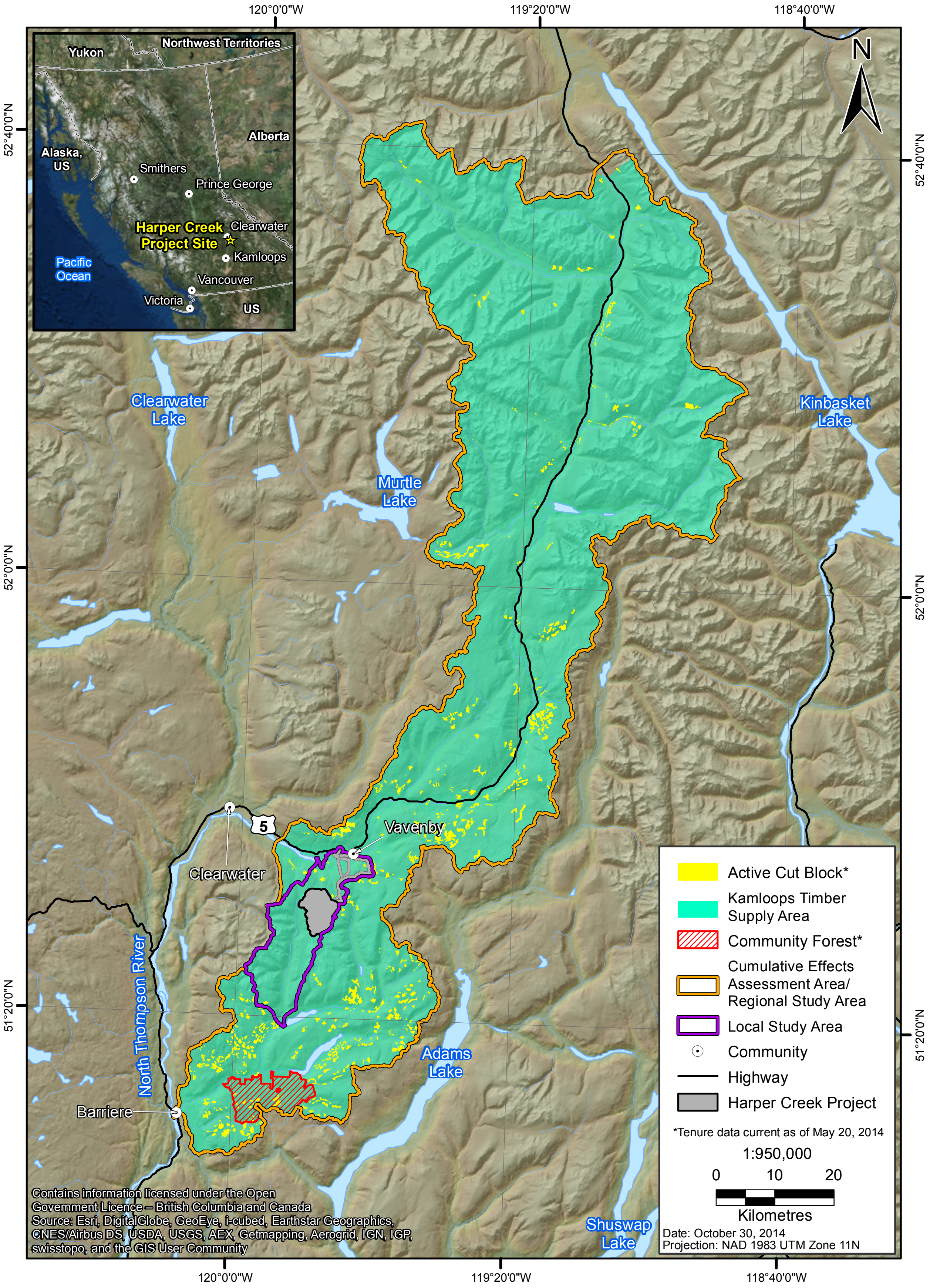
The predicted changes in water quantity in upper Harper Creek between P and T creeks, T Creek and P Creek, have a high likelihood of resulting in an adverse effect on fish and fish habitat. These sections of stream are likely to experience prolonged periods of decreased flow (through Post-Closure) below established threshold and pre-mine levels. These predicted periods of decreased streamflows are likely to result in a residual effect to fish habitat and the Bull Trout population. This residual effect was assessed to be **not significant (moderate)** in T Creek, P Creek, and upper Harper Creek, and **not significant (minor)** further downstream from the Project.

Residual effects to fish or aquatic resources associated with the potential for toxicity due to predicted changes in water quality in P Creek, T Creek, upper Harper Creek, and lower Harper Creek were identified, since predicted concentrations for a number of metals (e.g., cadmium, copper, selenium, and zinc) or ions (i.e., sulphate) are greater than BC WQGs. The change in water quality could potentially affect fish or aquatic resources by affecting health, abundance, or community structure. This residual effect was assessed to be **not significant (moderate)** in waterways downstream closest to the TMF (i.e., T Creek and upper Harper Creek), and **not significant (minor)** in waterways that are further away from the TMF (i.e., P Creek and lower Harper Creek).

Based on the residual effects analysis, effects to the abundance and community composition of primary and secondary producers are predicted to occur from the decreases in flow in headwater creeks (i.e., change in water quantity), such as P Creek. Predicted changes in water quality from nutrient loading are also predicted to cause observable changes in the primary and secondary producer communities in T Creek and upper Harper Creek. However, all of these predicted effects are restricted to the LSA. Therefore, because of the limited geographic extent and the expected recovery of aquatic resources in the long term, the residual effects were concluded to be **not significant** (**moderate**; Table 14.7-1).

Figure 14.6-2

Forestry in the Fish, Fish Habitat, and Aquatic Resources Cumulative Effects Assessment Area



*Tenure data current as of May 20, 2014

Date: October 30, 2014
Projection: NAD 1983 UTM Zone 11N

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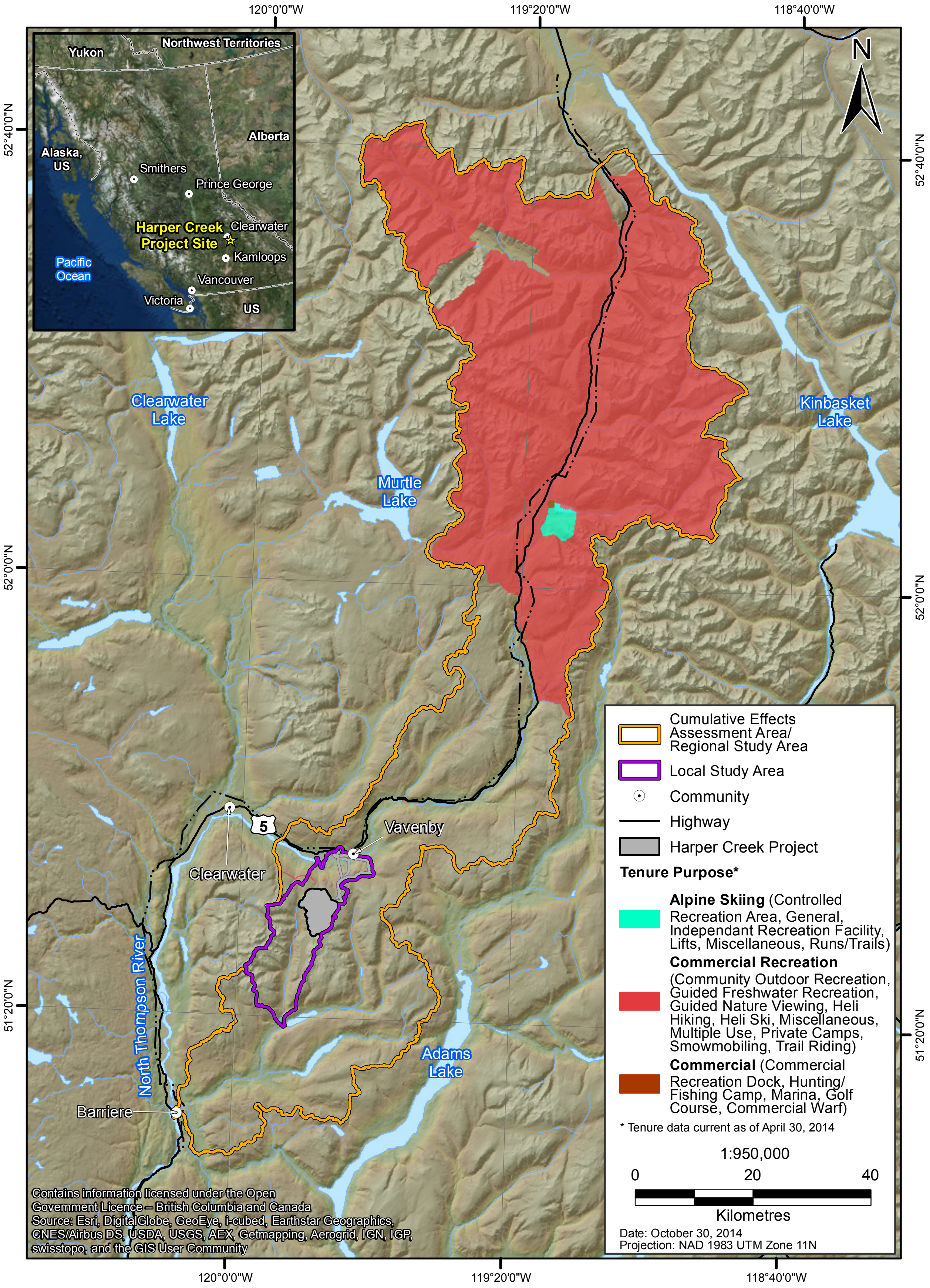
Figure 14.6-3

Commercial Recreation Tenures in the Fish, Fish Habitat, and Aquatic Resources Cumulative Effects Assessment Area



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Date: October 30, 2014
Projection: NAD 1983 UTM Zone 11N

Figure 14.6-4

Water Licences and Range Tenures in the Fish, Fish Habitat, and Aquatic Resources Cumulative Effects Assessment Area

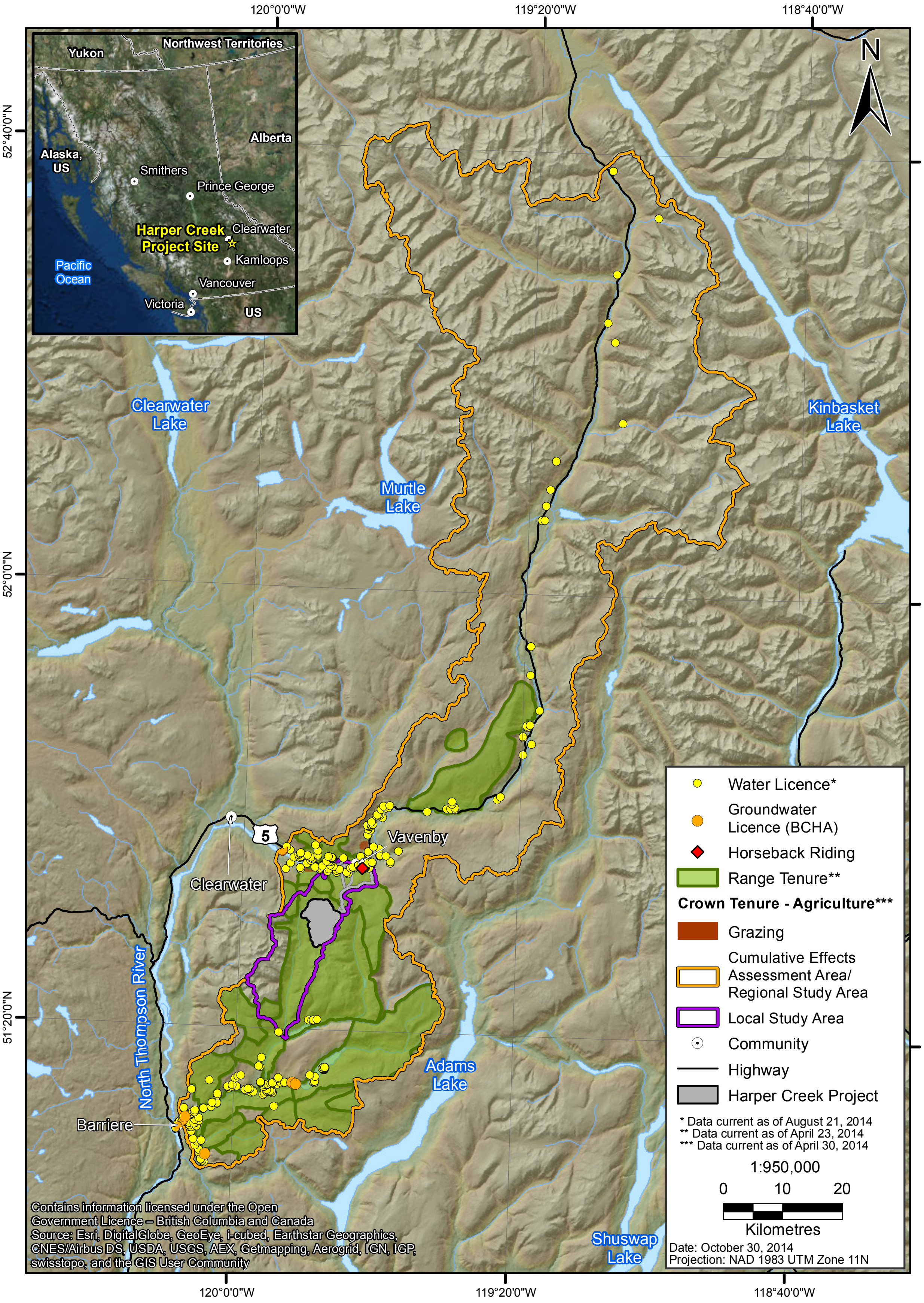

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Figure 14.6-5

BC Recreation Sites, Trails, and Private Campgrounds in the Fish, Fish Habitat, and Aquatic Resources Cumulative Effects Assessment Area

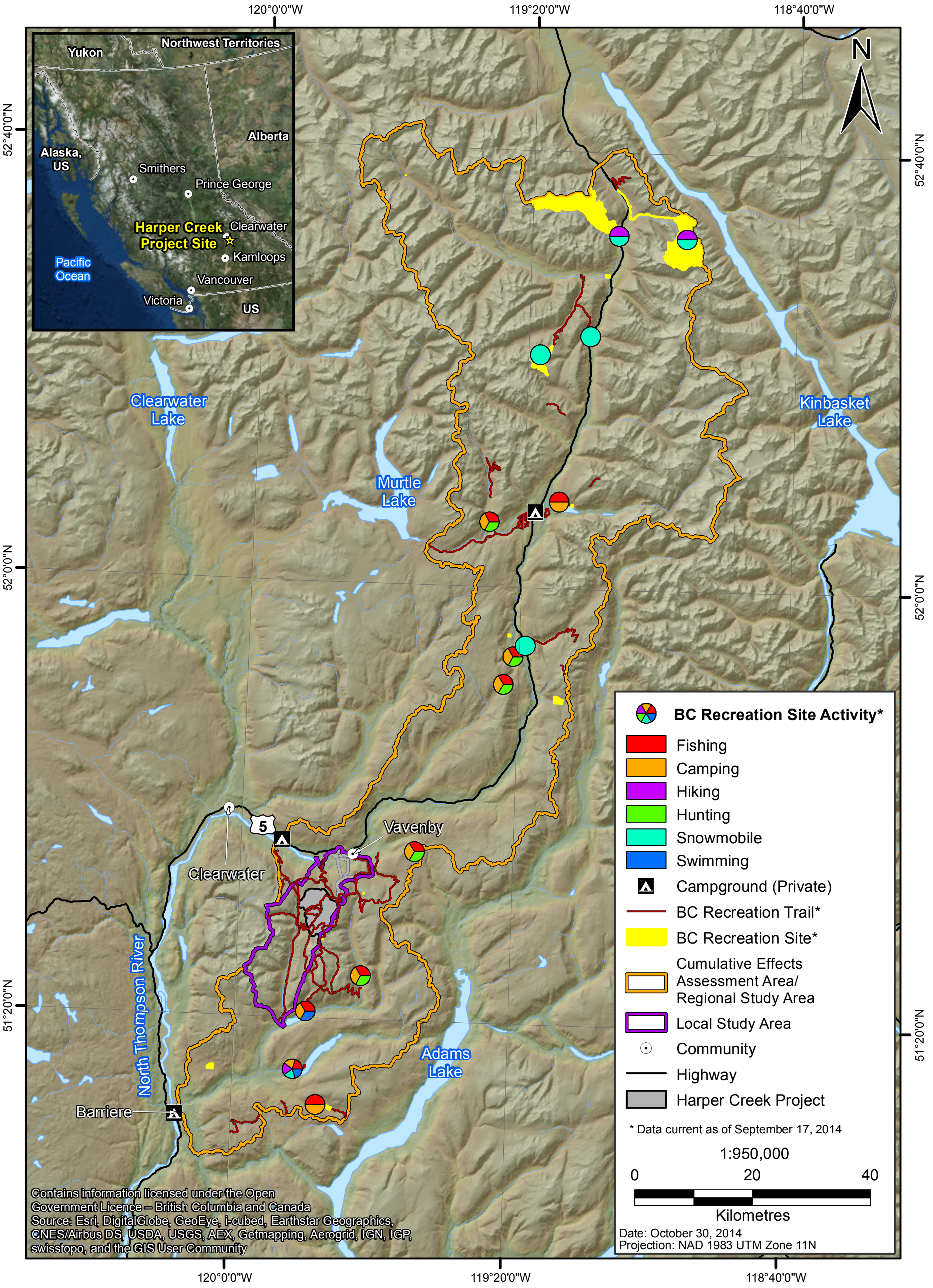

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Table 14.6-1. Impact Matrix for Screening and Ranking Potential Cumulative Effects on Fish, Fish Habitat, and Aquatic Resources

Residual Effects of the Harper Creek Project on VCs	Past Projects	Present Projects			Reasonably Foreseeable Future Projects		Activities										
	Weyerhaeuser Sawmill	Bone Creek	Trans Mountain Pipeline	Vavenby Sawmill	North Thompson Transmission Project	Trans Mountain Pipeline Expansion	Aboriginal Harvesting	Hunting	Trapping	Fishing	Non-commercial Recreation	Commercial Recreation	Mining and Mineral Exploration	Transportation	Agriculture	Forestry	Water Use
Fish																	
Changes in Water Quantity in Harper Creek watershed							🟢			🟢						🟢	
Changes in Water Quality in P Creek																🟢	
Changes in Water Quality in T Creek																🟢	
Changes in Water Quality in upper Harper Creek																🟢	
Changes in Water Quality in lower Harper Creek							🟢			🟢						🟢	
Fish Habitat																	
Changes in Water Quantity in Harper Creek watershed																🟢	
Aquatic Resources																	
Changes in Water Quantity in Jones Creek, Baker Creek, and Harper Creek watershed																🟢	
Changes in Water Quality (toxicity) in P Creek																🟢	
Changes in Water Quality (toxicity) in T Creek																🟢	
Changes in Water Quality (toxicity) in upper Harper Creek																🟢	
Changes in Water Quality (toxicity) in lower Harper Creek																🟢	
Changes in Water Quality (nutrient loading) in Jones Creek, Baker Creek, T Creek, P Creek, and Harper Creek																🟢	

Notes:

🟢 = *Negligible to minor risk of adverse cumulative effect; will not be carried forward in the assessment.*

🟡 = *Moderate risk of adverse cumulative effect; will be carried forward in the assessment.*

🔴 = *Major risk of adverse cumulative effect or significant concern; will be carried forward in the assessment.*

No cumulative effects are predicted because little to no spatial overlap between Project residual effects and other projects, activities, or human actions are expected within the CEA boundaries that are expected to result in a significant adverse effect.

Table 14.7-1. Summary of Key Project and Cumulative Residual Effects, Mitigation, and Significance for Fish, Fish Habitat, and Aquatic Resources Valued Components

Key Residual Effects	Project Phase	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Fish and Fish Habitat VCs				
Changes in Water Quantity to Upper Harper Creek, T Creek and P Creek (Bull Trout)	Construction, Operations, Closure, Post-Closure	Diverting non-contact and contact water; maintaining natural networks; reusing contact water to minimize the use of freshwater. Implementing the sedimentation and erosion control plan to avoid morphologic changes. Implementation of Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Site Water Management Plan (Section 24.13); Sediment and Erosion Control Plan (Section 24.11); Fish Habitat Offsetting Plan (Appendix 14-E)	Not significant (moderate)	N/A[a]
Potential for Toxicity due to Changes in Water Quality in P Creek (Bull Trout) and Lower Harper Creek (Bull Trout, Rainbow Trout, and Coho Salmon)	Construction, Operations, Closure, Post-Closure	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Not significant (minor)	N/A[a]
Potential for Toxicity due to Changes in Water in T Creek (Bull Trout) and Upper Harper Creek (Bull Trout)	Construction, Operations, Closure, Post-Closure	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Not significant (moderate)	N/A[a]

(continued)

Table 14.7-1. Summary of Key Project and Cumulative Residual Effects, Mitigation, and Significance for Fish, Fish Habitat, and Aquatic Resources Valued Components (completed)

Key Residual Effects	Project Phase	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Aquatic Resources				
Changes in Water Quantity	Construction, Operations, Closure, Post-Closure	Diverting non-contact and contact water; maintaining natural networks; reusing contact water to minimize the use of freshwater. Implementing the sedimentation and erosion control plan to avoid morphologic changes. Implementation of Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Site Water Management Plan (Section 24.13); Sediment and Erosion Control Plan (Section 24.11)	Not significant (moderate)	N/A[a]
Potential for Toxicity due to Changes in Water Quality in P Creek and Lower Harper Creek	Construction, Operations, Closure, Post-Closure	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Not significant (minor)	N/A[a]
Potential for Toxicity due to Changes in Water in T Creek and Upper Harper Creek	Construction, Operations, Closure, Post-Closure	Mine Waste and ML/ARD Management Plan (Section 24.9), Fish and Aquatic Effects Monitoring and Management Plan (Section 24.6), Selenium Management Plan (Section 24.12), Soil Salvage and Storage Plan (Section 24.14), Site Water Management Plan (Section 24.13), Sediment and Erosion Control Plan (Section 24.11), Explosives Handling Plan (Section 24.5)	Not significant (moderate)	N/A[a]
Effects due to Nutrient Loading	Construction, Operations, Closure, Post-Closure	Diverting contact and mine water to TMF; Explosives Handling plan; Diverting contact and mine water to TMF.	Not significant (moderate)	N/A[a]

[a] *No past, present, or reasonably foreseeable future projects are expected to interact with the Project residual effects.*

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