12. HYDROLOGY EFFECTS ASSESSMENT

The Harper Creek Project (the Project) is located in the Thompson-Nicola Regional District of BC, within the North Thompson River watershed on the sub-watershed divide between Baker, Jones, and Harper creeks (Figure 12-1). Baker and Jones creeks flow north directly into the North Thompson River. Harper Creek drains south into the Barrière River, which in turn drains into the North Thompson River. The North Thompson River is a tributary of the Thompson River which flows southwest to join the Fraser River, which drains to the Pacific Ocean at Richmond, BC. This chapter provides an evaluation of potential effects on hydrology as a result of the Project.

12.1 INTRODUCTION

Hydrology is a key component of the aquatic environment because it is linked to other ecosystem components, including surface water quality, fish and fish habitat, and aquatic resources. The Project could affect hydrology by altering streamflows (i.e., surface water quantity). In this chapter:

- baseline hydrologic conditions within the local and regional study areas are characterized;
- potential effects of the Project on hydrology are identified;
- mitigation measures for such effects are proposed;
- residual effects of the Project on hydrology, after implementation of mitigation measures, are predicted; and
- cumulative effects of the Project and other past, present, and foreseeable future projects on hydrology are assessed.

The term "hydrology" in this chapter refers to "surface water quantity." Groundwater quantity (Chapter 11), groundwater quality (Chapter 11), and surface water quality (Chapter 13) are discussed separately in the Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS).

This chapter follows the effects assessment methodology described in Chapter 8 of this Application/EIS. Baseline data and watershed modelling to support the abovementioned assessment are presented in Appendix 12-A (Surface Hydrology Baseline Report) and Appendix 12-B (Watershed Modelling Report).

12.2 REGULATORY AND POLICY FRAMEWORK

This section provides an overview of the relevant regulatory framework and regulatory requirements related to hydrology as summarized in Table 12.2-1.

Figure 12-1

Project Location and Surrounding Watersheds

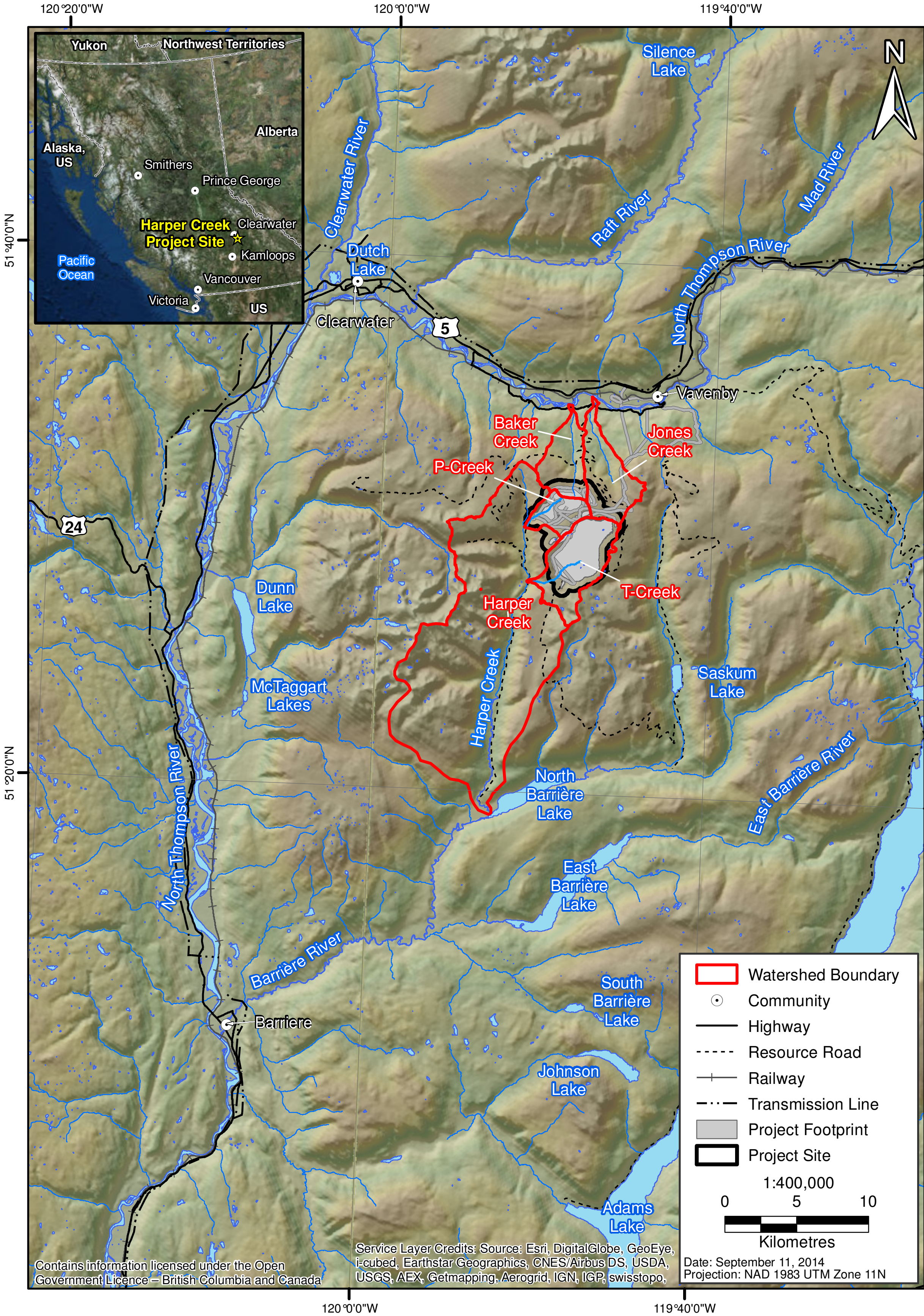


Table 12.2-1. Summary of Applicable Statutes and Guidelines Related to Hydrology

Name	Level of Government	Description
BC *Water Act* (1996)	Provincial	Diverting, storing, or using water, or causing changes in and about a stream for any purpose requires approvals and licenses under the Act.
Canada Water Act (1985a)	Federal	The Act provides the framework for joint federal-provincial management of Canada's water resources.
Fisheries Act (1985b)	Federal	Ensures sufficient flows for fish by preventing permanent alteration to, or destruction of, fish habitat.
Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators (BC MOE 2012)	Provincial	Outlines baseline study requirements for proposed mineral projects, including information requirements for surficial hydrology, water quality (physical and chemical parameters), aquatic sediments, tissue residues, and aquatic life.

12.3 Scoping the Effects Assessment

12.3.1 Valued Components

The BC EAO defines 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 AIR (BC EAO 2011) and in the Canadian Environmental Assessment Agency Background Information document (CEA Agency 2011).

12.3.1.1 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 federal, provincial, and local government agencies. A summary of how scoping feedback was incorporated into the selection of the hydrology assessment subject area and VC is summarized below in Table 12.3-1.

Table 12.3-1. Consultation Feedback on Proposed Valued Component

Subject Area	Feedback by*			Issues Raised	Proponent Response
	AG	G	P/S		
Hydrology	X	X		Addressing hydrologic variability (i.e., wet and dry conditions)	Sensitivity analyses include 50-year-dry and 50-year-wet conditions.

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

Aboriginal groups have commented on the importance of undertaking a hydrology effects assessment. Simpcw First Nation and Adams Lake Indian Band are concerned about downstream fisheries impacts and interested in the hydrologic regime (Appendix 3-E).

12.3.1.2 Selecting Valued Components

The Project components and activities associated with each phase of the Project were screened to identify potential interactions with proposed VCs. The list of key Project components and activities is based on the Project's Technical Report and Feasibility Study (Merit 2014). Table 12.3-2 identifies the Project components and activities that may interact with potential hydrology VCs with "X" indicating a potential interaction between the hydrology VC and the Project component or activity. Table 12.3-2 summarizes the VCs with the potential to interact with the Project.

The proposed VCs that were selected for assessment for the Project are summarized in Chapter 8, Table 8.4-3. This list was presented to the EA Working Group[1] for discussion. The VC selected for inclusion in this chapter is surface water quantity (Table 12.3-3).

The assessment of a change in a VC is evaluated using metrics that are relevant, practical, measurable, responsive, accurate, and predictable to measure the condition and trend of a VC. Streamflow was selected as the metric for the surface water quantity VC. Based on the natural flow regime paradigm (Poff et al. 1997; Poff et al. 2010), streamflow indices (i.e., annual and monthly flows, monthly distribution of runoff, peak flow, and low flow) are vital elements of aquatic environmental health.

12.3.2 Defining Assessment Boundaries

Assessment boundaries define the maximum limit within which the effects assessments are conducted. Boundaries encompass where and when the Project is expected to interact with the VCs; any political, social, and economic constraints; and limitations in predicting or measuring changes. Boundaries relevant to hydrology are described below.

12.3.2.1 Temporal Boundaries

Temporal boundaries, provided in Table 12.3-4, are the time periods considered in the assessment for various Project phases and activities. Temporal boundaries reflect those periods during which planned Project activities are reasonably expected to potentially affect a VC. Potential effects will be considered for each phase of the Project as described in Table 12.3-4.

[1] The EA Working Group is a forum for discussion and resolution of technical issues associated with the proposed Project, as well as providing technical advice to the BC EAO and CEA Agency, which remain ultimately responsible for determining significance. It comprises representatives of provincial, federal, and local government, and Aboriginal groups.

Table 12.3-2. Identification and Rationale for Selection of Surface Water Quantity Valued Component

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

(continued)

Table 12.3-2. Identification and Rationale for Selection of Surface Water Quantity Valued Component (continued)

Category	Project Components and Activities	Surface Water Quantity
Construction *(cont'd)*		
Stockpiles *(cont'd)*	PAG and Non-PAG Low-grade ore stockpiles foundation construction	X
	PAG Waste Rock stockpiles foundation construction	X
Tailings management	Coffer dam and South TMF embankment construction	X
	Tailings distribution system construction	
Temporary construction camp	Construction camp construction, operation, and decommissioning	X
Traffic	Traffic delivering equipment, materials and personnel to site	
Waste disposal	Waste management: garbage, incinerator and sewage waste facilities	X
Water management	Ditches, sumps, pipelines, pump systems, reclaim system and snow clearing/stockpiling	X
	Water management pond, sediment pond, diversion channels and collection channels construction	X
Operations 1		
Concentrate transport	Concentrate transport by road from mine to rail load-out facility	
Dangerous goods and hazardous materials	Explosives storage and use	
	Hazardous materials storage, transport, and off-site disposal	
	Spills and emergency management	
Environmental management and monitoring	Fish habitat offsetting site monitoring and maintenance	X
Equipment fleet	Mine site mobile equipment (excluding mining fleet) and vehicle use	
Fuel supply, storage and distribution	Fuel storage and distribution	
Mining	Mine pit operations: blast, shovel and haul	X
Ore processing	Ore crushing, milling, conveyance and processing	
Potable water supply	Process and potable water supply, distribution and storage	X
Power supply	Backup diesel generators	
	Electrical power distribution	
Processing	Plant operation: mill building, truck shop, warehouse and pipelines	X

(continued)

Table 12.3-2. Identification and Rationale for Selection of Surface Water Quantity Valued Component (continued)

Category	Project Components and Activities	Surface Water Quantity
Operations 1 ***(cont'd)***		
Procurement and labour	Employment and labour	
	Procurement of goods and services	
Rail load-out facility	Rail-load out activity (loading of concentrate; movement of rail cars on siding)	
Reclamation and decommissioning	Progressive mine reclamation	X
Stockpiles	Construction of Non-PAG tailings beaches	X
	Construction of PAG and Non-PAG Low Grade Ore Stockpile	X
	Non-PAG Waste Rock Stockpiling	X
	Overburden stockpiling	X
Tailings management	Reclaim barge and pumping from TMF to Plant Site	X
	South TMF embankment construction	X
	Sub-aqueous deposition of PAG waste rock into TMF	X
	Tailings transport and storage in TMF	X
	Treatment and recycling of supernatant TMF water	X
Traffic	Traffic delivering equipment, materials and personnel to site	
Waste disposal	Waste management: garbage and sewage waste facilities	X
Water management	Monitoring and maintenance of mine drainage and seepage	X
	Surface water management and diversions systems including snow stockpiling/clearing	X
Operations 2 - ***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
Reclamation and decommissioning	Partial reclamation of Non-PAG waste rock stockpile	X
	Partial reclamation of TMF tailings beaches and embankments	X
Tailings management	Construction of North TMF embankment and beach	X
	Deposit of low grade ore tailings into open pit	X
Water management	Surface water management	X

(continued)

Table 12.3-2. Identification and Rationale for Selection of Surface Water Quantity Valued Component (continued)

Category	Project Components and Activities	Surface Water Quantity
Closure		
Environmental management and monitoring	Environmental monitoring including surface and groundwater monitoring	X
	Monitoring and maintenance of mine drainage, seepage, and discharge	X
	Reclamation monitoring and maintenance	X
Open pit	Filling of open pit with water and storage of water as a pit lake	X
Procurement and labour	Employment and labour	
	Procurement of goods and services	
Reclamation and decommissioning	Decommissioning of rail concentrate load-out facility	
	Partial decommissioning and reclamation of mine site roads	X
	Decommissioning and removal of plant site, processing plant and mill, substation, conveyor, primary crusher, and ancillary infrastructure (e.g., explosives facility, truck shop)	X
	Decommissioning of diversion channels and distribution pipelines	X
	Decommissioning of reclaim barge	
	Reclamation of PAG LGO stockpile, overburden stockpile and Non-PAG waste rock stockpile	X
	Reclamation of TMF embankments and beaches	X
	Removal of contaminated soil	X
	Use of topsoil for reclamation	X
Stockpiles	Storage of waste rock in the non-PAG waste rock stockpile	X
Tailings management	Construction and activation of TMF closure spillway	X
	Maintenance and monitoring of TMF	X
	Storage of water in the TMF and groundwater seepage	X
	Sub-aqueous tailing and waste rock storage in TMF	X
	TMF discharge to T-Creek	X
Waste disposal	Solid waste management	

(continued)

Table 12.3-2. Identification and Rationale for Selection of Surface Water Quantity Valued Component (completed)

Category	Project Components and Activities	Surface Water Quantity
Post-Closure		
Environmental management and monitoring	Environmental monitoring including surface and groundwater monitoring	X
	Monitoring and maintenance of mine drainage, seepage, and discharge	X
	Reclamation monitoring and maintenance	X
Open pit	Construction of emergency spillway on open pit	X
	Storage of water as a pit lake	X
Procurement and labour	Procurement of goods and services	
Stockpiles	Storage of waste rock in the non-PAG waste rock stockpile	X
Tailings management	Storage of water in the TMF and groundwater seepage	X
	Sub-aqueous tailing and waste rock storage	X
	TMF discharge	X

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

Table 12.3-3. Valued Components Selected for Assessment

Assessment Category	Subject Area	Valued Components
Environment	Hydrology	Surface water quantity

Table 12.3-4. Temporal Boundaries Used in the Assessment for Hydrology

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 tailings management facility 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.

12.3.2.2 Spatial Boundaries

Project Site

The Project Site is defined by a buffer of 500 m around the primary Project components (Figure 12.3-1). Project components include :the open pit, the open pit haul road, primary crusher, and ore conveyor, mill plant site with ore processing facilities and intake/outtake pipelines, tailings management facility (TMF); overburden, topsoil, potentially acid-generating (PAG) waste rock, non-PAG waste rock stockpiles, and non-PAG and PAG low-grade ore stockpiles.

Local Study Area

The hydrology local study area (LSA) was selected to focus on the Project Site and infrastructure and surrounding area within which there is a reasonable potential for immediate direct and indirect effects on hydrology due to an interaction with Project components or activities. The hydrology LSA includes the Harper Creek watershed to its confluence with the Barrière River, and Baker Creek and Jones Creek watersheds to their confluence with the North Thompson River (Figure 12.3-1). The LSA includes 500 m buffer zones around the linear features of the project, i.e., roads, outside the abovementioned watersheds. Within the LSA, the Project has the potential to have quantifiable effects on streamflows.

Discrete sub-catchment areas were identified within the watersheds. Hydrologic conditions (i.e., streamflows) were modelled at the downstream extent of each sub-catchment area, referred to as a "Hydrology Assessment Node". Ten nodes were identified at the downstream of sub-catchments within the LSA (Figure 12.3-1; Table 12.3-5).

Figure 12.3-1

Project Site, and Local and Regional Study Areas for Hydrology Effects Assessment

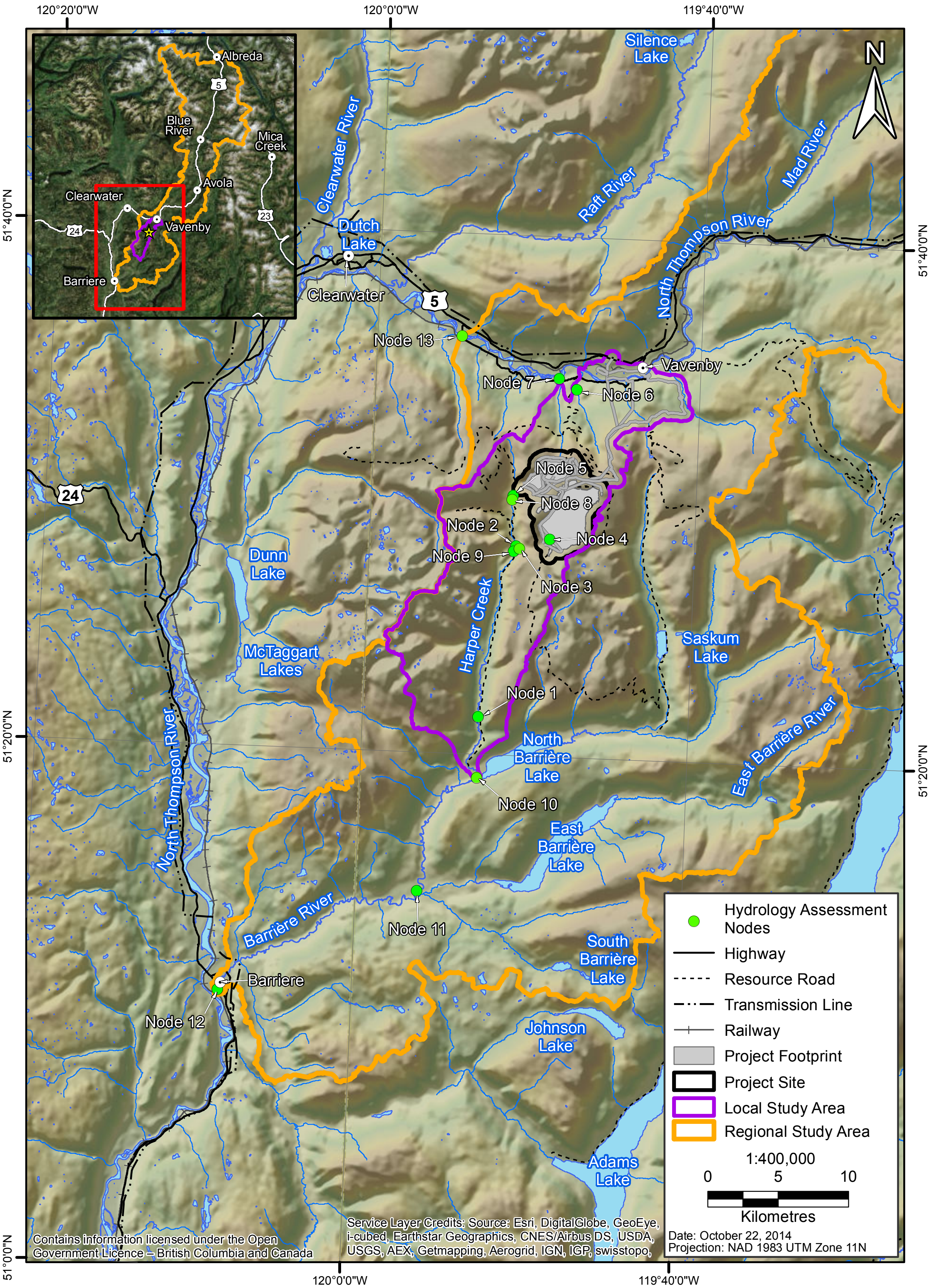


Table 12.3-5. Hydrology Assessment Nodes within the Local and Regional Study Areas

Hydrology Assessment Node	Corresponding Water Quality Modelling Node	Sub-catchment Description	Pre-mine Drainage Area (km^2)	Spatial Boundary
Node 1	n/a	Harper Creek near the Mouth (WSC Station: 08LB076)	166.4	LSA
Node 2	HM	Harper Creek above T-Creek confluence (HCMC station: HARPERUS)	47.0	LSA
Node 3	T-Creek	T-Creek at Harper Creek confluence (HCMC station: TSFDS)	23.4	LSA
Node 4	n/a	T-Creek upstream of Harper Creek confluence (HCMC station: TSFUS)	15.0	LSA
Node 5	P-Creek	P-Creek at Harper Creek confluence (HCMC station: OP)	7.6	LSA
Node 6	J1	Jones Creek above North Thompson River confluence (HCMC station: JONESUS)	17.6	LSA
Node 7	BK0	Baker Creek at North Thompson River confluence (HCMC station: BAKER)	14.0	LSA
Node 8	HP	Harper Creek below P-Creek confluence	16.6	LSA
Node 9	HT	Harper Creek below T-Creek confluence	70.4	LSA
Node 10	HB	Harper Creek at Barrière River confluence	185.6	LSA
Node 11	n/a	Barrière River below Sprague Creek (WSC Station: 08LB069)	624.0	RSA
Node 12	n/a	Barrière River at the Mouth (WSC Station: 08LB020)	1140	RSA
Node 13	n/a	North Thompson River at Birch Island (WSC Station: 08LB047)	4490	RSA

Regional Study Area

The hydrology regional study area (RSA) is the spatial area within which there is potential for direct and indirect interaction and/or cumulative effects to occur. The RSA encompasses the LSA and includes the Barrière River watershed to its mouth and the North Thompson River watershed to Birch Island (Figure 12.3-1).

Three regional Water Survey of Canada (WSC) gauges within the RSA were selected as "Hydrology Assessment Nodes" to assess Project impacts at the regional scale (Figure 12.3-1; Table 12.3-5).

No administrative or technical boundaries were applied to the hydrology effects assessment.

12.4 BASELINE CONDITIONS

12.4.1 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.

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 1800 metres above sea level (masl). Minimum and maximum mean monthly temperatures range between approximately -10°C in December and 10°C in July. The mean annual precipitation at the Project Site is estimated to be in the order of 1,050 mm, with 40% falling as rain and 60% falling as snow (Appendix 12-A).

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 effect of elevation on runoff pattern 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 winter or late summer. 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).

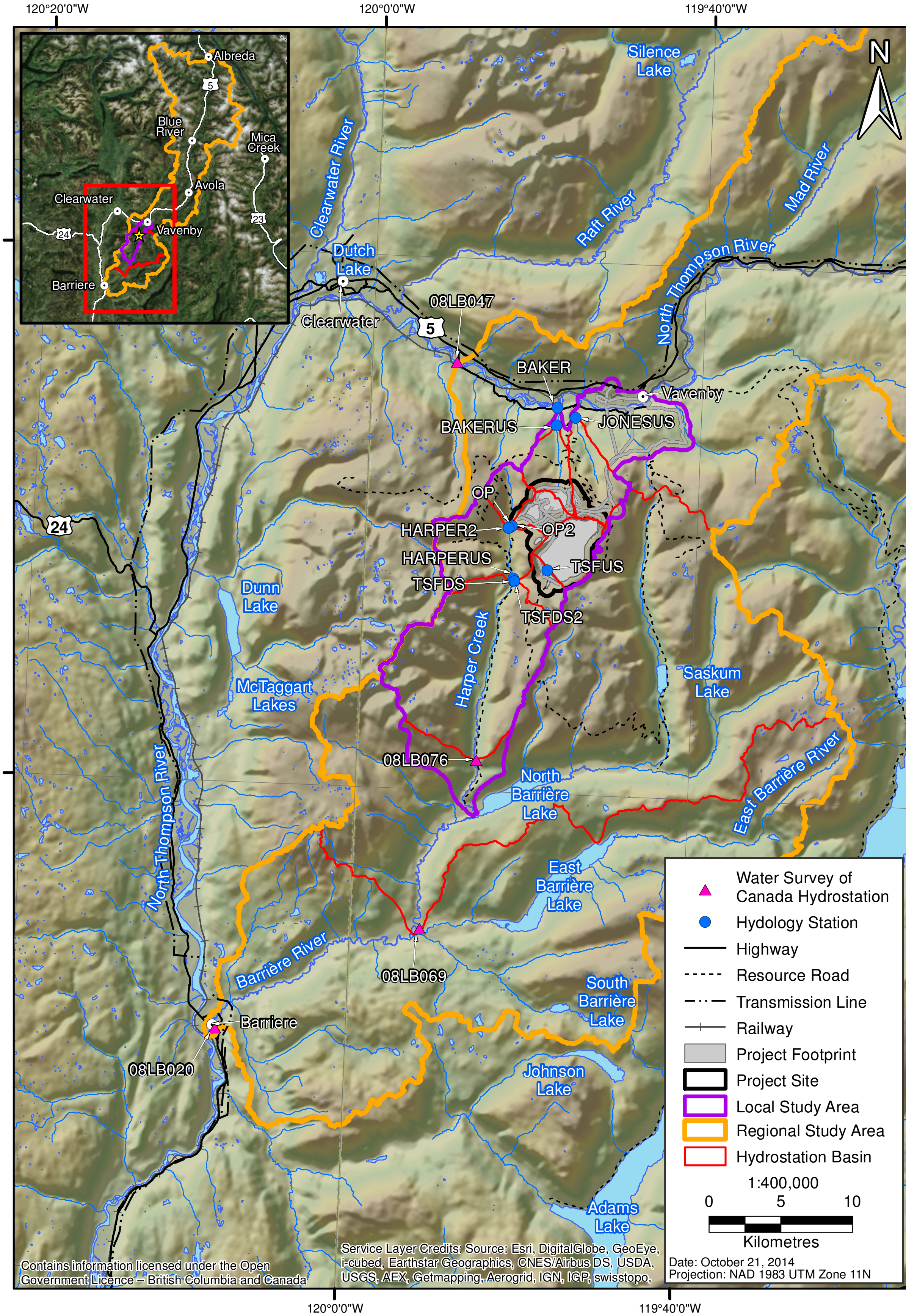
12.4.1.1 Watersheds

Baker Creek (drainage area = 14.3 kilometres^2 [km^2]) and Jones Creek (drainage area = 17.6 km^2) are north-facing watersheds and flow approximately 5 km from their headwaters at the Project Site to the North Thompson River (drainage area = 4,490 km^2 at Birch Island; Figure 12.4-1). Harper Creek (drainage area = 185.6 km^2) flows south from the Project Site for approximately 25 km and discharges into the western end of North Barrière Lake, just upstream of the lake outlet (Figure 12.4-1). The Barrière River (drainage area = 1,140 km^2) flows out of the lake in a southwesterly direction for approximately 27 km before meeting the North Thompson River at the community of Barriere, 58 km north of Kamloops.

The proposed infrastructure would be mainly located in the upper, eastern part of the Harper Creek watershed, and in the headwaters of Baker and Jones creeks, at elevations between approximately 1,600 and 1,900 masl (Figure 12.4-1). Baker Creek, Jones Creek, and Harper Creek watersheds are described below, along with two sub-watersheds of Harper Creek (i.e., P-Creek and T-Creek) which lie within the Project Site (Appendix 12-A).

Figure 12.4-1

Sub-watersheds within the Local and Regional Study Areas



The distribution of elevations within each watershed is plotted in the form of hypsometric curves (Figure 12.4-2). These curves show that the maximum elevations in Baker, Jones, and P creeks are similar, at around 1,850 to 1,900 masl, as these watersheds share drainage divides within the Project Site. Baker and Jones creeks have lower median elevations than P-Creek because they descend into the lower North Thompson River Valley (430 masl) compared to the Harper Creek Valley for P-Creek (1,215 masl). Harper Creek has a higher maximum elevation than its sub-watersheds, P-Creek and T-Creek, because its watershed contains higher alpine terrain to the west of the proposed Project Site.

Baker Creek Watershed

Baker Creek drains a north-facing watershed with an area of 14.3 km^2. The Baker Creek headwaters drain steep, high-elevation catchments but transition to moderate gradient reaches until the confluence with the North Thompson River. The average channel gradient of Baker Creek is 16.6% (Appendix 12-A). The watershed is covered in coniferous forest with some logging activity throughout the watershed. Additionally, some farming activity is present in the lower section of the watershed and a few small intakes remove water from lower Baker Creek for irrigation. The watershed elevation ranges from 430 to 1,850 masl, with a median elevation of 1,360 masl.

The Baker Creek channel is confined by the hillslopes and the dominant stream morphology is step-pool (Montgomery and Buffington 1997). Bed materials consist primarily of cobbles and gravels. The dominant riparian vegetation includes immature and mature trees along mossy banks.

Jones Creek Watershed

Jones Creek drains a north-facing watershed with an area of 17.6 km^2. The Jones Creek headwaters drain moderate-gradient high-elevation catchments, and the mainstem channel continues at a moderate gradient until the confluence with the North Thompson River. The average channel gradient of Jones Creek is 12.9% (Appendix 12-A). The watershed is covered in coniferous forest with some logging activity throughout the watershed. Additionally, some farming activity is present in the lower section of the watershed and a few small intakes remove water from lower Jones Creek for irrigation. The watershed elevation ranges from 430 to 1,865 masl, with a median elevation of 1,375 masl.

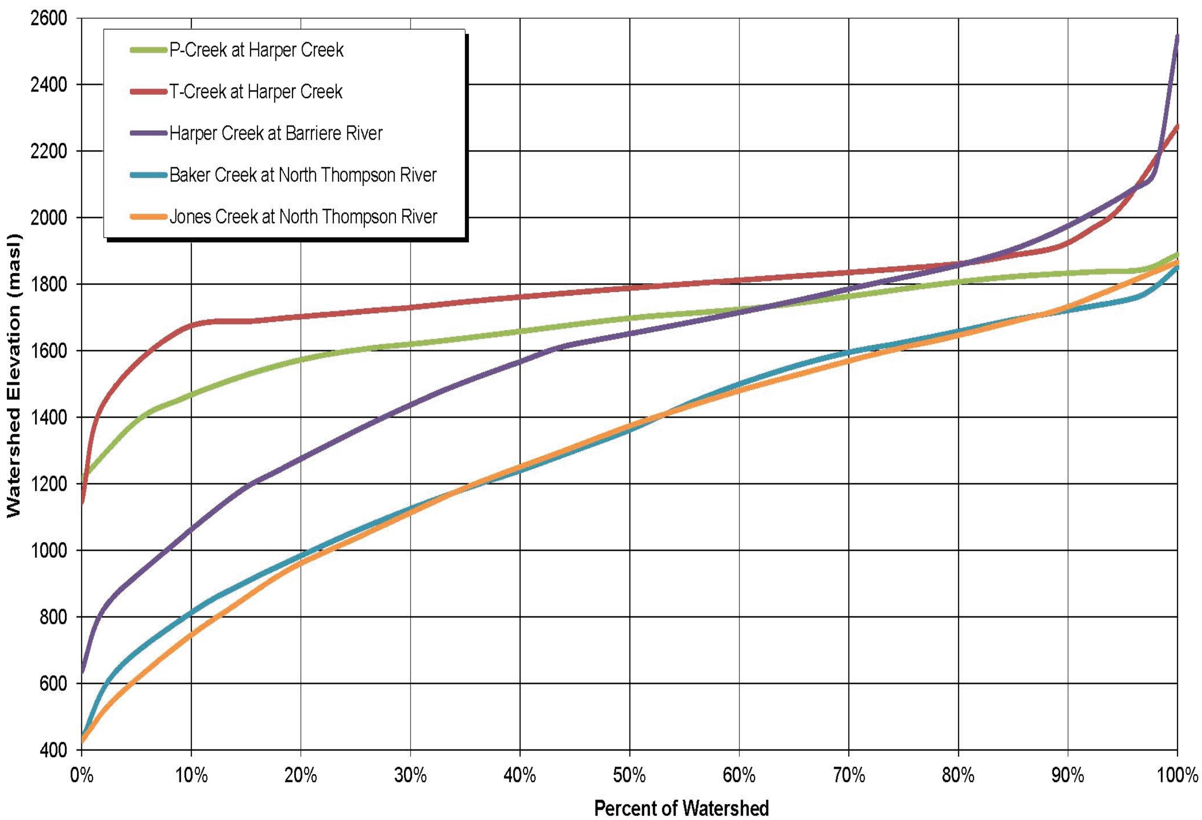
The Jones Creek channel is confined by hillslopes and the dominant stream morphology is step-pool (Montgomery and Buffington 1997). Bed material consists primarily of cobbles and gravels. Riparian vegetation includes immature and mature trees along mossy banks.

Harper Creek Watershed

Harper Creek drains a southerly facing watershed with an area of 185.6 km^2. The Harper Creek headwaters and tributaries drain steep mountain catchments. The mainstem channel is confined by valley hillslopes throughout much of its length, although the channel meanders slightly in some places through areas where a small valley flat has developed. The creek crosses a low-gradient fan before discharging near the outlet of North Barrière Lake. The catchment is partially covered in coniferous forest with extensive logging on the east side of the watershed. The west side of the watershed consists of higher mountains with alpine terrain and some exposed rock.

Figure 12.4-2

Hypsometric Curves for Sub-watersheds within the Local Study Area



The average channel gradient of Harper Creek is 3.0% (Appendix 12-A); however, the creek transitions from moderate gradient sections in the upper watershed to low-gradient sections through much of the middle and lower sections of the watershed. Elevations in the Harper Creek watershed range from approximately 640 masl near the confluence with North Barrière Lake to over 2,600 masl at the peak of Granite Mountain, with a median elevation of 1,660 masl.

The dominant stream morphology in Harper Creek is rapids (Montgomery and Buffington 1997), although intermittent low-gradient sections occur where the morphology is riffle-pool and the channel is less confined. Alluvial bed materials consisting primarily of cobbles interspersed with boulders and gravels occur throughout Harper Creek. The dominant riparian vegetation includes overhanging alders with mature trees along mossy banks. The banks are undercut in some sections and can be 0.5 m high.

P-Creek: Harper Creek Sub-Watershed

P-Creek, a previously unnamed tributary of Harper Creek, drains a south–southwest facing watershed area of 7.7 km^2. The upper portion of this tributary overlaps the proposed open pit for the Project, and therefore it is called P-Creek. The watershed is partially covered in coniferous forest but has undergone extensive logging. The average channel gradient of lower sections of P-Creek is 9.6% (Appendix 12-A); however, the upper portion of the watershed is steeper, and gradually transitions to a lower gradient near the confluence. The watershed elevation ranges from 1,215 to 1,890 masl with a median elevation of 1,700 masl.

The dominant stream morphology in P-Creek is cascade (Montgomery and Buffington 1997) with bedrock controls. Bed material in P-Creek is dominated by coarse materials with the vast majority classified as angular cobble with some boulders. The dominant riparian vegetation is overhanging alders and mature trees along the mossy creek banks. Some large instream woody debris produces log jam stream features as they are filled with bed material. Below the Harper Creek Forest Service Road (FSR) the channel flows onto a fan and the valley is less confined by the hillslopes. The channel meanders somewhat and channel avulsions were noted.

T-Creek: Harper Creek Sub-Watershed

T-Creek, a previously unnamed tributary of Harper Creek, drains a west-facing watershed area of 23.4 km^2. The upper portion of this watershed contains the proposed TMF for the Project, and therefore it is called T-Creek. The watershed is partially covered in coniferous forest but has undergone extensive logging. The average channel gradient of T-Creek is 7.3% (Appendix 12-A); however, much of the upper watershed contains a low-gradient hanging valley, which then drops steeply to meet Harper Creek. The watershed elevation ranges from 1,145 to 2,275 masl, with a median elevation of 1,790 masl.

The dominant stream morphology in lower T-Creek is step-pool and cascade (Montgomery and Buffington 1997). Bed material is dominated by coarse materials with the vast majority being classified as boulder and cobbles with some gravels. In contrast, in the upper hanging valley the morphology is pool-riffle and bed material is gravel dominated. The dominant riparian vegetation is overhanging alders and mature trees along the mossy banks. Some large instream woody debris produce log jam stream features as they are filled with bed material. The channel is largely confined by the hillslopes or incised within remnant fan deposits until approximately 100 m upstream of the Harper Creek confluence.

12.4.1.2 Streamflow Trends with Climate Change

According to the Pacific Climate Impacts Consortium (PCIC), mean temperatures in the Thompson-Nicola region of BC are predicted to warm by approximately 1.8°C over the next 40 years. Furthermore, winter precipitation is predicted to increase by approximately 7% and summer precipitation to decrease by 8% (PCIC 2012) over the same time period. Winter snowfall is predicted to decrease by 10%, meaning the increase in winter precipitation will fall as rain (PCIC 2012; Table 12.4-1).

Table 12.4-1. Summary of Climate Change for the Thompson-Nicola Region in the 2050s

		Projected Change from 1961-1990 Baseline in the 2050s		
Climate Variable	Season	Ensemble Median	10th Percentile	90th Percentile
Mean Temperature	Annual	1.8°C	1.1°C	2.7°C
Precipitation	Annual	6%	11%	-1%
	Summer	-8%	2%	-17%
	Winter	7%	15%	-4%
Snowfall	Winter	-10%	2%	-18%
	Spring	-54%	-12%	-75%

Source: PCIC (2012)

These changes could affect streamflow patterns. Warmer winter temperatures would raise freezing levels within the watersheds, shorten the period of snowfall, and increase the proportion of winter precipitation that would occur as rain. Increased rain during the winter, combined with higher winter precipitation, could increase the winter flows and decrease the corresponding freshet flows through reduced snowpack. Decreasing summer precipitation may result in lower summer flows, and this effect could be increased further by higher summer temperatures and correspondingly higher evaporation.

In an effort to address the representativeness of historical flow data to assess hydrologic conditions in the future, historical trends of annual temperature, precipitation, and discharge were examined in the general region of the Project based on regional climate and streamflow data collected by Environment Canada (Appendix 12-B). A review of long-term regional climatic and streamflow records indicates some changes in hydrologic conditions near the Project Site. However, it is not clear if these are the result of climate change or local climatic patterns. Additionally, climate change predictions, such as those presented by PCIC (2012), include allowances for recent anthropogenic influence on climate that may not be evident in historic records. Regardless, inherent variability, the cyclic nature of climate, and the current inability to accurately predict and model future climate patterns, leads to the reasonable conclusion that current hydrologic records provide an appropriate basis for assessing the conditions in the Project area over the expected life of the mine. As well, it is standard engineering practice to apply conservatism in hydrologic predictions where appropriate (e.g., a factor of safety on peak flow estimates).

12.4.2 Baseline Studies

The hydrology baseline study (Appendix 12-A) included the Baker Creek, Jones Creek, and Barrière River watersheds. Within the Barrière River watershed, more intensive data collection focused on the upper part of the Harper Creek sub-watershed where the Project infrastructure would be located. The watersheds and watercourses in the baseline study area are shown in Figure 12.4-1.

The hydrology baseline monitoring program (2011 to 2014) was established to characterize the spatial and temporal variation in flows in the LSA. Hydrometric stations were established at multiple creeks that could potentially be affected by the proposed Project. Specific objectives of the baseline hydrology study were to:

- operate and maintain hydrometric stations that contribute to characterization of the hydrologic regime;
- develop and improve the stage-discharge curves at hydrometric monitoring stations;
- calculate flow discharge estimates and generate annual hydrographs for each hydrometric station within the monitored drainage areas; and
- integrate the site specific data with regional analyses to estimate hydrologic indices related to annual and monthly flows, monthly distribution of runoff, as well as peak and low flows.

12.4.2.1 Data Sources

Streamflow records have been collected at 13 gauging stations in the baseline study area (Table 12.4-2; Figure 12.4-1). Four of these stations are long-term gauging stations operated by the WSC with 30+ years of record at each station. The other nine stations were established and operated by HCMC specifically to support the Project (six stations in 2011 and three new stations in 2013). The station locations were selected to represent spatial variability in streamflow throughout the baseline study area, and to characterize streamflow conditions at key sites downstream from proposed Project infrastructure. The gauging station locations are shown in Table 12.4-2 and Figure 12.4-1.

12.4.2.2 Methods

The hydrometric program was initiated in 2011 to collect and analyze baseline hydrologic data for specific streams within the LSA and RSA. The monitoring program began in 2011 with six HCMC hydrometric stations. In 2013, three new HCMC hydrometric stations were established (Table 12.4-2). Installation and operation of the HCMC gauging stations were in accordance with the requirements of the *Manual of British Columbia Hydrometric Standards* (RISC 2009). Automated hydrometric stations recorded water levels every 15 minutes during open water periods (usually from April to October) to monitor surface water flows in order to characterize the hydrological variation in these water bodies (see Appendix 12-A for details).

Manual flow measurements performed at HCMC hydrometric stations during the open water periods were used to develop stage-discharge rating curves for each station. Using the developed rating curves, the continuously recorded water levels were converted into continuous flow discharge hydrographs during the open water periods (Appendix 12-A).

Table 12.4-2. Hydrometric Monitoring Stations in the Hydrology Baseline Study

Station ID	Description	Drainage Area (km²)	Coordinates Easting (m)	Coordinates Northing (m)	Coordinates UTM Zone	Period of Stage Record
BAKER	Baker Creek 0.1 km upstream from the North Thompson River confluence	14.3	305,162	5,717,700	11	2011-2012
BAKERUS	Baker Creek 1.1 km upstream from station BAKER	12.4	305,107	5,716,436	11	2012-2013
JONESUS	Jones Creek 1.5 km upstream from the North Thompson River confluence	17.6	306,413	5,716,982	11	2012-2013
OP	P-Creek 0.1 km upstream from the Harper Creek confluence (upstream of the Harper Creek FSR bridge)	7.7	301,903	5,709,369	11	2011-2013
OP2	P-Creek 0.1 km upstream from station OP	7.5	301,987	5,709,420	11	2013
HARPER2	Harper Creek immediately downstream of the P-Creek confluence	16.6	301,753	5,709,295	11	2013
HARPERUS	Harper Creek immediately upstream of the T-Creek confluence	47.1	302,085	5,705,776	11	2011-2013
TSFDS	T-Creek 0.1 km upstream from the Harper Creek confluence (upstream of the Harper Creek FSR bridge)	23.4	302,116	5,705,584	11	2011-2013
TSFUS	T-Creek 2.9 km upstream from the Harper Creek confluence at the proposed location of the TMF	15.0	304,465	5,706,344	11	2011-2012
WSC 08LB076	Harper Creek near the mouth	166	299,434	5,693,150	11	1960-2013[1]
WSC 08LB069	Barrière River below Sprauge Creek	624	295,478	5,681,398	11	1964-2013[1]
WSC 08LB020	Barrière River at the mouth	1140	700,550	5,673,756	10	1915-2013[1]
WSC 08LB047	North Thompson River at Birch Island	4490	298,118	5,720,886	11	1973-2013[2]

[1]: *2012 and 2013 data are provisional*
[2]: *2011, 2012, and 2013 data are provisional*

The stations were removed in the autumn once snow and ice began to accumulate in the channels. Continuous stage records collected during winter conditions (i.e., November to March) would be of little value because the presence of ice and snow in the channel changes the relationship between stage and discharge. During November to March, scaling factors were calculated from the ratio of manually measured flow at HCMC stations to Harper Creek (WSC 08LB076) flow on the same date. A scaling factor for each calendar day was then determined by interpolating between the observed conditions. In this way, the shape of the Harper Creek (WSC 08LB076) record was transposed to the HCMC stations, but the flow magnitude was scaled to match the conditions observed (Appendix 12-A).

Three snow course survey sites were established at the Project Site in 2008 and samples were collected in April and May of that year. In 2012, two samples in February, one in March, and one in May were collected (Appendix 12-D). The temporal distribution of snow depth and snowmelt was different between regional and on-site locations. Given these results, regional and on-site snowmelt results were not directly used in the water balance model. Instead, the snowmelt regime in the water balance model was based on observed streamflow data (Appendices 12-B and 12-D).

Streamflows collected from the HCMC hydrometric stations described above were augmented with long-term (i.e., 1974 to 2010) streamflows from the four WSC hydrometric stations (see Appendices 12-A and 12-E for details, including the regional hydrologic analysis). These streamflow data were used in a month-to-month watershed modelling (i.e., water balance modelling) approach to characterize the baseline hydrologic regime for all hydrology assessment nodes in Table 12.3-5. Details of water balance modelling are available in Appendix 12-B. The model was developed in spreadsheet format where the watersheds were divided into sub-catchments within which groundwater and surface water flows were modelled. Spatial variability of climate due to differences in elevation was considered within each sub-catchment. Adjacent sub-catchments were linked together to allow surface and groundwater flows to be routed to downstream sub-catchments (see Appendix 12-B for details).

A regional analysis was used to estimate pre-mine peak flows at hydrology assessment points (see Appendices 12-A and 12-B for details). Pre-mine peak flows were calculated for each assessment node using the equation below to translate the surface hydrology peak flows from a nearby WSC hydrometric station.

$$Q_1 = Q_2 * (A_1 / A_2)^{0.75}$$

where:

Q_1 is the sought return period discharge at the location of interest (i.e., the hydrology assessment node).

Q_2 is the corresponding return period discharge of the reference WSC hydrometric station.

A_1 is the upstream contributing area of the location of interest (i.e., the hydrology assessment node).

A_2 is the upstream contributing area of the reference WSC hydrometric station.

It should be noted that the estimated peak flow values have been increased by 15% to account for possible future climate change effects, which is consistent with general practice guidance in BC (APEGBC 2012).

Based on the observation of monthly flows at baseline conditions, as well as the predicted monthly flows, the lowest monthly flows annually occur in February or March. Further, significant intra-month variations were not expected, nor were observed, in the baseline flows during February and March (Appendix 12-A). Therefore, the minimum monthly flows at each assessment node were used as an estimate for low flows during different phases of the Project in this assessment.

12.4.2.3 Incorporated Recommendations from First Nations, Public, and Government Agencies

Aboriginal groups were interested in consideration of dry/wet variability in hydrology effects assessment (See Chapter 3, Information Distribution and Consultation, for details). Streamflows for dry and wet years with 5-, 10-, 20-, and 50-year return periods are estimated and presented in Appendix 12-B, and summarized in Section 12.4.3.

12.4.2.4 Limitations to the Information Collected or Methodology

Pre-mine hydrologic conditions were characterized through integration of streamflows collected from on-site and regional hydrometric stations with a watershed modelling approach

(Section 12.4.2.4; Appendix 12-B). Simulated flows were deemed reliable for effects assessment purposes. Simulated flows, as well as reliability of such flows for effects assessment, are discussed in Appendix 12-B.

12.4.3 Existing Conditions

A summary of estimated pre-mine hydrologic conditions is provided below; details of estimating hydrologic indices based on the hydrometric monitoring program, regional analysis, and watershed modelling are provided in Appendices 12-A, 12-B, and 12-E. Average monthly and annual flows are presented in Table 12.4-3.

Mean annual discharge is generally controlled by drainage area (i.e., a positive correlation is observed between mean annual discharge and drainage area; Table 12.4-3). The monthly distribution of annual runoff (Figure 12.4-3) indicates that flow is concentrated in the open water season (April to October) with less than 11% of the annual runoff occurring from November to March. During the open water season the distribution of flow depends on the timing of freshet, with more than 50% of the annual runoff occurring during May and June at a majority of the assessment nodes, with the exception of Node 13 (Appendix 12-B).

Pre-mine monthly flows for dry and wet years with 5-, 10-, 20-, and 50-year return periods are estimated and presented in Appendix 12-B. Annual summaries of these estimates are provided in Table 12.4-4.

Estimated pre-mine peak flows with 2-, 5-, 10-, 20-, 50-, 100-, and 200-year return periods are presented in Table 12.4-5. The pre-mine annual low flows (i.e., minimum monthly flows) with return periods of 5, 10, 20, and 50 years are provided in Table 12.4-6.

12.5 Effects Assessment and Mitigation

12.5.1 Screening and Analyzing Project Effects

The purpose of this section is to identify the potential effects that can result from the interaction of the Project components and activities with surface water quantity (i.e., the VC selected in Section 12.3.1) within the boundaries selected in Section 12.3.2. The potential effects were identified through professional experience with other mining project Applications/EISs in BC and through consultation with the EA Working Group. Effects to hydrology could potentially occur during all phases of the Project. Components and activities, which were selected in the scoping process (Table 12.3-2), for each temporal phase are discussed to describe the pathways that can lead to effects on the surface water quantity VC (Table 12.5.1). Note that the potential for spills and accidents involving large quantities of water, tailings, and sediment are not considered here as these are related to occurrences of low likelihood outside of normal operating conditions. These are instead addressed in Chapter 24 (Accidents and Malfunctions).

High and moderate risk interactions with potential major or moderate adverse effects were identified as those that warrant further consideration and assessment. Interactions of Project activities with the potential for negligible or minor expected adverse effects that require implementation of best practices or standard mitigation and management measures were not further considered in the effects assessment.

Table 12.4-3. Pre-mine Average Monthly and Annual Flows at Hydrology Assessment Nodes within the Local and Regional Study Areas

Assessment Node		Drainage Area (km^2)	Average Flow (m^3/s)												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Node 1	Harper Creek at the WSC 08LB076 Station	166.4	0.68	0.57	0.54	3.30	11.39	11.36	5.15	2.28	1.71	1.90	1.18	0.84	3.41
Node 2	Harper Creek Above T-Creek Confluence	47.0	0.24	0.20	0.18	0.82	3.42	3.32	1.45	0.70	0.53	0.59	0.41	0.29	1.01
Node 3	T-Creek at Harper Creek Confluence	23.4	0.02	0.01	0.01	0.22	1.57	2.03	0.85	0.24	0.14	0.13	0.05	0.02	0.44
Node 4	T-Creek Upstream of Harper Creek Confluence	15.0	0.00	0.00	0.00	0.12	1.01	1.37	0.57	0.14	0.08	0.07	0.02	0.00	0.28
Node 5	P-Creek at Harper Creek Confluence	7.6	0.01	0.01	0.01	0.09	0.55	0.52	0.15	0.05	0.03	0.04	0.02	0.01	0.12
Node 6	Jones Creek Above North Thompson River Confluence	17.6	0.01	0.01	0.01	0.25	0.74	0.86	0.47	0.16	0.07	0.10	0.10	0.03	0.23
Node 7	Baker Creek at North Thompson River Confluence	14.0	0.01	0.00	0.03	0.26	0.56	0.62	0.32	0.10	0.04	0.08	0.07	0.02	0.18
Node 8	Harper Creek Below P-Creek Confluence	16.6	0.04	0.03	0.03	0.25	1.14	0.87	0.24	0.10	0.07	0.11	0.07	0.04	0.25
Node 9	Harper Creek Below T-Creek Confluence	70.4	0.26	0.22	0.19	0.98	4.77	4.98	2.11	0.88	0.63	0.66	0.45	0.32	1.37
Node 10	Harper Creek at Barrière River Confluence	185.6	0.73	0.61	0.65	4.09	12.42	12.02	5.40	2.43	1.82	2.12	1.30	0.91	3.71
Node 11	Barrière River Below Sprague Creek WSC 08LB069	624.0	2.49	2.32	2.81	9.66	38.41	43.89	16.45	5.45	4.12	4.56	4.61	3.07	11.48
Node 12	Barrière River at the Mouth WSC 08LB020	1140	3.57	3.43	4.32	14.41	49.09	52.87	20.35	6.96	5.26	5.60	5.96	4.17	14.66
Node 13	North Thompson River at Birch Island WSC 08LB047	4490	29.6	28.0	33.5	90.4	295.3	436.8	345.1	216.9	130.2	91.5	64.7	35.1	149.8

Figure 12.4-3

Pre-mine Monthly Distribution of Annual Runoff at Hydrology Assessment Nodes within the Local and Regional Study Area

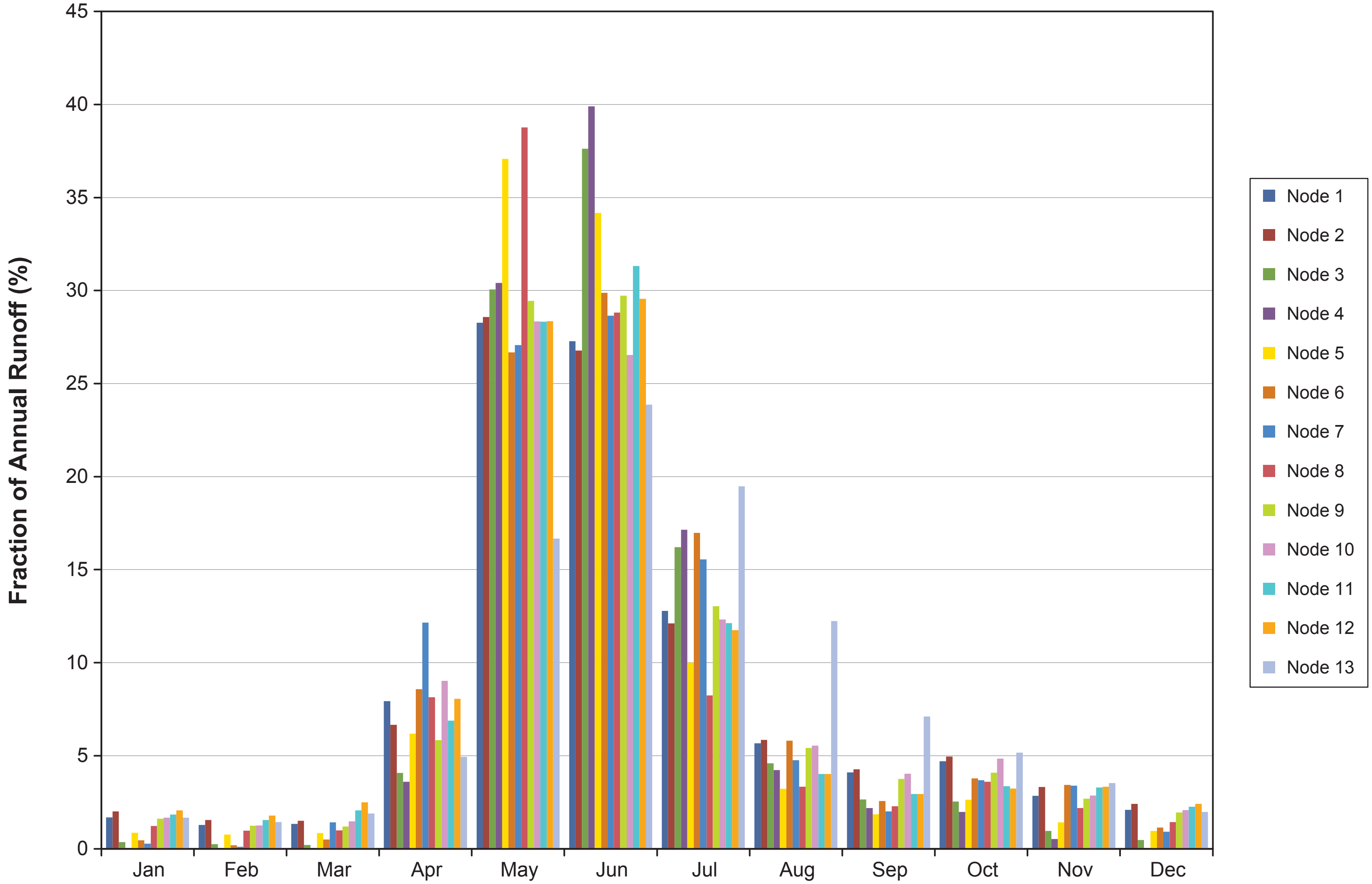


Table 12.4-4. Pre-mine Wet and Dry Annual Flows at Hydrology Assessment Nodes within the Local and Regional Study Area

Assessment Node		Drainage Area (km²)	Estimated Return Period Annual Flow (m³/s)								
			Dry					Wet			
			50 Year	20 Year	10 Year	5 Year	Mean	5 Year	10 Year	20 Year	50 Year
Node 1	Harper Creek at the WSC 08LB076 Station	166.4	1.73	1.99	2.33	2.63	3.41	4.15	4.61	4.90	5.38
Node 2	Harper Creek Above T-Creek Confluence	47.0	0.47	0.54	0.63	0.71	0.93	1.13	1.24	1.33	1.48
Node 3	T-Creek at Harper Creek Confluence	23.4	0.19	0.23	0.27	0.32	0.44	0.56	0.62	0.67	0.74
Node 4	T-Creek Upstream of Harper Creek Confluence	15.0	0.13	0.15	0.18	0.20	0.28	0.35	0.40	0.42	0.47
Node 5	P-Creek at Harper Creek Confluence	7.6	0.06	0.07	0.08	0.09	0.12	0.16	0.17	0.18	0.21
Node 6	Jones Creek Above North Thompson River Confluence	17.6	0.08	0.11	0.13	0.16	0.23	0.29	0.34	0.37	0.42
Node 7	Baker Creek at North Thompson River Confluence	14.0	0.06	0.08	0.10	0.12	0.18	0.22	0.26	0.28	0.32
Node 8	Harper Creek Below P-Creek Confluence	16.6	0.12	0.13	0.15	0.18	0.25	0.31	0.34	0.37	0.43
Node 9	Harper Creek Below T-Creek Confluence	70.4	0.65	0.76	0.91	1.04	1.37	1.70	1.87	1.99	2.19
Node 10	Harper Creek at Barrière River Confluence	185.6	1.87	2.16	2.52	2.87	3.71	4.51	5.01	5.35	5.88
Node 11	Barrière River Below Sprague Creek WSC 08LB069	624.0	6.93	7.72	8.44	9.33	11.51	13.47	15.10	16.81	19.31
Node 12	Barrière River at the Mouth WSC 08LB020	1140	8.64	9.58	10.47	11.61	14.70	17.42	19.88	22.56	26.63
Node 13	North Thompson River at Birch Island WSC 08LB047	4490	120.0	124.9	129.5	135.6	150.4	164.2	173.2	181.1	190.6

Table 12.4-5. Pre-mine Annual Instantaneous Peak Flows at Hydrology Assessment Nodes within the Local and Regional Study Area

Assessment Node		Drainage Area (km^2)	Return Period Peak Flows (m^3/s)						
			2 Year	5 Year	10 Year	20 Year	50 Year	100 Year	200 Year
Node 1	Harper Creek at the WSC 08LB076 Station	166.4	43	53	59	63	68	71	74
Node 2	Harper Creek Above T-Creek Confluence	47.0	16	22	26	31	36	40	44
Node 3	T-Creek at Harper Creek Confluence	23.4	9	13	16	18	22	25	27
Node 4	T-Creek Upstream of Harper Creek Confluence	15.0	7	10	12	14	16	19	21
Node 5	P-Creek at Harper Creek Confluence	7.6	4	6	7	8	10	12	13
Node 6	Jones Creek Above North Thompson River Confluence	17.6	7	11	13	15	18	21	23
Node 7	Baker Creek at North Thompson River Confluence	14.0	6	9	11	13	16	18	20
Node 8	Harper Creek Below P-Creek Confluence	16.6	7	10	13	15	18	21	23
Node 9	Harper Creek Below T-Creek Confluence	70.4	21	30	36	41	48	54	59
Node 10	Harper Creek at Barrière River Confluence	185.6	47	58	64	69	74	78	81
Node 11	Barrière River Below Sprague Creek WSC 08LB069	624.0	93	118	135	152	173	190	207
Node 12	Barrière River at the Mouth WSC 08LB020	1140	111	137	153	167	184	195	207
Node 13	North Thompson River at Birch Island WSC 08LB047	4490	796	927	1014	1096	1208	1279	1362

Table 12.4-6. Pre-mine Low Flows at Hydrology Assessment Nodes within the Local and Regional Study Area

Assessment Node		Drainage Area (km^2)	Average Annual Low Flows (m^3/s)	Return Period Low Flows (m^3/s)			
				5 Year	10 Year	20 Year	50 Year
Node 1	Harper Creek at the WSC 08LB076 Station	166.4	0.54	0.43	0.36	0.34	0.33
Node 2	Harper Creek Above T-Creek Confluence	47.0	0.18	0.15	0.13	0.12	0.11
Node 3	T-Creek at Harper Creek Confluence	23.4	0.01	0.00	0.00	0.00	0.00
Node 4	T-Creek Upstream of Harper Creek Confluence	15.0	0.00	0.00	0.00	0.00	0.00
Node 5	P-Creek at Harper Creek Confluence	7.6	0.01	0.01	0.01	0.01	0.01
Node 6	Jones Creek Above North Thompson River Confluence	17.6	0.01	0.00	0.00	0.00	0.00
Node 7	Baker Creek at North Thompson River Confluence	14.0	0.00	0.00	0.00	0.00	0.00
Node 8	Harper Creek Below P-Creek Confluence	16.6	0.03	0.02	0.02	0.01	0.01
Node 9	Harper Creek Below T-Creek Confluence	70.4	0.19	0.15	0.13	0.12	0.11
Node 10	Harper Creek at Barrière River Confluence	185.6	0.61	0.47	0.40	0.38	0.35
Node 11	Barrière River Below Sprague Creek WSC 08LB069	624.0	2.32	1.52	1.37	1.28	1.20
Node 12	Barrière River at the Mouth WSC 08LB020	1140	3.43	2.25	2.03	1.86	1.59
Node 13	North Thompson River at Birch Island WSC 08LB047	4490	28.0	20.3	17.7	16.0	14.3

Table 12.5-1. Risk Ratings of Project Effects on Surface Water Quantity Valued Component

Project Component/Activity and Potential Effects	Hydrology
Construction	
Construction of fish habitat offsetting sites	🟡
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	🔴
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	🔴
Construction camp construction, operation, and decommissioning	🟡
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*	
Fish habitat offsetting site monitoring and maintenance	🟢
Mine pit operations: blast, shovel and haul	🟡
Process and potable water supply, distribution and storage	🟡
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	🔴

(continued)

Table 12.5-1. Risk Ratings of Project Effects on Surface Water Quantity Valued Component (continued)

Project Component/Activity and Potential Effects	Hydrology
Operations *(cont'd)*	
Sub-aqueous deposition of PAG waste rock into TMF	🟡
Tailings transport and storage in TMF	🟡
Treatment and recycling of supernatant TMF water	🟡
Waste management: garbage and sewage waste facilities	🟢
Monitoring and maintenance of mine drainage and seepage	🟢
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	🔴
Partial decommissioning and reclamation of mine site roads	🟡
Decommissioning and removal of plant site, processing plant and mill, substation, conveyor, primary crusher, and ancillary infrastructure (e.g., explosives facility, truck shop)	🟢
Decommissioning of diversion channels and distribution pipelines	🔴
Reclamation of Non-PAG LGO stockpile, overburden stockpile and Non-PAG waste rock stockpile	🟢
Reclamation of TMF embankments and beaches	🟢
Removal of contaminated soil	🟡
Use of topsoil for reclamation	🟢
Storage of waste rock in the non-PAG waste rock stockpile	🟡
Construction and activation of TMF closure spillway	🟡
Maintenance and monitoring of TMF	🟢
Storage of water in the TMF and groundwater seepage	🔴
Sub-aqueous tailing and waste rock storage in TMF	🟡
TMF discharge to T-Creek	🔴
Post-Closure	
Environmental monitoring including surface and groundwater monitoring	🟡
Monitoring and maintenance of mine drainage, seepage, and discharge	🟢
Reclamation monitoring and maintenance	🟢
Construction of emergency spillway on open pit	🟡

(continued)

Table 12.5-1. Risk Ratings of Project Effects on Surface Water Quantity Valued Component (completed)

Project Component/Activity and Potential Effects	Hydrology
Post-Closure *(cont'd)*	
Storage of water as a pit lake	● (red)
Storage of waste rock in the non-PAG waste rock stockpile	● (yellow)
Storage of water in the TMF and groundwater seepage	● (red)
Sub-aqueous tailing and waste rock storage	● (yellow)
TMF discharge	● (red)

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

In general, the Project has the potential to affect hydrology by changing the streamflow. The following hydrologic indicators are selected to represent the timing, volume, and extreme values of streamflow:

- annual flows;
- monthly flows (monthly distribution of annual flow);
- peak flows; and
- low flows.

The following sections identify the potentially major or moderate changes to streamflow from activities in each Project phase.

Construction

During the Construction phase (two years), activities with potentially major or moderate effects on streamflow will include the following:

- the establishment of water management structures (e.g., runoff diversion channels, sediment ponds, coffer dam, the TMF embankment, ditches, sumps, and pipelines) can alter natural flow pathways;
- earth moving, road widening, and site clearing and stripping activities have the potential to cause erosion and sedimentation, and alter infiltration; and
- construction of camp and mine infrastructure (e.g., plant site, stockpiles, erosion and sedimentation ponds) and the initiation of open pit mining can alter natural flow pathways, and hence the hydrologic regime.

Operations

During the Operations 1 (23 years) and Operations 2 (5 years) phases, activities with the potential to affect streamflow will include:

- non-contact water diversion, contact water collection, and water use activities (e.g., reclaim water from the TMF) can affect the Project Site water balance and therefore can alter surface water quantity; and
- mine pit operation and stockpiling can alter natural flow pathways and hence the hydrologic regime.

Closure

Closure phase (7 years) activities with the potential to affect streamflow include the following:

- decommissioning of Project Site infrastructure and components (e.g., roads, plant, and stockpiles) has the potential to affect streamflow by altering natural flow pathways and by affecting infiltration rates; and
- water management activities (i.e., TMF storage and discharge) affect the Project Site water balance, and therefore can alter streamflow.

Post-Closure

The Post-Closure phase will last until long-term environmental objectives are achieved (currently estimated to be 50 years). Surface water and groundwater monitoring will take place during this phase.

Activities with the potential to affect surface water in Post-Closure will include the following:

water management activities (i.e., storage of water in the TMF and pit lake, and TMF discharge) affect the Project Site water balance, and therefore can alter surface water quantity.

The abovementioned Project components and activities have the potential to affect the streamflows in Baker, Jones, T, P, and Harper creeks, as well as streamflows in the Barrière and North Thompson rivers. Thirteen hydrology assessment nodes (Table 12.3-5) were selected to represent the streamflow in these water bodies.

12.5.2 Mitigation Measures

The Site Water Management Plan (Section 24.13) describes the mitigation measures to reduce or eliminate the potential effects of the Project on hydrology. The Project has been designed to reduce adverse effects by optimizing alternatives, incorporating specific design changes, following best management practices (BMPs), and enhancing Project benefits. Mitigation by design includes a variety of diversion, collection, and storage/settlement structures to manage water for the Project. The primary goals of water management activities are to divert non-contact water, and to collect and reuse contact water in the plant.

Supernatant water from the TMF is envisaged to be reclaimed and reused to supply process water for ore processing. There is no requirement for additional make-up water from outside of the system (Appendix 12-B). By reusing contact water in the plant, the amount of contact water that is discharged to the environment is minimized.

Additional mitigation measures to avoid and minimize adverse effects to hydrology include implementation of the Sedimentation and Erosion Control Plan (Section 24.11) and Groundwater Management Plan (Section 24.8).

The Site Water Management Plan (Section 24.13), Sedimentation and Erosion Control Plan (Section 24.11), and Groundwater Management Plan (Section 24.8) will be implemented soon after Project approvals are received and before the construction commences. Water diversion and sediment collection structures will be established as a first step to work activities. In addition to diversion ditches, small-scale runoff collection measures may be used locally (e.g., temporary sediment fences around the perimeter of stockpiles).

Erosion prevention and sediment control BMPs will be implemented. These include isolation of work areas from surface waters and proper use of structural practices such as sediment traps, geotextile cloth, sediment fences, gravel berms, and straw bales to mitigate and control erosion and sediment. Roads will be constructed and upgraded according to the *Forest Road Engineering Guidebook* (BC MOF 2002) and *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEM 2008). Roads will be maintained to ensure low landslide risk and continuous, efficient, controlled water drainage. Therefore, no effect on hydrology is expected due to road construction, upgrade, and maintenance.

Water management and sediment control structures will be regularly inspected and maintained. Maintenance procedures will include prompt attention to potential erosion sites, ditch or culvert failure, ditch or culvert blockage, or outside seepage, because such problems could lead to structure failure and sediment transport. Maintenance will also include routine removal of accumulated sediment from ditches and retention structures. The sediment removed will be used as fill or deposited on stockpiles.

These mitigation measures reduce the potential effects of the Project on hydrology; however, they are not expected to fully eliminate such effects. That is, the mitigation measures are thought to be moderately effective, and residual changes to stream flows are expected within the Baker, Jones, T, P, and Harper creeks (Table 12.5-2).

Table 12.5-2. Proposed Mitigation Measures and their Effectiveness

Potential Effect	Proposed Mitigation Measure	Mitigation Effectiveness (Low/Moderate/High/Unknown)	Residual Effect (Y/N)
Altered streamflow	Water management structure (e.g., non-contact water diversion, contact water collection, and sediment control); reclaim and reuse contact water	Moderate	Y

12.5.3 Predicted Residual Effects and Characterization

12.5.3.1 Residual Effects on Surface Water Quantity

Altered Streamflow

A water balance model, with monthly time-step, was developed 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.

Based on professional judgement, it is reasonable to account for at least a 5% error in streamflow estimates due to the inherent data and modelling uncertainty in hydrologic studies. Therefore, it was assumed that any streamflow change of less than 5%, compared to the pre-mine flows, could be an artifact of data and/or modelling uncertainty and is considered a negligible change.

The base case modelling scenario for monthly streamflows during Construction, Operations, Closure, and Post-Closure represents average climate conditions (i.e., average of synthetic long-term streamflows from 1914 to 2012; Appendix 12-B). The following are effects on mean annual flows during each phase of the Project under the base case scenario (Table 12.5-3).

- Construction: the decrease in mean annual flows, compared to the pre-mine condition, is most noticeable at T-Creek (Node 3; 66% reduction) and Harper Creek below T-Creek (Node 9, 16% reduction). Annual flows in Harper Creek downstream of P-Creek (Node 8), Harper Creek at the WSC station (Node 1),Harper Creek at the Barrière River Confluence (Node 10), and Baker Creek (Node 7) are decreased by up to 6%. Flow reductions are negligible at P-Creek (Node 5), Jones Creek (Node 6), and Harper Creek upstream of T-Creek (Node 2). Likewise, the decrease in mean annual flow at all RSA assessment nodes that are not within the LSA is negligible. These include the Barrière River below Sprague Creek (Node 11), the Barrière River at the mouth (Node 12), and North Thompson River at Birch Island (Node 13).
- Operations: the mean annual flows are noticeably decreased, compared to the pre-mine condition, at T-Creek (Node 3; 73% reduction), P-Creek (Node 5; 65% reduction), Harper Creek below P-Creek (Node 8, 31% reduction), Harper Creek below T-Creek (Node 9, 31% reduction), and Baker Creek (Node 7; 16% reduction). Annual flows in Harper Creek upstream of T-Creek (Node 2), Harper Creek at the WSC station (Node 1), and Harper Creek at the Barrière River Confluence (Node 10) are decreased by up to 13%. Flow reductions are negligible at Jones Creek (Node 6). Likewise, the decrease in mean annual flow at all RSA assessment nodes that are not within the LSA is negligible. These include the Barrière River below Sprague Creek (Node 11), the Barrière River at the mouth (Node 12), and North Thompson River at Birch Island (Node 13).
- Closure: the mean annual flows are prominently less than the pre-mine flows at P-Creek (Node 5; 61% reduction), T-Creek (Node 3; 42% reduction), Harper Creek below P-Creek (Node 8, 28% reduction), Harper Creek below T-Creek (Node 9, 20% reduction), and Baker Creek (Node 7; 15% reduction). Annual flows in Harper Creek upstream of T-Creek (Node 2), Harper Creek at the WSC station (Node 1), and Harper Creek at the Barrière River

Confluence (Node 10) are decreased by up to 12%. Flow reductions are negligible at Jones Creek (Node 6). Likewise, the decrease in mean annual flow at all RSA assessment nodes that are not within the LSA is negligible. These include the Barrière River below Sprague Creek (Node 11), the Barrière River at the mouth (Node 12), and North Thompson River at Birch Island (Node 13).

- Post-Closure: permanent change in mean annual flows, compared to the pre-mine condition, is predicted at P-Creek (Node 5; 61% reduction), Harper Creek below P-Creek (Node 8, 28% reduction), T-Creek (Node 3; 20% increase), Baker Creek (Node 7; 15% reduction), and Harper Creek upstream of T-Creek (Node 2, 12% reduction). Flow reductions are negligible at all other assessment nodes.

In summary, the effect on mean annual flows are limited to the LSA. The decrease in mean annual flow at all RSA assessment nodes (i.e., Nodes 11, 12, and 13) is less than 5%, which is within the range of inherent data and/or modelling uncertainty.

Effects of the Project on monthly flows (Tables 12-C1a to 12-C13a in Appendix 12-C) generally follow the same pattern as those of the annual flows. Although monthly flow reductions are moderate to high within the LSA, monthly flows at RSA assessment nodes (i.e., Nodes 11, 12, and 13) are decreased to a lesser extent (i.e., up to 5% reduction during July, and up to 4% reduction during the rest of the year). Figures 12.5-1 to 12.5-13 show that the Project will not alter the monthly distribution of flow at the hydrology assessment nodes.

The effects on low flows during each phase of the Project under the base case scenario are summarized in Table 12.5-4. Similar to mean annual flows, the effects of the Project on low flows are most noticeable at the headwater sub-watersheds of the LSA. The changes to low flows during different phases of the Project include:

- Construction: Annual low flows are increased by 12 to 44% in the upper reaches of Harper Creek (Nodes 2, 8, and 9), and ceased in T-Creek (Nodes 3 and 4) and Jones Creek (Node 6). Changes to annual low flows in the lower reaches of Harper Creek (Nodes 1 and 10), P-Creek (Node 5), and the RSA assessment points (Nodes 11, 12, and 13) are negligible.
- Operations: Annual low flows are ceased in T-Creek (Nodes 3 and 4), P-Creek (Node 5), and Jones Creek (Node 6). Changes to annual low flows in Harper Creek (Nodes 1, 2, 8, 9, and 10) vary between 9 to 42% reduction. Changes to annual low flows in the RSA assessment points (Nodes 11, 12, and 13) are negligible.
- Closure: Annual low flows are increased by more than 100% in T-Creek (Nodes 3 and 4), and ceased in P-Creek (Node 5) and Jones Creek (Node 6). Annual low flows in Harper Creek (Nodes 1, 2, 8, 9, and 10) are decreased by 4 to 40% compared to the pre-mine flows. Changes to annual low flows in the RSA assessment points (Nodes 11, 12, and 13) are negligible.
- Post-Closure: Annual low flows are increased by more than 100% in T-Creek (Nodes 3 and 4), and ceased in P-Creek (Node 5) and Jones Creek (Node 7). Annual low flows in Harper Creek (Nodes 1, 2, 8, 9, and 10) can decrease (up to 41%) or increase (up to 50%) compared to the pre-mine flows. Changes to annual low flows in the RSA assessment points (Nodes 11, 12, and 13) are negligible.

Table 12.5-3. Average Annual Streamflows within the Project Area during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation)

Project Phase	Parameter	Unit	Node 1 Harper Creek at the WSC 08LB076 Station	Node 2 Harper Creek Above T-Creek Confluence	Node 3 T-Creek at Harper Creek Confluence	Node 4 T-Creek Upstream of Harper Creek Confluence	Node 5 P-Creek at Harper Creek Confluence	Node 6 Jones Creek Above North Thompson River Confluence	Node 7 Baker Creek at North Thompson River Confluence	Node 8 Harper Creek Below P-Creek Confluence	Node 9 Harper Creek Below T-Creek Confluence	Node 10 Harper Creek at Barrière River Confluence	Node 11 Barrière River Below Sprague Creek WSC 08LB069	Node 12 Barrière River at the Mouth WSC 08LB020	Node 13 North Thompson River at Birch Island WSC 08LB047
Pre-Mine	Annual Flow	(m^3/s)	3.41	1.01	0.44	0.28	0.12	0.23	0.18	0.25	1.37	3.71	11.48	14.66	149.8
Construction (Year -1)	Annual Flow	(m^3/s)	3.22	1.00	0.15	0.00	0.12	0.23	0.17	0.26	1.15	3.53	11.31	14.49	149.8
	Change from Pre-mine	(m^3/s)	-0.19	-0.02	-0.29	-0.28	0.00	0.00	-0.01	0.01	-0.22	-0.17	-0.17	-0.17	0.0
		(%)	-6%	-2%	-66%	-100%	n/a*	n/a*	-6%	4%	-16%	-5%	-2%	-1%	0%
Operations 1 (Year 10)	Annual Flow	(m^3/s)	2.99	0.89	0.13	0.00	0.05	0.23	0.16	0.17	0.97	3.28	11.06	14.24	149.7
	Change from Pre-mine	(m^3/s)	-0.42	-0.12	-0.32	-0.28	-0.08	-0.01	-0.02	-0.08	-0.41	-0.42	-0.42	-0.42	0.0
		(%)	-12%	-12%	-71%	-100%	-64%	-4%	-10%	-30%	-30%	-11%	-4%	-3%	0%
Operations 1 (Year 22)	Annual Flow	(m^3/s)	2.97	0.89	0.12	0.00	0.04	0.23	0.15	0.17	0.95	3.27	11.04	14.22	149.7
	Change from Pre-mine	(m^3/s)	-0.44	-0.12	-0.32	-0.28	-0.08	0.00	-0.03	-0.08	-0.42	-0.44	-0.44	-0.44	0.0
		(%)	-13%	-12%	-73%	-100%	-65%	n/a*	-16%	-31%	-31%	-12%	-4%	-3%	0%
Operations 2 (Year 27)	Annual Flow	(m^3/s)	2.98	0.89	0.13	0.00	0.05	0.23	0.15	0.18	0.96	3.28	11.06	14.24	149.7
	Change from Pre-mine	(m^3/s)	-0.43	-0.12	-0.32	-0.28	-0.08	0.00	-0.03	-0.07	-0.41	-0.42	-0.42	-0.42	0.0
		(%)	-13%	-12%	-72%	-98%	-62%	n/a*	-15%	-29%	-30%	-11%	-4%	-3%	0%
Closure (Year 30)	Annual Flow	(m^3/s)	3.11	0.89	0.26	0.14	0.05	0.23	0.15	0.18	1.09	3.41	11.19	14.37	149.7
	Change from Pre-mine	(m^3/s)	-0.30	-0.12	-0.18	-0.14	-0.08	0.00	-0.03	-0.07	-0.28	-0.30	-0.30	-0.30	0.0
		(%)	-9%	-12%	-42%	-51%	-61%	n/a*	-15%	-28%	-20%	-8%	-3%	-2%	0%
Post-closure (Year 50)	Annual Flow	(m^3/s)	3.39	0.89	0.53	0.38	0.05	0.23	0.15	0.18	1.36	3.67	11.45	14.63	149.7
	Change from Pre-mine	(m^3/s)	-0.02	-0.12	0.09	0.10	-0.08	0.00	-0.03	-0.07	-0.01	-0.04	-0.04	-0.04	0.0
		(%)	-1%	-12%	20%	36%	-61%	n/a*	-15%	-28%	-1%	-1%	0%	0%	0%

**: Flow change is very low (less than 0.005 m^3/s); not representative if provided as percent of pre-mine flows*

Table 12.5-4. Low Flows at Hydrology Assessment Nodes during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation)

Project Phase	Parameter	Unit	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10	Node 11	Node 12	Node 13
			Harper Creek at the WSC 08LB076 Station	Harper Creek Above T-Creek Confluence	T-Creek at Harper Creek Confluence	T-Creek Upstream of Harper Creek Confluence	P-Creek at Harper Creek Confluence	Jones Creek Above North Thompson River Confluence	Baker Creek at North Thompson River Confluence	Harper Creek Below P-Creek Confluence	Harper Creek Below T-Creek Confluence	Harper Creek at Barrière River Confluence	Barrière River Below Sprague Creek WSC 08LB069	Barrière River at the Mouth WSC 08LB020	North Thompson River at Birch Island WSC 08LB047
Pre-Mine	Annual Low Flow	(m^3/s)	0.54	0.18	0.01	0.00	0.01	0.01	0.00	0.03	0.19	0.61	2.32	3.43	28.0
Construction (Year -1)	Annual Low Flow	(m^3/s)	0.57	0.20	0.00	0.00	0.01	0.00	0.00	0.04	0.22	0.64	2.35	3.45	28.0
	Change from Pre-mine	(m^3/s)	0.03	0.02	-0.01	0.00	0.00	-0.01	0.00	0.01	0.03	0.03	0.03	0.03	0.0
		(%)	5%	12%	-99%	n/a*	n/a**	-99%	n/a*	44%	14%	4%	1%	1%	0%
Operations 1 (Year 10)	Annual Low Flow	(m^3/s)	0.49	0.16	0.00	0.00	0.00	0.00	0.00	0.02	0.16	0.56	2.27	3.37	28.0
	Change from Pre-mine	(m^3/s)	-0.05	-0.02	-0.01	0.00	-0.01	-0.01	0.00	-0.01	-0.03	-0.06	-0.06	-0.06	0.0
		(%)	-9%	-10%	-100%	n/a*	-96%	-99%	n/a*	-40%	-15%	-9%	-2%	-2%	n/a**
Operations 1 (Year 22)	Annual Low Flow	(m^3/s)	0.48	0.16	0.00	0.00	0.00	0.00	0.00	0.02	0.16	0.55	2.26	3.36	28.0
	Change from Pre-mine	(m^3/s)	-0.05	-0.02	-0.01	0.00	-0.01	-0.01	0.00	-0.01	-0.04	-0.06	-0.06	-0.06	0.0
		(%)	-10%	-13%	-100%	n/a*	-96%	-99%	n/a*	-41%	-18%	-10%	-3%	-2%	n/a**
Operations 2 (Year 27)	Annual Low Flow	(m^3/s)	0.47	0.15	0.00	0.00	0.00	0.00	0.00	0.02	0.15	0.55	2.26	3.36	28.0
	Change from Pre-mine	(m^3/s)	-0.07	-0.03	-0.01	0.00	-0.01	-0.01	0.00	-0.01	-0.04	-0.06	-0.06	-0.06	0.0
		(%)	-13%	-17%	-100%	n/a*	-96%	-99%	n/a*	-42%	-21%	-10%	-3%	-2%	n/a**
Closure (Year 30)	Annual Low Flow	(m^3/s)	0.51	0.16	0.03	0.03	0.00	0.00	0.00	0.02	0.19	0.58	2.29	3.39	28.0
	Change from Pre-mine	(m^3/s)	-0.03	-0.03	0.01	0.03	-0.01	-0.01	0.00	-0.01	-0.01	-0.03	-0.03	-0.03	0.0
		(%)	-5%	-14%	>100%	n/a*	-96%	-99%	n/a*	-40%	-4%	-5%	-1%	-1%	n/a**
Post-closure (Year 50)	Annual Low Flow	(m^3/s)	0.64	0.16	0.07	0.05	0.00	0.00	0.00	0.02	0.29	0.69	2.40	3.50	28.0
	Change from Pre-mine	(m^3/s)	0.10	-0.03	0.05	0.05	-0.01	-0.01	0.00	-0.01	0.10	0.08	0.08	0.08	0.0
		(%)	19%	-15%	>100%	n/a*	-96%	-95%	n/a*	-41%	50%	12%	3%	2%	n/a**

**: Pre-mine flow is very low (less than 0.005 m^3/s); therefore, flow changes are not representative if provided as percent of pre-mine flows*

***: Flow change is very low (less than 0.005 m^3/s); not representative if provided as percent of pre-mine flows*

Figure 12.5-1

Monthly Flows at Hydrology Assessment Node 1 (Harper Creek at the WSC 08LB076 Station)

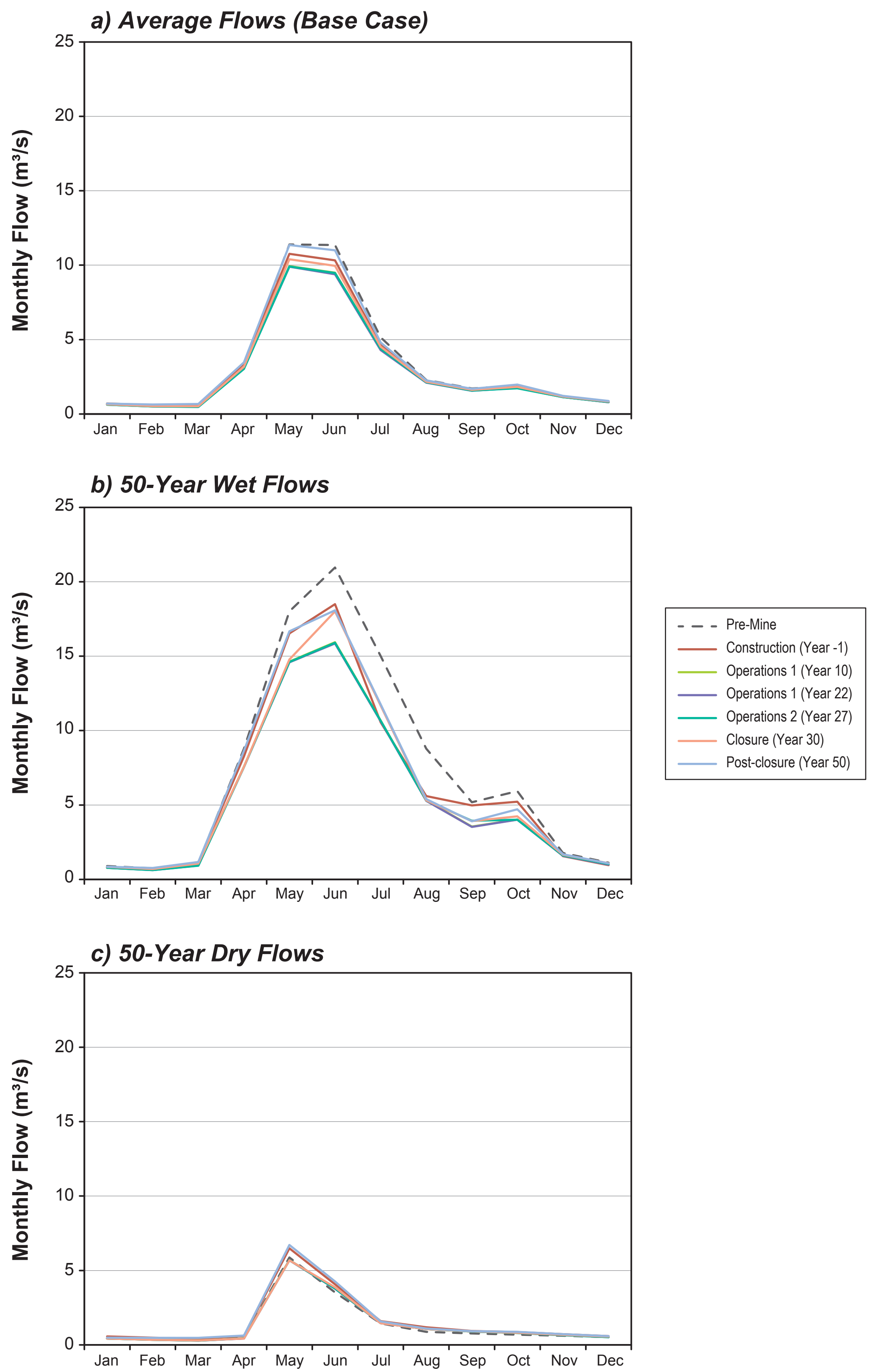


Figure 12.5-2

Monthly Flows at Hydrology Assessment Node 2 (Harper Creek Above T-Creek Confluence)

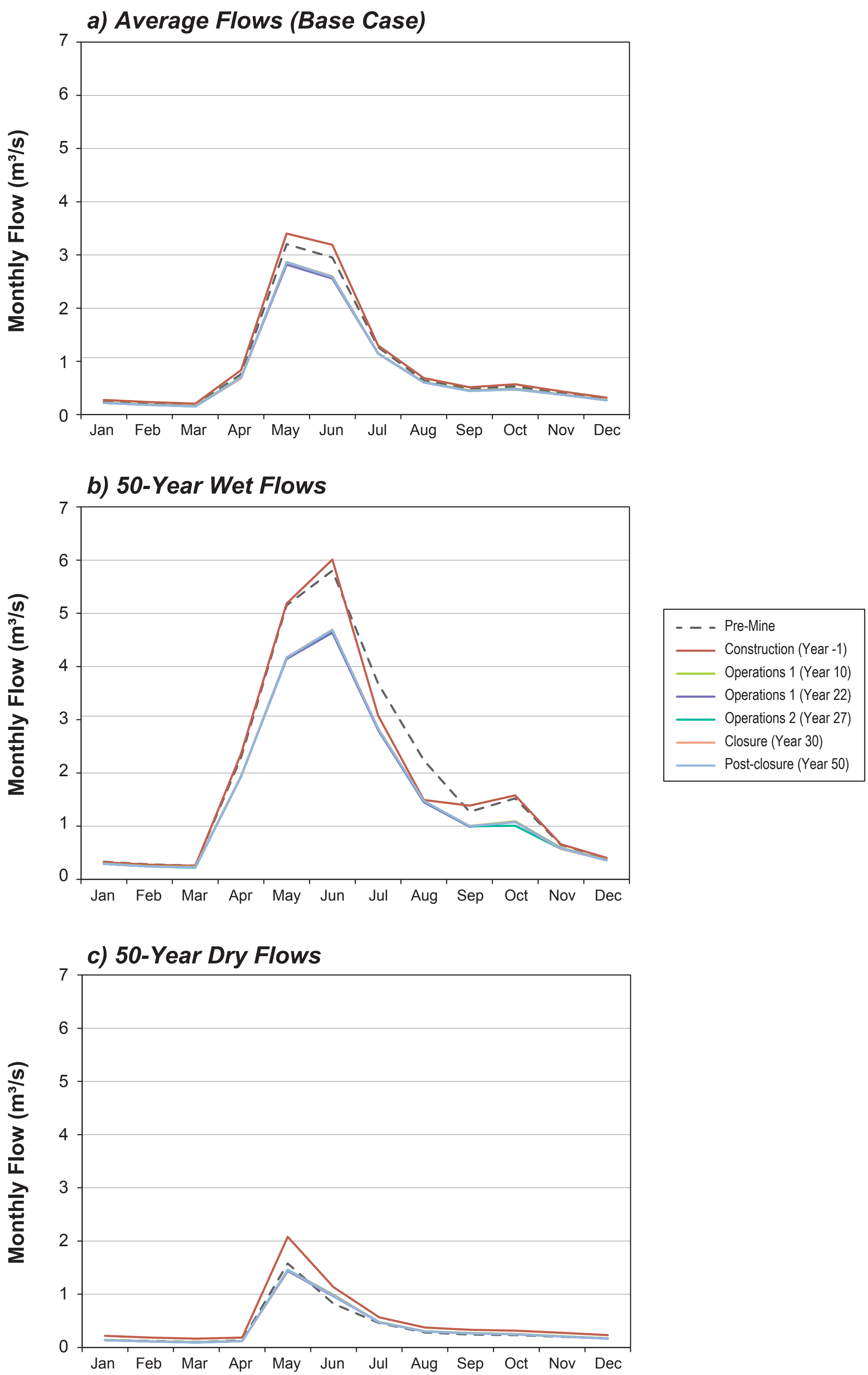


Figure 12.5-3

Monthly Flows at Hydrology Assessment Node 3 (T-Creek at Harper Creek Confluence)

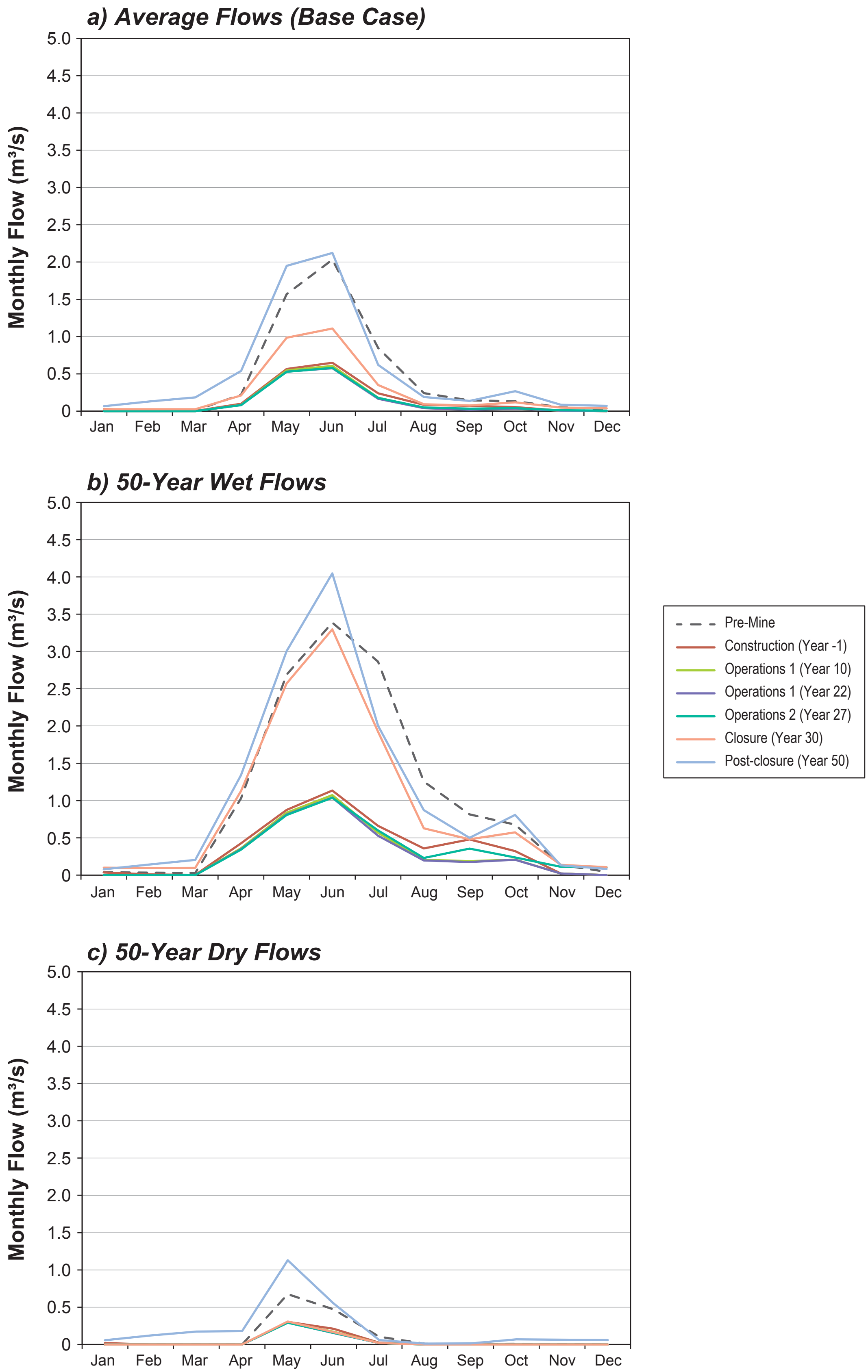


Figure 12.5-4

Monthly Flows at Hydrology Assessment Node 4 (T-Creek Upstream of Harper Creek Confluence)

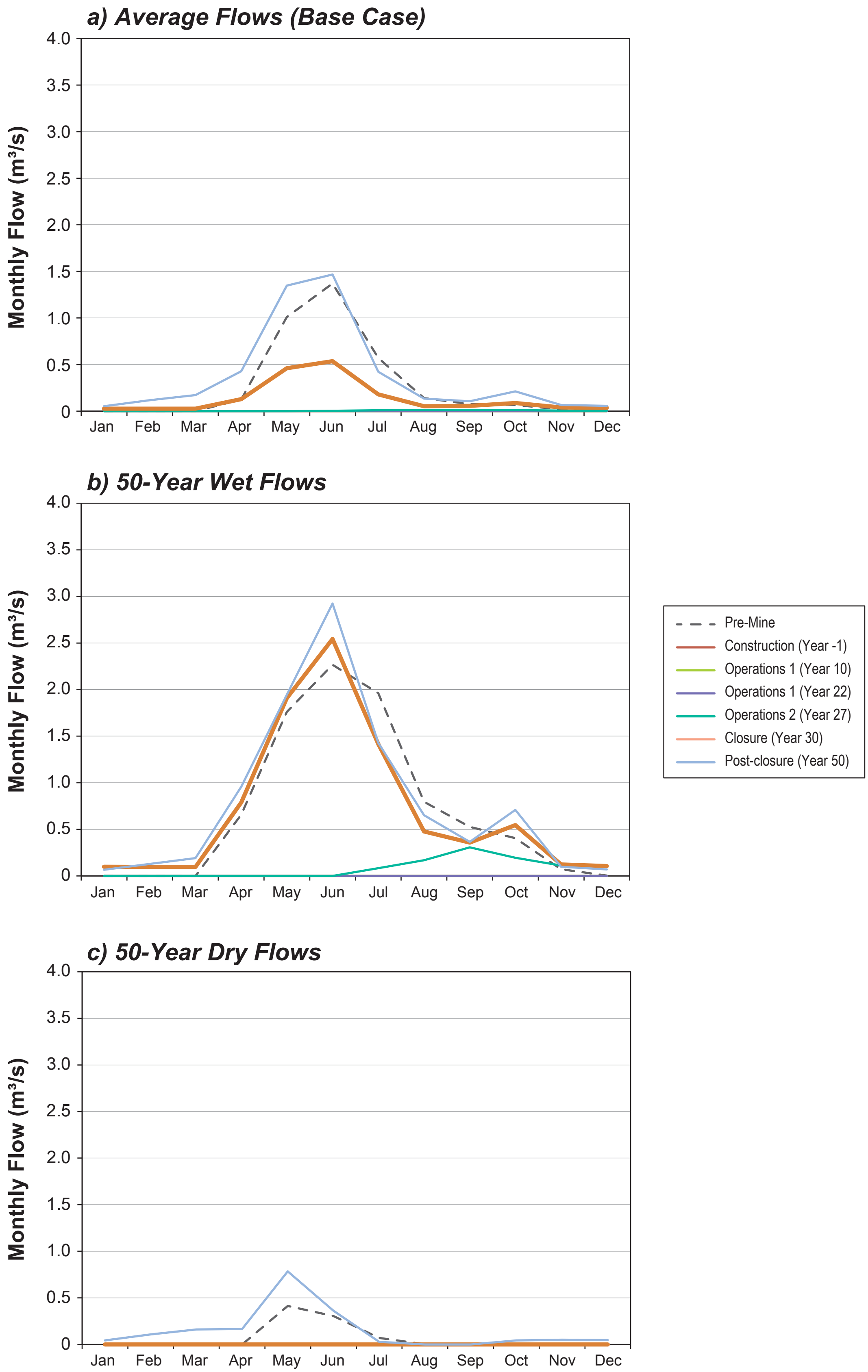


Figure 12.5-5

Monthly Flows at Hydrology Assessment Node 5 (P-Creek at Harper Creek Confluence)

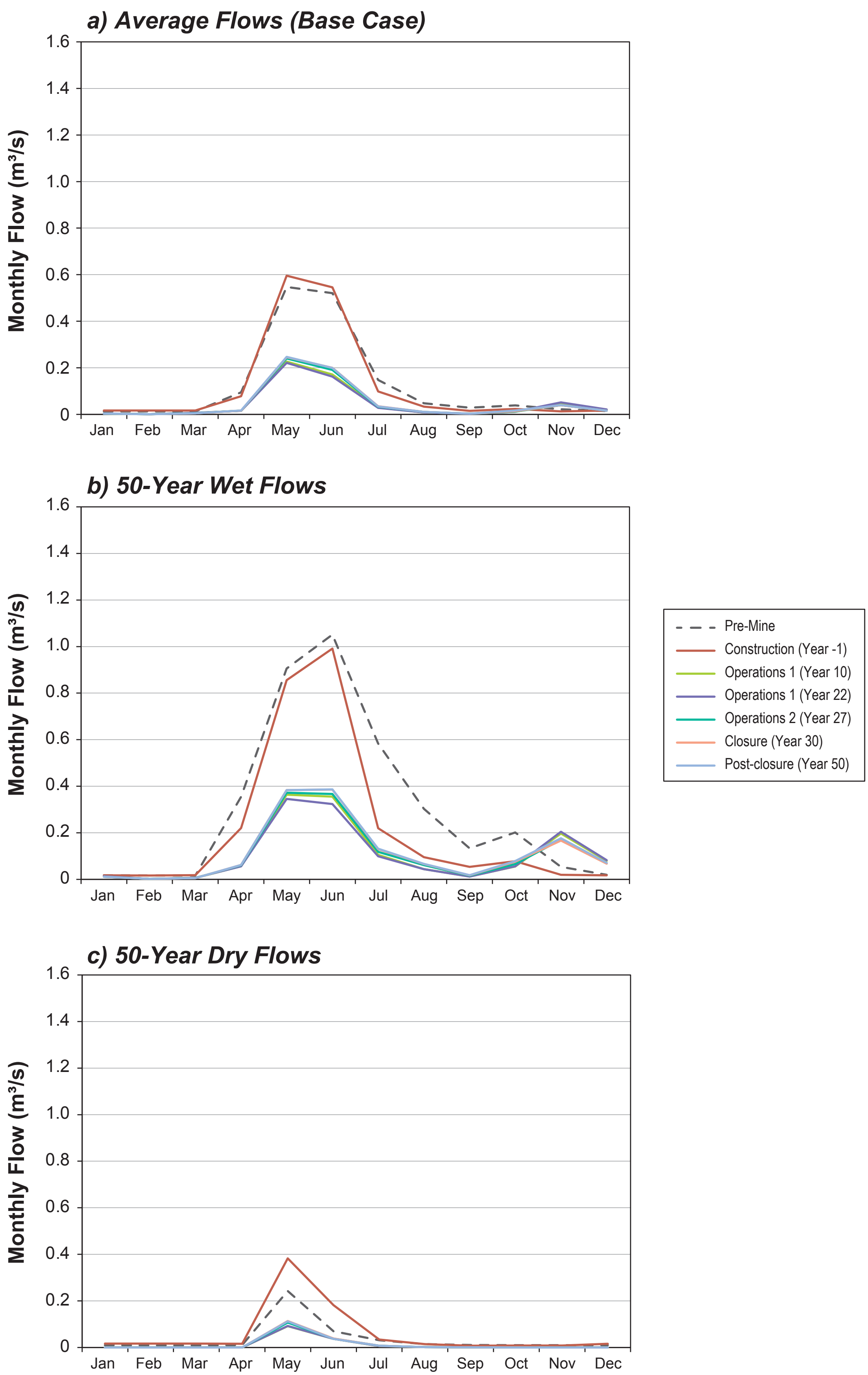


Figure 12.5-6

Monthly Flows at Hydrology Assessment Node 6 (Jones Creek Above North Thompson River Confluence)

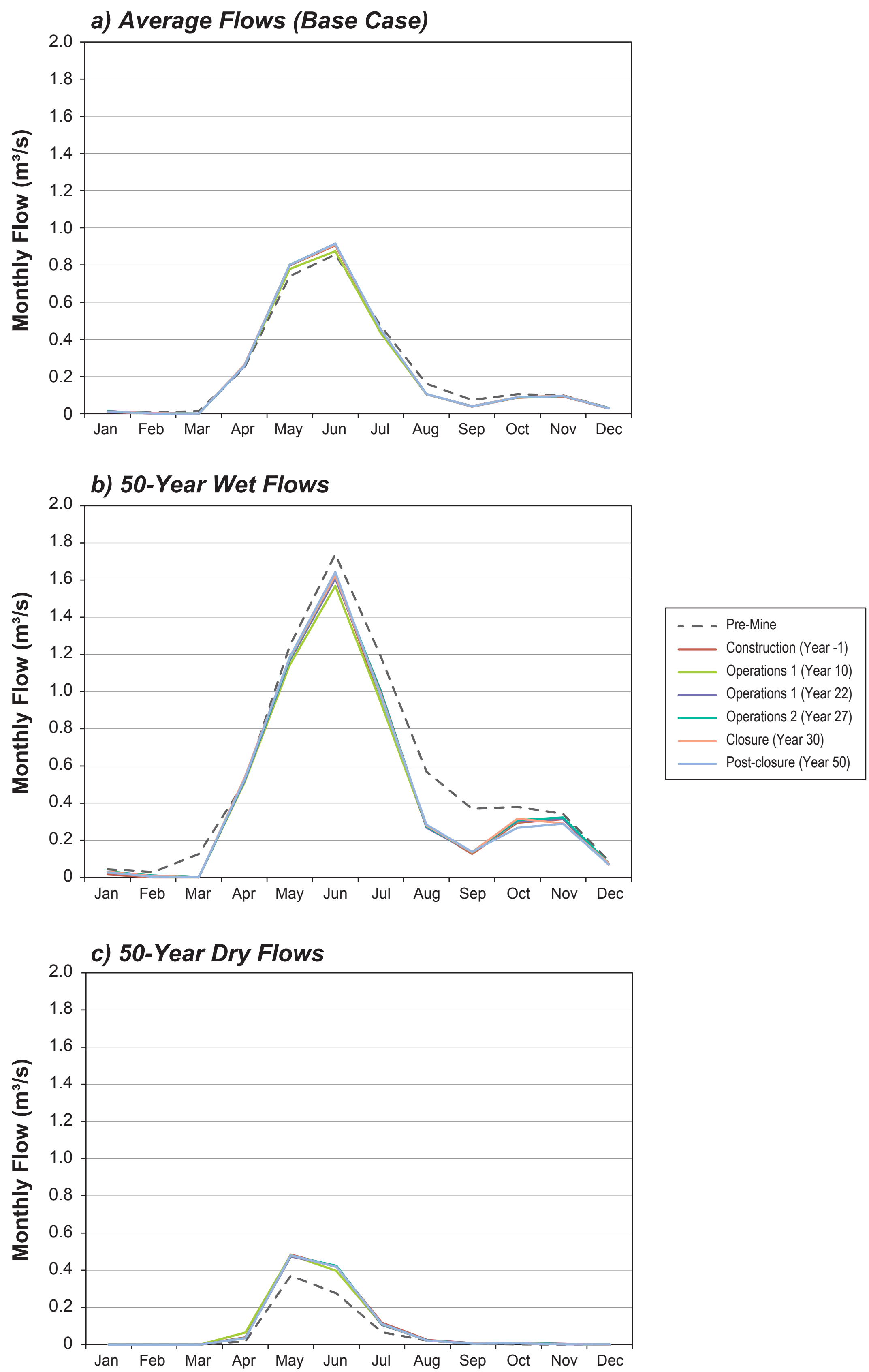


Figure 12.5-7

Monthly Flows at Hydrology Assessment Node 7 (Baker Creek at North Thompson River Confluence)

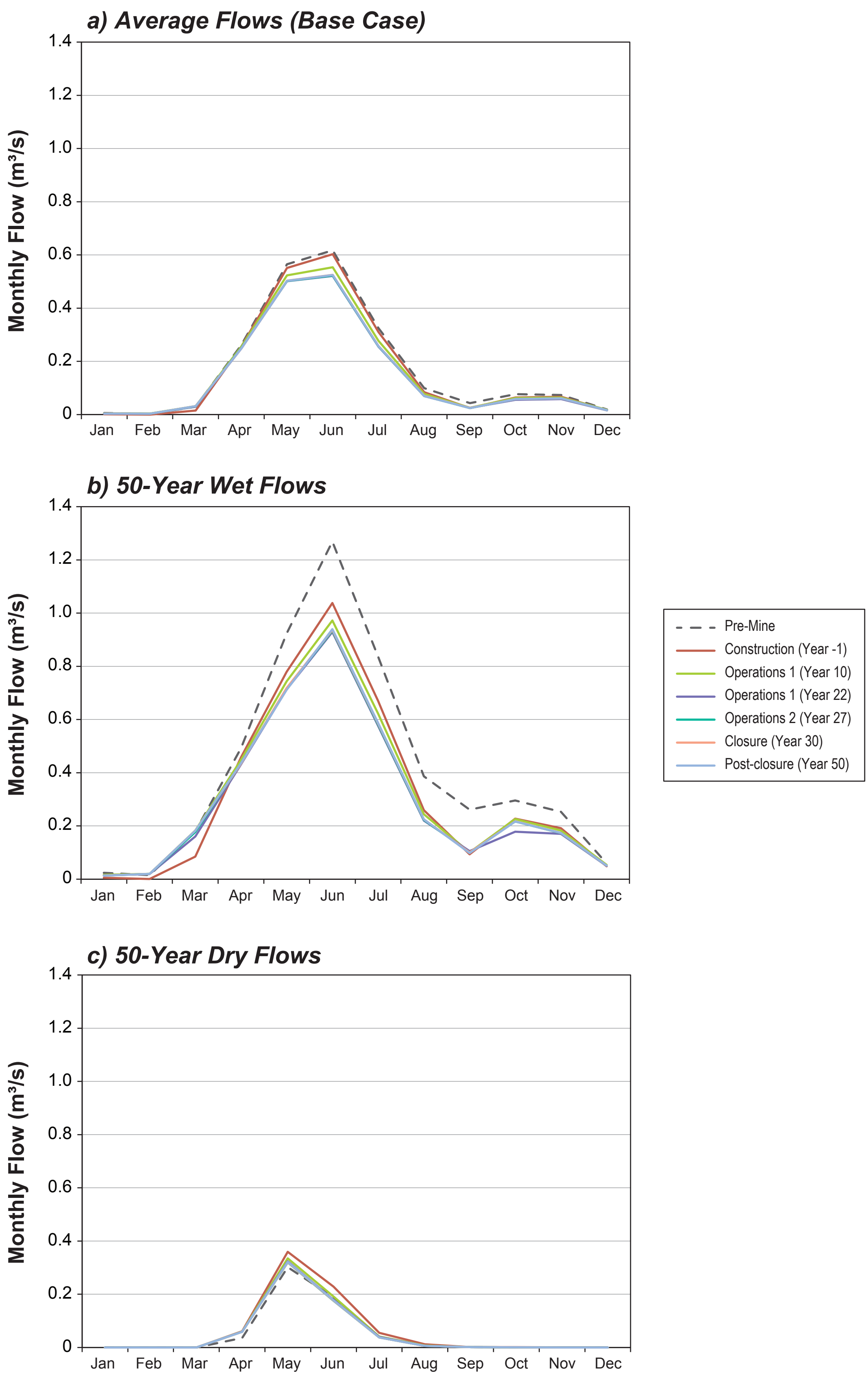


Figure 12.5-8

Monthly Flows at Hydrology Assessment Node 8 (Harper Creek Below P-Creek Confluence)

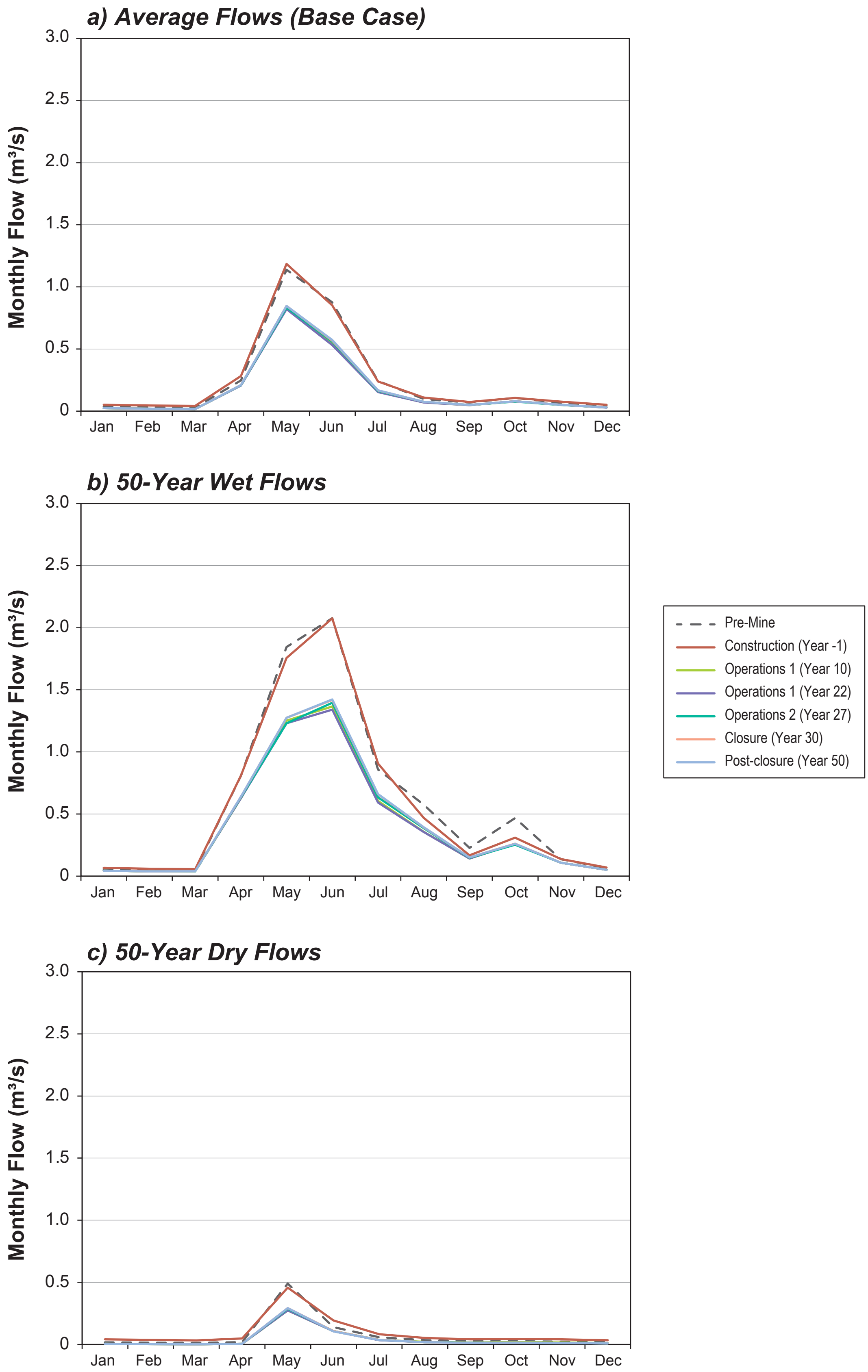


Figure 12.5-9

Monthly Flows at Hydrology Assessment Node 9 (Harper Creek Below T-Creek Confluence)

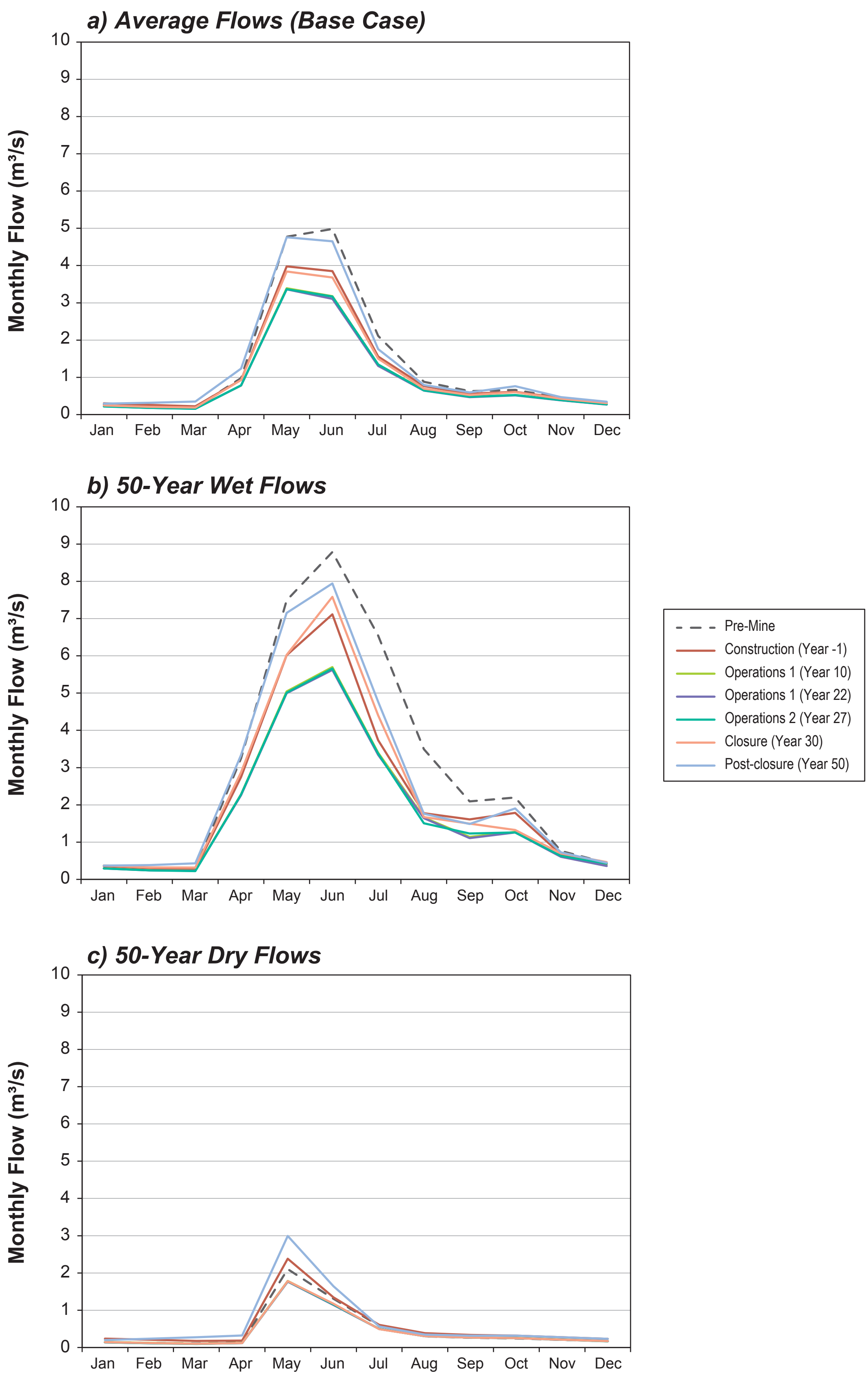


Figure 12.5-10

Monthly Flows at Hydrology Assessment Node 10 (Harper Creek at Barrière River Confluence)

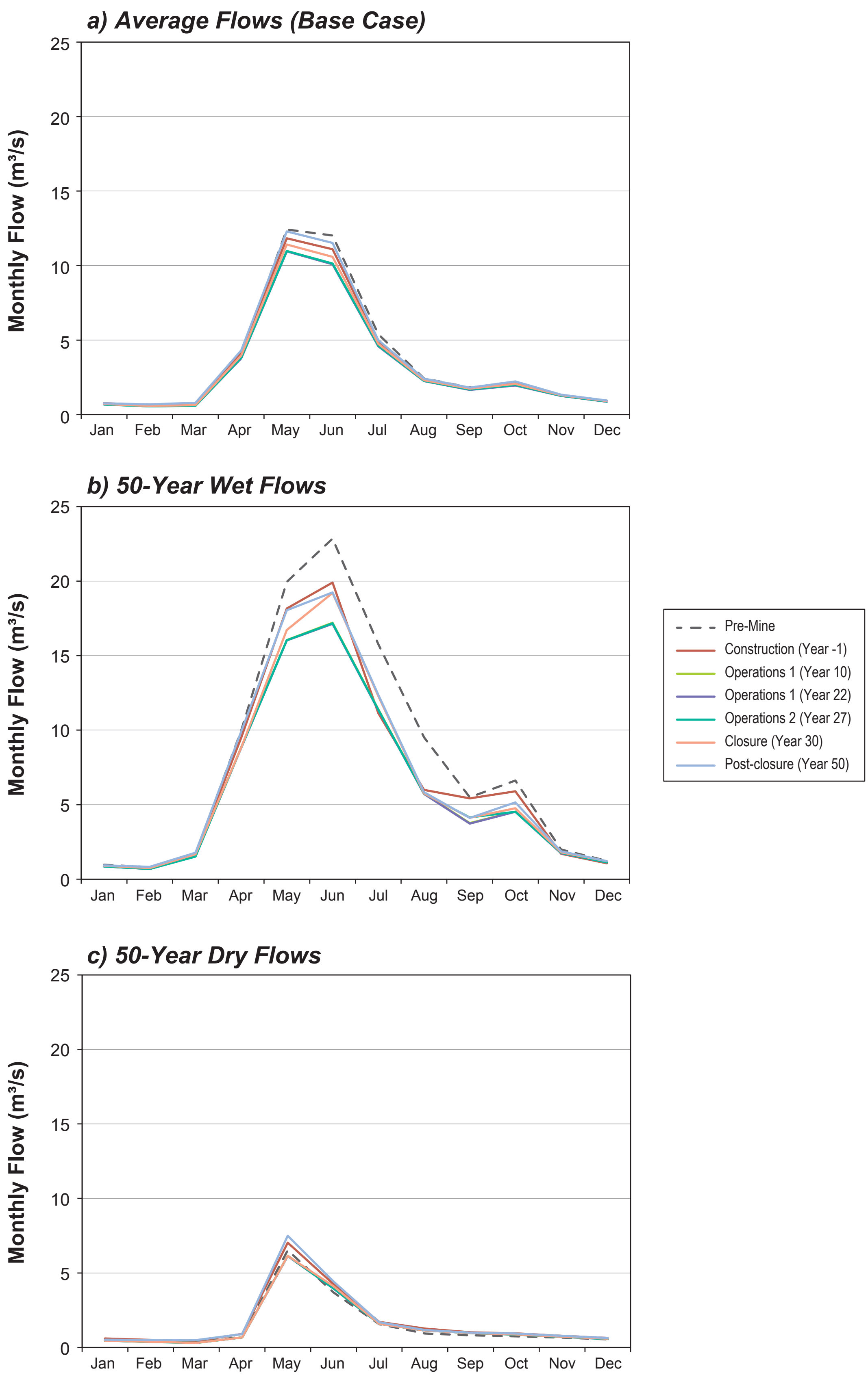


Figure 12.5-11

Monthly Flows at Hydrology Assessment Node 11 (Barrière River Below Sprague Creek WSC 08LB069)

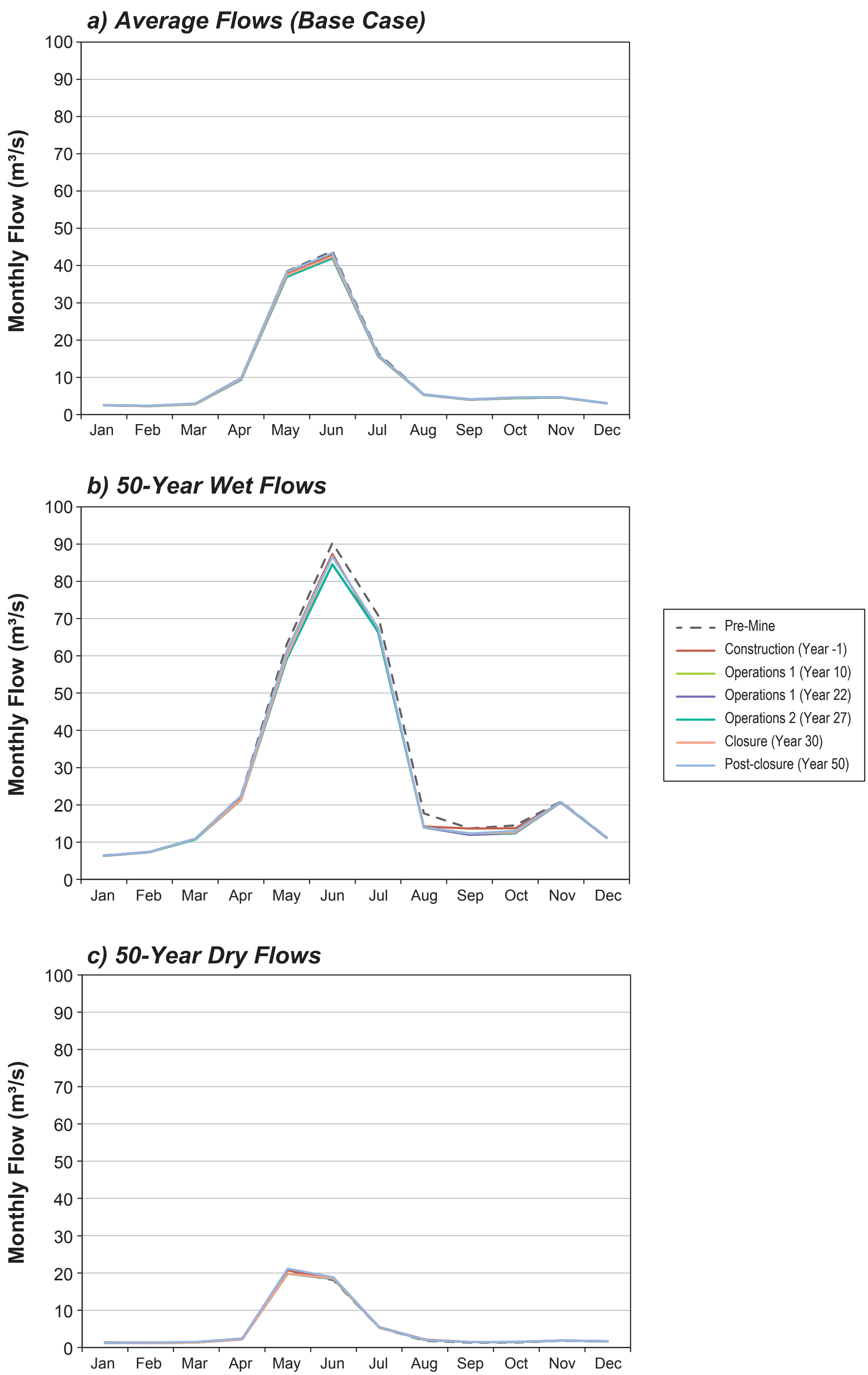


Figure 12.5-12

Monthly Flows at Hydrology Assessment Node 12 (Barrière River at the Mouth WSC 08LB020)

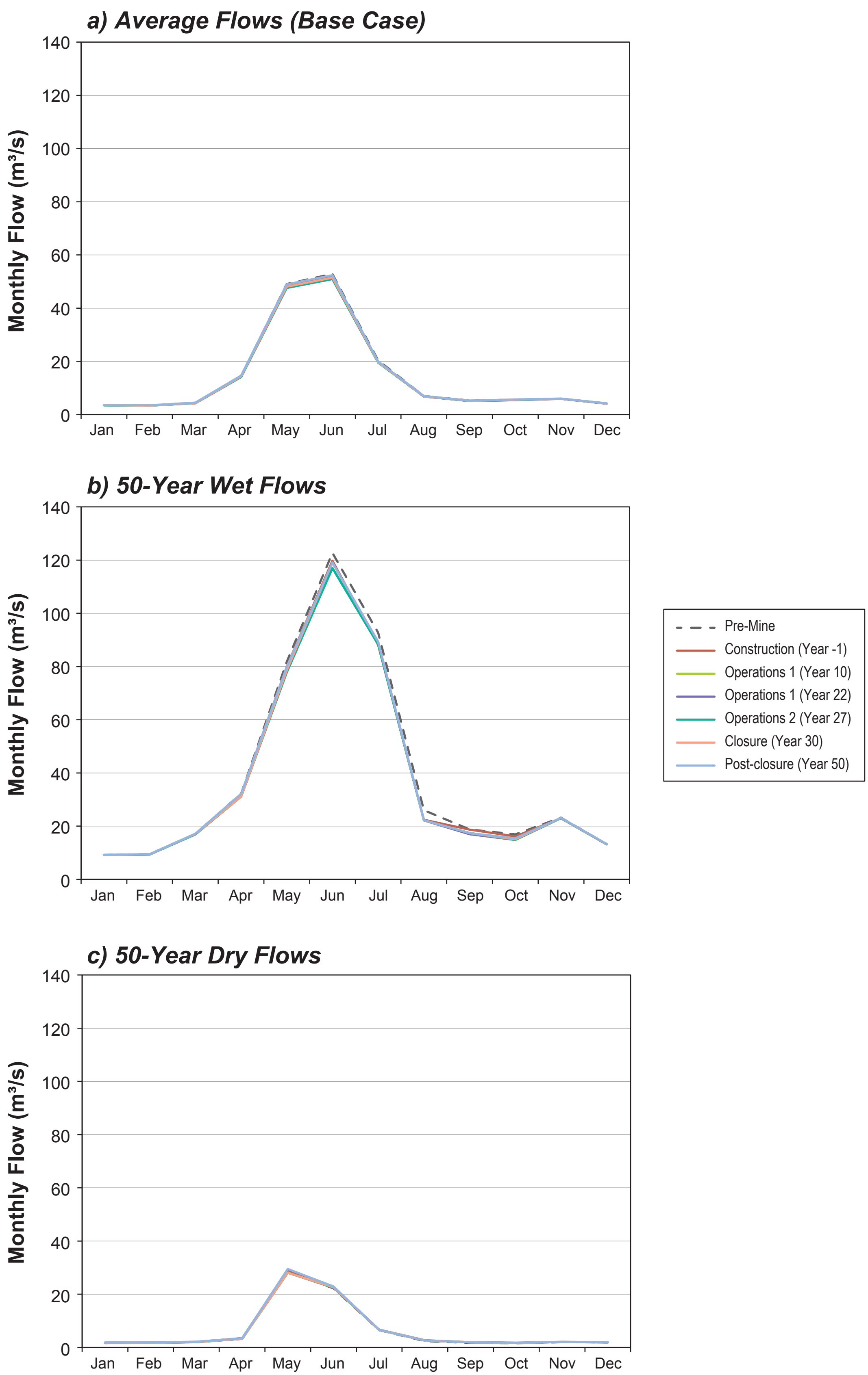
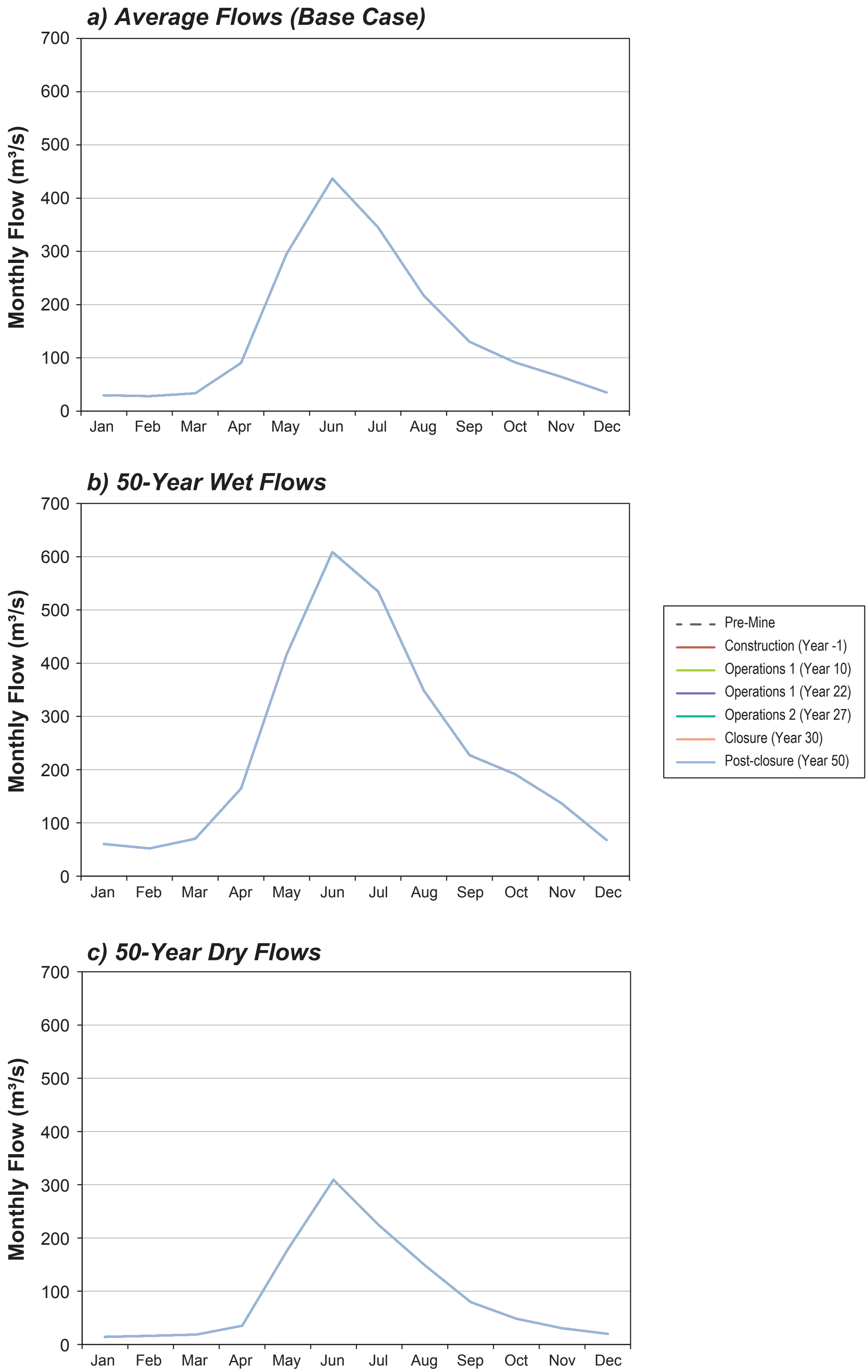


Figure 12.5-13

Monthly Flows at Hydrology Assessment Node 13 (North Thompson River at Birch Island WSC 08LB047)



The formula in Section 12.4.2.2 was used to estimate peak flows with different return periods for each node during different phases of the Project (Appendix 12-B). Because the catchment area of assessment nodes are reduced compared to the pre-mine condition (Table 12.5-5), the peak flows during the life of the mine are less than pre-mine peak flows (Table 12.5-6). Effects of the Project on peak flows are up to 100% flow reduction in T-Creek, 36% in P-Creek, 21% in Harper creek, and 7% in Baker Creek. Changes to peak flows in Jones Creek and the RSA assessment points (Nodes 11, 12, and 13) are negligible.

To investigate the potential variability in the base case effects assessment, sensitivity scenarios were used for two climate estimates (i.e., 50-year dry and 50-year wet streamflows). Sensitivity analysis results (Figures 12.5-1 to 12.5-13; Tables 12-C1b to 12-C13b in Appendix 12-C) are consistent with base case assessment results in that the effects of the Project streamflows are most noticeable at the headwater sub-watersheds of the LSA and negligible at the RSA assessment points. Generally, flow reduction (i.e., percent change to annual and monthly flows) for the 50-year wet and 50-year dry scenarios were higher and lower than those of the base case scenario, respectively (Tables 12-C1b to 12-C13b in Appendix 12-C). For example, maximum annual flow reduction in Harper Creek at the Barrière River confluence (Node 10) is 12% for the base case, 23% for the 50-year wet case, and no flow reductions for the 50-year dry case.

12.5.3.2 Characterization of Altered Streamflow

Residual effects of the Project on surface water quantity (Section 12.5.3.1) are further characterized in this section. The characterization is 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 12.5-7 provides a summary of definitions for each characterization criterion, specific to the surface water quantity VC. Ratings for these criteria are described here.

- Magnitude: Based on estimated effects of the Project on surface water quantity (Section 12.5.3.1) and the ratings in Table 12.5-7, low, medium, and high magnitude changes are predicted for different sub-watersheds within the LSA. For RSA watersheds, the magnitude of changes is negligible.
- Duration: Residual effects on flows will be detectable during all proposed Project phases; therefore, the residual effects are considered far future in duration.
- Frequency: Streamflow is a continuous context that would be affected on an ongoing basis, though not to the same degree.
- Geographic Extent: Effects of the Project on streamflows, beyond the LSA assessment points, are negligible. That is, effects of the Project on surface water quantity are local and restricted to the LSA.
- Reversibility: Effects on streamflows are partially reversible if natural sub-drainages are restored.
- Resiliency: For surface water quantity, there is not a direct measure of resilience, and therefore a **neutral** resiliency level was selected in this assessment. Indirect measures, i.e., resilience of downstream fisheries and aquatic resources to streamflow changes, are discussed in Chapter 14, Fish and Aquatic Resources Effects Assessment.

Table 12.5-5. Drainage Area of Hydrology Assessment Nodes during Different Phases of the Project

Project Phase	Drainage Area	Node 1 Harper Creek at the WSC 08LB076 Station	Node 2 Harper Creek Above T-Creek Confluence	Node 3 T-Creek at Harper Creek Confluence	Node 4 T-Creek Upstream of Harper Creek Confluence	Node 5 P-Creek at Harper Creek Confluence	Node 6 Jones Creek Above North Thompson River Confluence	Node 7 Baker Creek at North Thompson River Confluence	Node 8 Harper Creek Below P-Creek Confluence	Node 9 Harper Creek Below T-Creek Confluence	Node 10 Harper Creek at Barrière River Confluence	Node 11 Barrière River Below Sprague Creek WSC 08LB069	Node 12 Barrière River at the Mouth WSC 08LB020	Node 13 North Thompson River at Birch Island WSC 08LB047
Pre-Mine	(km^2)	166.4	47.0	23.4	15.0	7.6	17.6	14.0	16.6	70.4	185.6	624.0	1140	4490
Construction (Year -1)	(km^2)	150.9	46.7	8.2	0.0	7.3	17.5	13.8	16.3	54.9	170.1	608.5	1124	4490
	% Change from Pre-mine	-9%	-1%	-65%	-100%	-4%	-1%	-1%	-2%	-22%	-8%	-2%	-1%	0%
Operations 1 (Year 10)	(km^2)	148.1	44.4	7.8	0.0	5.0	17.1	13.2	13.9	52.2	167.3	605.7	1122	4489
	% Change from Pre-mine	-11%	-6%	-67%	-100%	-35%	-3%	-5%	-16%	-26%	-10%	-3%	-2%	0%
Operations 1 (Year 22)	(km^2)	147.1	43.6	7.5	0.0	4.2	17.0	12.8	13.2	51.1	166.3	604.7	1121	4488
	% Change from Pre-mine	-12%	-7%	-68%	-100%	-45%	-4%	-9%	-21%	-27%	-10%	-3%	-2%	0%
Operations 2 (Year 27)	(km^2)	147.4	43.9	7.6	0.0	4.5	17.2	12.8	13.5	51.5	166.6	605.0	1121	4489
	% Change from Pre-mine	-11%	-7%	-68%	-100%	-41%	-2%	-8%	-19%	-27%	-10%	-3%	-2%	0%
Closure (Year 30)	(km^2)	162.5	44.0	22.6	15.0	4.5	17.4	12.8	13.5	66.6	181.8	620.2	1136	4489
	% Change from Pre-mine	-2%	-7%	-3%	0%	-40%	-1%	-8%	-19%	-5%	-2%	-1%	0%	0%
Post-closure (Year 50)	(km^2)	162.7	44.0	22.8	15.0	4.6	17.6	12.9	13.5	66.7	181.9	620.3	1136	4489
	% Change from Pre-mine	-2%	-6%	-3%	0%	-40%	0%	-8%	-18%	-5%	-2%	-1%	0%	0%

Table 12.5-6. Annual Peak Flows (1-in-50 Year Return Period) at Hydrology Assessment Nodes during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation)

Project Phase	Parameter	Unit	Node 1 Harper Creek at the WSC 08LB076 Station	Node 2 Harper Creek Above T-Creek Confluence	Node 3 T-Creek at Harper Creek Confluence	Node 4 T-Creek Upstream of Harper Creek Confluence	Node 5 P-Creek at Harper Creek Confluence	Node 6 Jones Creek Above North Thompson River Confluence	Node 7 Baker Creek at North Thompson River Confluence	Node 8 Harper Creek Below P-Creek Confluence	Node 9 Harper Creek Below T-Creek Confluence	Node 10 Harper Creek at Barrière River Confluence	Node 11 Barrière River Below Sprague Creek WSC 08LB069	Node 12 Barrière River at the Mouth WSC 08LB020	Node 13 North Thompson River at Birch Island WSC 08LB047
Pre-Mine	Annual Flow	(m^3/s)	68.2	35.8	22.0	16.3	10.1	18.4	15.9	18.2	48.4	74.1	172.9	183.6	1208
Construction (Year -1)	Annual Flow	(m^3/s)	63.4	35.6	10.0	0.0	9.8	18.3	15.8	17.9	40.2	69.4	169.7	181.7	1208
	Change from Pre-mine	(m^3/s)	-4.8	-0.2	-12.0	-16.3	-0.3	-0.1	-0.1	-0.3	-8.2	-4.7	-3.2	-1.9	0
		(%)	-7%	0%	-54%	-100%	-3%	0%	-1%	-1%	-17%	-6%	-2%	-1%	0%
Operations 1 (Year 10)	Annual Flow	(m^3/s)	62.5	34.2	9.6	0.0	7.4	18.0	15.2	16.0	38.6	68.6	169.1	181.4	1208
	Change from Pre-mine	(m^3/s)	-5.7	-1.5	-12.4	-16.3	-2.8	-0.4	-0.6	-2.2	-9.8	-5.5	-3.8	-2.2	0
		(%)	-8%	-4%	-56%	-100%	-27%	-2%	-4%	-12%	-20%	-7%	-2%	-1%	0%
Operations 1 (Year 22)	Annual Flow	(m^3/s)	62.2	33.8	9.4	0.0	6.5	17.9	14.8	15.3	38.1	68.3	168.9	181.3	1208
	Change from Pre-mine	(m^3/s)	-6.0	-2.0	-12.6	-16.3	-3.7	-0.5	-1.0	-2.9	-10.3	-5.9	-4.0	-2.3	0
		(%)	-9%	-6%	-57%	-100%	-36%	-3%	-7%	-16%	-21%	-8%	-2%	-1%	0%
Operations 2 (Year 27)	Annual Flow	(m^3/s)	62.3	34.0	9.4	0.0	6.8	18.1	14.9	15.6	38.3	68.4	169.0	181.3	1208
	Change from Pre-mine	(m^3/s)	-5.9	-1.8	-12.5	-16.3	-3.3	-0.3	-1.0	-2.6	-10.1	-5.8	-4.0	-2.3	0
		(%)	-9%	-5%	-57%	-100%	-33%	-1%	-6%	-14%	-21%	-8%	-2%	-1%	0%
Closure (Year 30)	Annual Flow	(m^3/s)	67.0	34.0	21.4	16.3	6.9	18.3	14.9	15.6	46.4	73.0	172.1	183.1	1208
	Change from Pre-mine	(m^3/s)	-1.2	-1.8	-0.5	0.0	-3.3	-0.1	-1.0	-2.6	-2.0	-1.2	-0.8	-0.5	0
		(%)	-2%	-5%	-3%	0%	-32%	-1%	-6%	-14%	-4%	-2%	0%	0%	0%
Post-closure (Year 50)	Annual Flow	(m^3/s)	67.1	34.0	21.5	16.3	6.9	18.4	14.9	15.6	46.5	73.0	172.2	183.2	1208
	Change from Pre-mine	(m^3/s)	-1.1	-1.8	-0.5	0.0	-3.2	0.0	-0.9	-2.6	-1.9	-1.1	-0.8	-0.4	0
		(%)	-2%	-5%	-2%	0%	-32%	0%	-6%	-14%	-4%	-1%	0%	0%	0%

Table 12.5-7. Definitions of Specific Characterization Criteria for Surface Water Quantity

Timing*	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Resiliency
When will the effect begin?	*How severe will the effect be?*	*How far will the effect reach?*	*How long will the effect last?*	*How often will the effect occur?*	*To what degree is the effect reversible?*	*How resilient is the receiving environment or population? Will it be able to adapt to or absorb the change?*
Construction phase	**Negligible:** the change in streamflow is less than the inherent data and modelling uncertainty in hydrologic studies (i.e., 5%).	**Discrete:** effect is limited to the Project Site.	**Short term:** effect lasts less than 2 years (e.g., during the Construction phase of the Project).	**One time:** effect is confined to one discrete event.	**Reversible:** effect can be reversed.	**High:** the receiving environment or population has a high natural resilience to imposed stresses, and can respond and adapt to the effect.
Operations 1 and 2 phases	**Low:** the change in streamflow is less than 10% of the baseline flow. This is in agreement with recommendations from the Science Advisory, Fisheries and Oceans Canada (DFO 2013).	**Local:** effect is limited to the LSA.	**Medium term:** effect lasts from 2 to 30 years (e.g., during the Operations phases of the Project).	**Sporadic:** effect occurs rarely and at sporadic intervals.	**Partially reversible:** effect can be partially reversed.	**Neutral:** the receiving environment or population has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.
Closure phase	**Medium:** the change in streamflow is between 10%, as explained above, and 30%, as explained below.	**Regional:** effect occurs throughout the RSA.	**Long term:** effect lasts from 30 to 37 years (e.g., during the Closure phase of the Project).	**Regular:** effect occurs on a regular basis.	**Irreversible:** effect cannot be reversed, is of permanent duration.	**Low:** the receiving environment or population has a low resilience to imposed stresses, and will not easily adapt to the effect.
Post-Closure phase	**High:** the change in streamflow is greater than 30% of the baseline flow. This threshold was selected based on professional judgment on what would generally result in major fish habitat loss in BC streams.	**Beyond regional:** effect extends beyond the RSA.	**Far future:** effect lasts more than 37 years (e.g., during the Post-Closure phase and beyond).	**Continuous:** effect occurs constantly.		

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

12.5.3.3 Likelihood of Altered Streamflow

Likelihood refers to the probability of the predicted residual effect occurring and is determined according to the attributes identified in Table 12.5-8. Project activities include diversion of natural flow pathways, surface disturbance (and therefore alteration of runoff and infiltration processes), and storage of contact water. These activities will directly affect the natural streamflow regime. The probability of changes in streamflow regime is **high**.

Table 12.5-8. Attributes of Likelihood of Effects

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

12.5.3.4 Summary of Residual Effects on Surface Water Quantity

Residual effects of the Project on surface water quantity are summarized in Table 12.5-9. Streamflows are altered during Construction, Operations, Closure, and Post-Closure. Mitigation measures reduce the potential effects of the Project on surface water quantity; however, they are not expected to fully eliminate effects.

Table 12.5-9. Summary of Residual Effects on Surface Water Quantity

Valued Component	Project Phase (Timing of Effect)	Cause-Effect [1]	Mitigation Measure(s)	Residual Effect
Surface Water Quantity	Construction, Operations, Closure, and Post-Closure	Diversion of flow pathways, surface disturbance (and therefore alteration of runoff and infiltration processes), and storage of contact water change the natural streamflow regime	Separating non-contact and contact water, and reusing contact water to minimize the use of freshwater, and therefore to minimize streamflow changes. Implementing the sedimentation and erosion control plan to avoid morphologic changes.	Altered streamflows

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

12.5.4 Significance of Residual Effects

Based on predicted effects of the Project on surface water quantity (i.e., the water balance modelling results; Section 12.5.3.1) and the ratings in Table 12.5-7, medium and high magnitude changes to streamflow can occur within the LSA. However, such changes are negligible (less than 5%) at the RSA assessment nodes. Thus, from a watershed-based perspective, the residual effects on surface water quantity due to Project activities are predicted to be **moderate**, and therefore the residual effects are **not significant**.

12.5.5 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.

Streamflows were simulated through integration of on-site and regional flow data with a watershed modelling approach (Section 12.4.2.4; Appendix 12-B). Simulated flows were deemed reliable for effects assessment purposes (Appendix 12-B). Thus, the confidence associated with baseline data and modelling technique is considered to be **high**.

12.5.6 Summary of the Assessment of Residual Effects for Surface Water Quantity

Table 12.5-10 provides a summary of the residual effects, mitigation, and significance on surface water quantity.

12.6 Cumulative Effects Assessment

12.6.1 Scoping Cumulative Effects

12.6.1.1 Valued Components and Project-related Residual Effects

The identified residual effect on surface water quantity (i.e., altered streamflow) was carried forward and considered for the cumulative effects assessment (CEA).

12.6.1.2 Defining Assessment Boundaries

Similar to the Project-related effects, assessment boundaries define the maximum limit within which the CEA is conducted. Boundaries relevant to hydrology CEA are described below.

The temporal boundaries for the identification of physical projects and activities have been categorized into past, present, and reasonably foreseeable future 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 taking into account any far-future effects from past projects and activities.[2]
- 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.

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

Table 12.5-10. Summary of Key Effects, Mitigation, Residual Effects Characterization Criteria, Likelihood, Significance, and Confidence

Key Effect	Mitigation Measures	Summary of Residual Effects Characterization Criteria *(Magnitude, Geographic Extent, Duration, Frequency, Reversibility, Resiliency)*	Likelihood *(High, Moderate, Low)*	Significance of Adverse Residual Effects: Scale *(Minor, Moderate, Major)*	Significance of Adverse Residual Effects: Rating *(Not Significant; Significant)*	Confidence *(High, Moderate, Low)*
Altered streamflow	Separating non-contact and contact water, and reusing contact water to minimize the use of freshwater, and therefore to minimize streamflow changes. Implementing the sedimentation and erosion control plan to avoid morphologic changes.	• Magnitude: varies from **low** to **high** within the LSA, and is **negligible** at the RSA assessment nodes. • Geographic Extent: **local.** • Duration: **far future**. • Frequency: **continuous**. • Reversibility: **partially reversible**. • Resiliency: **neutral**.	High	Moderate	Not significant	High

The spatial boundaries for the identification of other physical projects and activities for the assessment of cumulative effects have been identified in the AIR as the Kamloops Land and Resource Management Plan boundary, and are illustrated in Figure 8.7-1. These boundaries are referred to as the CEA area.[3]

12.6.1.3 Projects and Activities Considered

Past, present, and reasonably foreseeable future projects and activities within the boundaries described above were considered in the CEA (Figure 12.6-1). The project list was developed from a wide variety of information sources, including municipal, regional, provincial, and federal government agencies; other stakeholders; and companies' and businesses' websites. The projects and activities considered in the CEA are presented in Chapter 8 in Tables 8.7-1 and 8.7-2, respectively. The methodology used in the CEA is provided in Chapter 8, Section 8.7.

Project-related residual effects on surface water quantity were predicted within the LSA only. Therefore, the potential for interaction with surface water quantity effects from other projects and activities were only considered for the LSA watersheds.

12.6.2 Screening and Analyzing Cumulative Effects

Project-related residual effects on surface water quantity beyond the LSA boundaries were not predicted. No past, present, or reasonably foreseeable future project is expected to affect streamflows within the Project LSA (Figure 12.6-1; Table 8.7-1). Thus, no interactions between the Project and other projects are expected with regards to streamflow changes, and therefore no CEA regarding streamflows was undertaken. Water use activities (Table 8.7-2) occur within the RSA and therefore have the potential to interact with effects of the Project on surface water quantity. The land use effects assessment found no interactions between the Project and water use activities (Section 18.6.2).

12.6.3 Follow-up Programs

A hydrometric monitoring program is proposed to confirm the predicted residual effects on surface water quantity (Section 12.5.3). Details of the hydrometric monitoring program are provided in the Site Water Management Plan (Section 24.13).

12.7 CONCLUSIONS FOR HYDROLOGY

Quantitative information, including baseline studies and watershed modelling, was used to assess the potential for Project-related effects to surface water quantity. Predicted effects to surface water quantity are summarized in Table 12.7-1. After considering mitigation measures, residual effects, i.e., altered streamflows, were identified for surface water quantity.

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

The residual effects on surface water quantity as a result of Project activities are predicted to be **not significant (moderate)**. Medium and high streamflow changes are anticipated to be confined within the LSA. Predicted effects on the RSA streamflows (i.e., Barrière and North Thompson rivers) are negligible (less than 5% flow reduction).

Project-related residual effects were carried forward to the CEA. Potential interactions with other projects and activities were considered in the CEA. No interactions were identified for potential cumulative effects due to a change in surface water quantity.

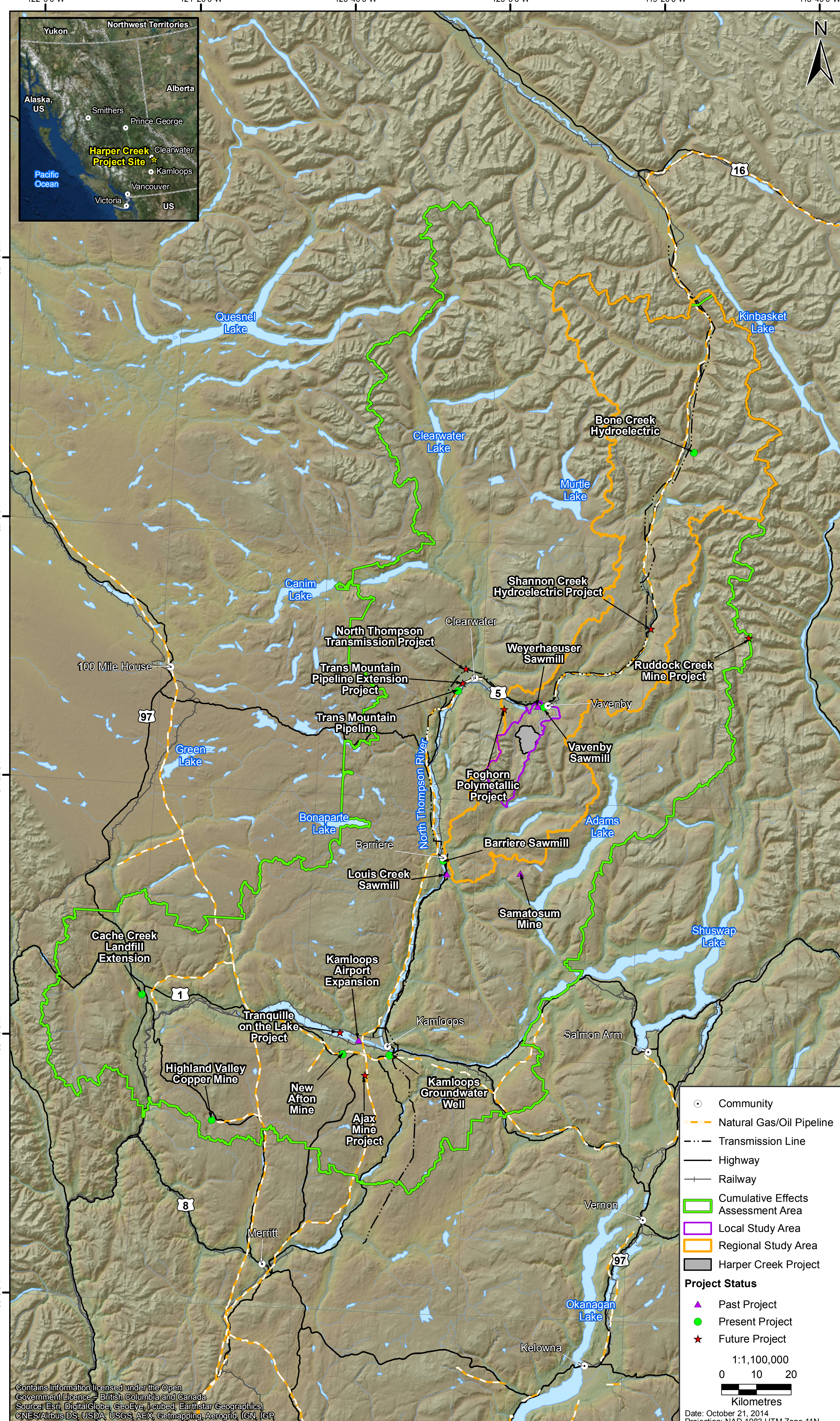
Table 12.7-1. Summary of Key Project and Cumulative Residual Effects, Mitigation, and Significance for Surface Water Quantity

Key Residual Effects	Project Phase	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Hydrology				
Altered streamflow	Construction, Operations, Closure, Post-Closure	Separating non-contact and contact water, and reusing contact water to minimize the use of freshwater, and therefore to minimize streamflow changes. Implementing the sedimentation and erosion control plan to avoid morphologic changes.	Not significant (moderate)	n/a

Figure 12.6-1

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

ERM



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