

7.2 REGULATORY AND POLICY FRAMEWORK

Surface water is a critical component of the biological and physical environment and is protected under the British Columbia (BC) *Water Sustainability Act* (2014) and the *Canada Water Act* (1985). Surface water baseline studies for the Project were designed to meet the *Joint Application Information Requirements for Mines Act and Environmental Management Act Permits* (Joint AIR for MA/EMA Permits; BC MEM and MOE 2016).

7.3 EXISTING INFORMATION

Readily available sources of existing hydrology data were reviewed, and a summary of the review is provided in Table 7.3-1.

Table 7.3-1. Hydrology Data Information Table

Documents Reviewed	• Extracted from the Environment and Climate Change Canada Real-time Hydrometric Data web site https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html ▪ Telkwa River Below Tsai Creek (08EE020) ▪ Bulkley River at Quick (08EE0004) ▪ Bulkley River Near Smithers (08EE0005) • Extracted from the Environment and Climate Change Canada Historical Hydrometric Data web site (https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html) ▪ Goathorn Creek Near Telkwa (08EE008) • Extracted from the BC Environmental Assessment Office Project web site (https://www.projects.eao.gov.bc.ca/project) ▪ Telkwa Coal – Type: Mine ▪ Final Project Report Specifications for Manalta Coal Ltd.’s Proposed Telkwa Coal Project. Submitted by the Telkwa Coal Project Committee. August 1997. ▪ Telkwa Coal Project: Application for a Project Approval Certificate – Volumes I-V. Submitted by Manalta Coal Ltd. January 31, 1997. ▪ Davidson – Type: Mine ▪ Davidson Project: Application for Environmental Assessment Certificate. Submitted by Blue Pearl Mining Inc. August 2008. ▪ Davidson Project Meteorology and Hydrology Baseline report 2006-2008. Submitted by Blue Pearl Mining Inc. May 2009. • Extracted from historical records provided by the Client ▪ AGRA Earth & Environmental Ltd. (February 1999). <i>Telkwa Coal Mine Surface Water Monitoring Program 1998</i>. AGRA Earth & Environmental Ltd. ▪ AGRA Earth & Environmental Ltd. (March 2000). <i>Telkwa Coal Project 1999 Baseline Surface Flow and Water Quality Final Data Report</i>. AGRA Earth & Environmental Ltd ▪ Piteau Engineering Ltd. (August 1998). <i>Water Management for the Telkwa Coal Project</i>. Manalta Coal Ltd. ▪ R. Nijman. (April 1986). <i>Ambient Water Quality Objectives for the Bulkley River Basin: Overview Report</i>. B.C. Ministry of Environment. ▪ R. Nijman. (April 1986). <i>Ambient Water Quality Objectives for the Bulkley River Basin: Technical Appendix</i>. B.C. Ministry of Environment.
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Table 7.3-1. Hydrology Data Information Table (continued)

General Remarks	Overall, the amounts of existing relevant data are small in extent but the quality of the data that is available for the general project region is good. Some of the regional daily discharge data records from the Water Survey of Canada date back to 1915 while daily water level data becomes available as of 2011. A detailed and high quality analysis was performed for the Davidson project, located in the greater watershed of the Tenas Project area, and a similar analysis is available for the original Telkwa Mine Project in the 1990s.
Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (Joint AIR for MA/EMA Permits)	• A recommended minimum two year surface water hydrology study of the mine property. • Identify relevant existing data and whether they represent un-impacted baselines or are influenced by development. • Provide detailed analysis of key drainages within the project area and establish continuous hydrometric data collection of drainages potentially affected by effluent discharge, water diversions, and/ or seepage from waste rock and/or tailings. • Provide detailed maps of hydrometric stations relevant to effluent discharge locations, seepages, points of diversion and water quality or other aquatic monitoring locations. • Include a database of manual low-flow streamflow measurement and document hydrometric station installation, sampling and QA/QC procedures. • Determine critical low-flow metrics for waters important to aquatic life, drinking water, wildlife, irrigation and other water users. • Develop a quantitative water balance model for the study area including worst case scenarios, upper and lower bound estimates, expected groundwater recharge and justifications for inclusion an exclusion of all components and their estimation methods. • Identify spatial and/or temporal gaps in the database.
Existing Data	Telkwa Coal Project: Application for a Project Approval Certificate (1997) • Overview of local hydrological features and characteristics within the project boundaries and the greater Skeena Watershed such as watershed area, tributaries, and sediment loading. Provides a summary of information on three Water Survey of Canada hydrometric stations active at the time of reporting with data dating back to 1930. Final Project Report Specifications for Manalta Coal Ltd.'s Proposed Telkwa Coal Project (1997) • Details regarding Manalta's permits regarding hydrology and water management, including a requirement for the development of flow estimates and water balance modelling. Goathorn Creek Near Telkwa - WSC Station ID 08EE008 (1960-Present) • Daily discharge data 1960 to present; daily water level data 2011 to present. Telkwa River Below Tsai Creek - WSC Station ID 08EE020 (1975-Present) • Daily discharge data 1975 to present; daily water level 2011 to present. Bulkley River at Quick - WSC Station ID 08EE004 (1930-Present) • Daily discharge data 1930 to present; daily water level 2011 to present. Sporadic seasonal discharge measurements prior to 1957. Bulkley River Near Smithers - WSC Station ID 08EE0005 (1915-Present) • Daily discharge data 1915 to present; daily water level 2011 to present. Station not operational between the years 1916-1945, 1952-1970, and 1972-2007.

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Table 7.3-1. Hydrology Data Information Table (continued)

Existing Data (<i>cont'd</i>)	Davidson Project: Application for Environmental Assessment Certificate (2008) - Detailed description of hydrological setting, local field data, regional analysis, and summary of the site's key hydrological parameters. Davidson Project Meteorology and Hydrology Baseline Report 2006-2008 (2006-2008) - Hydrological baseline study of WSC hydrometric stations Bulkley River at Quick and Simpson Creek, as well as six hydrometric stations established for the Davidson Project. Ambient Water Quality Objectives for the Bulkley River Basin – Overview Report and Technical Appendix (1986) - Very high level overview of Bulkley River and its tributaries with one-in-ten-year 7-day flow estimates for hydrometric stations near Houston, at Quick, and at Smithers. Water Management For the Telkwa Coal Project (1998) - Summary of mean annual, maximum mean monthly, and minimum mean monthly flow rates for the WSC station #08EE020 for the 1975-1995 period. Telkwa Coal Mine Surface Water Monitoring Program 1998 (1999) - A report on the streamflow monitoring for the baseline hydrological analysis completed for the Telkwa Coal Project. It encompasses monitoring data from eleven monitoring locations deemed to have the potential to be impacted by the mine's activities, including three WSC stations: 08EE020, 08EE008, and 08EE004. Telkwa Coal Project 1999 Baseline Surface and Water Quality Final Data Report (2000) - Baseline hydrology and water quality report for five hydrometric stations located on Tenas Creek, Four Creek, Hubert Creek, and Goathorn Creek. Consists of a compilation of memos sent to Luscar Ltd. as updates on the surface water monitoring program.
Existing Data Issues	There are existing hydrology data available for the region including streams within the greater Bulkley River watershed. However, detailed site specific data for potentially affected streams are lacking. The Water Survey of Canada provides historical data for streams in the Bulkley, Telkwa and Goathorn watersheds which includes some that are relatively close to the Project, but they are not all site specific and the timing of verified (QA/QCed) data availability does not meet the baseline data needs. The detailed analysis undertaken by the proposed Davidson project was specific to the proposed Davidson site, limiting its relevancy to the Tenas Project. While there are some hydrometric analysis data for the original Telkwa Mine Project, it is now almost 20 years old.
Missing Data	Up to the initiation of the 2017-2019 hydrology program, there were no current site specific data available for the Project, including three locations within the Project area where hydrometric stations were installed in May 2017.
2017–2019 Baseline Program	Historically, there are no site specific hydrometric data available for the Project. The baseline program addresses this gap with the installation of three hydrometric stations. These stations were used to provide seasonal water level and discharge hydrometric data from May–October as of 2017. Additionally, monthly winter low flow discharge measurements provide data during the periods (winter) when the stations are inactive (ice cover prevents continuous monitoring).

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Table 7.3-1. Hydrology Data Information Table (completed)

Key Issues	Without the collection of site specific data for the mine property it will not be possible to meet the minimum requirements of the BC Environmental Assessment application or the Joint AIR permit application.
Other Comments	N/A

The Water Survey of Canada (WSC) maintains, and has maintained in the past, numerous hydrometric stations in the region surrounding the Project. The Environmental Assessment Office of British Columbia also provides public access to a number of documents from previous mining projects within the region, some of which include varying extents of hydrometric data and analysis pertaining to their respective sites. Telkwa Coal also supplied various historical documents pertaining to the hydrology of the Project and the surrounding watershed. These data files and documents were reviewed to ascertain their relevance to the Project and mine site (Table 7.3-1).

Historical regional flow data are available from the WSC from a number of stations as far back as 1915. While there have been various studies of regional hydrology, they generally focussed on major hydrological features such as regional watersheds and major tributaries. A small number of more in-depth baseline studies have been completed for historical mining project proposals in the area, with those pertaining to the Telkwa Coal Mine being the most relevant to the Project. The AGRA Earth & Environmental (1998) report is the most detailed site specific report, although the monitoring program experienced various instrumental problems which limited its analysis of the local hydrology to one open-water season (1998) and one short low-flow period (1997).

7.4 METHODOLOGY

7.4.1 Overview

This section describes the monitoring network and methodology used in the 2017-2019 baseline hydrometric monitoring program. The monitoring program design and quality assurance/quality control (QA/QC) standards were developed in conformance with the *British Columbia Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016).

7.4.2 Hydrometric Monitoring Network

A network of three automated hydrometric monitoring stations was established in May of 2017 and operated in and around the Project area as a part of the 2017-2019 baseline monitoring program (Figure 7.4-1; Table 7.4-1). In addition to Project specific hydrometric monitoring stations, four regional WSC hydrometric monitoring stations were identified (Table 7.4-1).

7.4.3 Hydrometric Station Setup

The Project hydrometric monitoring stations consisted of a PS98i® 0-5 PSI vented pressure transducer paired with a GDL® data logger (Instrumentation Northwest Inc.).

Table 7.4-1. Tenas Project Hydrometric Monitoring Stations

Waterbody	Station	UTM Location ¹		Area (km ²)	Median Elevation (masl)	Glacier Coverage (%)	Period of Operation ²
		Easting (m)	Northing (m)				
Project Stations							
Tenas Creek	Tenas-Hydro	616914	6053490	47.4	1292	0	2017
Tenas Creek	Tenas-Hydro B	616806	6053377	47.0	1296	0	2018 - 2019
Goathorn Creek	Goathorn-Hydro	621100	6057441	121.6	1164	0.5	2017 - 2019
Telkwa River	Telkwa-Hydro	617964	6057860	966.9	1222	1.3	2017 - 2019
Regional Stations							
Goathorn Creek	Goathorn Creek Near Telkwa (08EE008)	621106	6057277	125	N/A	N/A	1960 - Present
Telkwa River	Telkwa River Below Tsai Creek (08EE020)	597101	6052062	367	N/A	N/A	1975 - Present
Bulkley River	Bulkley River at Quick (08EE0004)	635614	6054348	7340	N/A	N/A	1930 - Present
Bulkley River	Bulkley River Near Smithers (08EE0005)	620101	6070765	8940	N/A	N/A	1915 - Present

Notes:

¹ UTM Zone 9U; NAD83

² For Project stations, they were only operational during the open water season (April/May through October/November) each year. For regional stations, the periods of operation do not represent the total years of data collected as stations have not all operated continuously.

N/A = Information not available

The pressure transducers and cabling were inserted into a flexible aluminum conduit with one end of the conduit secured in a 1.5 m long aluminum tube or secured to a 1.5 m angle iron. The aluminum tube was open at both ends and a series of small diameter holes were drilled along its length to allow water to pass in and out of the pipe freely. The aluminum tube/angle iron was then placed into the water and secured to the bank. The data loggers were housed in steel, waterproof enclosures attached to trees on the adjacent channel bank above the expected high water level. Specific details for each station setup are provided in Sections 7.4.3.1 through 7.4.3.3 below.

At each station, a pressure transducer was installed as deep in the channel as possible to allow for continuous monitoring of water levels at all ranges of flows. Pressure transducers continuously recorded water level at a ten-minute interval.

7.4.3.1 Tenas-Hydro and Tenas-Hydro B

Hydrometric monitoring station Tenas-Hydro was established on Tenas Creek downstream of the proposed pit in early May 2017 (Figure 7.4-1; Photo 7.4-1). The station was co-located with water quality site WQS02. The pressure transducer and cabling were inserted into a flexible aluminum conduit with one end of the conduit secured in an aluminum pipe. The aluminum pipe was then placed into the water and fixed to re-bar that was pounded into the streambed and bank. The data logger was housed in a steel, waterproof enclosure and secured to a mature tree well above the high water mark.

Figure 7.4-1
Hydrometric Monitoring Stations

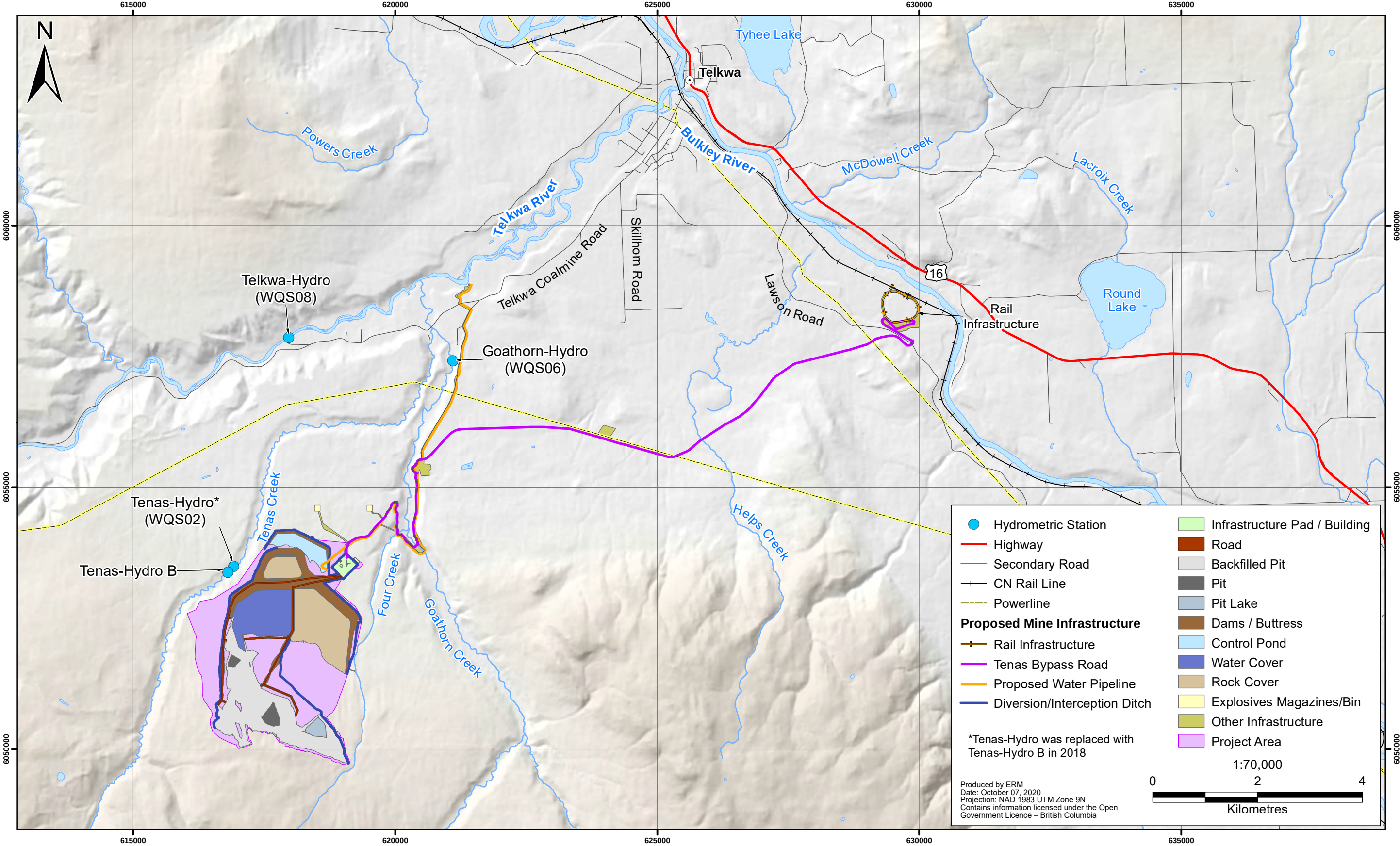




Photo 7.4-1. Hydrometric monitoring station Tenas-Hydro. May 18, 2017.

In late October of 2017, a peak flow event eroded the bank and washed away hydrometric monitoring station Tenas-Hydro. Changes to the channel caused by the peak flow event rendered the monitoring location unsuitable for continuous monitoring, due to the unstable banks, poor water elevation control, and lack of a suitable place to anchor the instrumentation. In May 2018, a new monitoring station (Tenas-Hydro B) was established approximately 200 m upstream at a location that best met the “Desirable Criteria for a Basic Station” (RISC 2018; Photo 7.4-2). The station was re-established by inserting the pressure transducer and cabling into a flexible aluminum conduit, and fixing the conduit to angle iron that was pounded into the streambed and secured to the bank using rebar. The data logger was housed in a steel, waterproof enclosure and secured to a mature tree well above the high water mark. In April of 2019 the station Tenas-Hydro B was re-established at the same location, after being removed for the 2018-2019 winter period to protect the instrumentation from ice damage.

The new monitoring station Tenas-Hydro B was sited close enough to the original monitoring location to allow for comparison between the years of data collection. Although a new rating curve was required for the station, measured discharge, along with calculated runoff and indices are not affected by the move. This is accounted for by the negligible change in drainage area and that there are no tributaries between the 2017 and 2018/2019 locations.



Photo 7.4-2. Hydrometric monitoring station Tenas-Hydro B. May 2, 2018.

7.4.3.2 Goathorn-Hydro

Hydrometric monitoring station Goathorn-Hydro was established on Goathorn Creek downstream of the proposed pit in early May 2017 (Figure 7.4-1; Photo 7.4-3). The station was co-located with water quality site WQS06, and is in close proximity to a WSC hydrometric station (08EE008), which at the date that Goathorn-Hydro station was established had data available from 1960 to the end of 2014. The pressure transducer and cabling were inserted into a flexible aluminum conduit with one end of the conduit secured in an aluminum pipe. The aluminum pipe was then placed into the water and secured to bedrock along the bank using threaded anchor rods. The rods were drilled into the bedrock and anchored in place with quick setting epoxy. The data logger was housed in a steel, waterproof enclosure and secured to a mature tree well above the high water mark. The station was re-established in May 2018 at the same location, after being removed for the 2017-2018 winter period to protect the instrumentation from ice damage, and again in April of 2019 after being removed for the 2018-2019 winter period.

7.4.3.3 Telkwa-Hydro

Hydrometric monitoring station Telkwa-Hydro was established on the Telkwa River upstream of the confluence with Goathorn Creek in early May 2017 (Figure 7.4-1; Photo 7.4-4). The station was co-located with water quality site WQS08. The pressure transducer and cabling were inserted into a flexible aluminum conduit with one end of the conduit secured in an aluminum pipe. The aluminum pipe was then placed into the water and secured to a large boulder along the bank using threaded anchor rods. The rods were drilled into the boulder and anchored in place with quick setting epoxy. The data logger was housed in a steel, waterproof enclosure and secured to a mature tree well above the high water mark. The station was re-established in May 2018 at the same location, after being removed for the 2017-2018 winter period to protect the instrumentation from ice damage, and again in April of 2019 after being removed for the 2018-2019 winter period.



Photo 7.4-3. Hydrometric monitoring station Goathorn-Hydro. May 17, 2017.



Photo 7.4-4. Hydrometric Monitoring Station Telkwa-Hydro. May 16, 2017.

7.4.4 Hydrometric Station Surveys

Hydrometric levelling surveys are important to ensure vertical elevation control is maintained at each station and the water surface elevation (i.e., stage) measured is reliable and accurate. To establish and maintain vertical elevation control at stations where stage is measured, it is common practice to determine the stage relative to a specified reference surface or gauge datum. The water surface is surveyed to this datum during station visits, allowing the continuous data to be post-processed and corrected to gauge height.

The gauge datum is a critical concept in hydrometric monitoring. It is established using a series of benchmarks, which are physical installations, occurring within a network at each monitoring station. Concrete expansion bolts, secured into bedrock and/or large stable boulders, or spikes driven into the base of sturdy trees near the monitoring stations, were used as benchmarks. One bench mark at each station was identified as the primary reference point, and assigned an arbitrary local elevation of 100.000 m above the datum. A minimum of three benchmarks were installed at each station (Table 7.4-2). All recorded water levels were then referenced relative to this primary bench mark.

Table 7.4-2. Hydrometric Monitoring Station Benchmarks

Station	Benchmark	Elevation ¹ (m)	Benchmark Information
Tenas-Hydro (2017)	78	100.000	Spike in the base of tree ~7 m downstream of station
	79	97.972	Spike in the base of tree ~4 m downstream of station
	80	99.904	Spike in the base of tree ~2 m downstream of station
Tenas-Hydro B (2018 - 2019)	1	100.000	Spike in the base of tree ~5 m downstream of station
	2	99.578	Spike in the base of tree ~2 m upslope of data logger
	3	99.072	Spike in the base of tree with the data logger
Goathorn-Hydro (2017 - 2019)	72	100.000	Concrete expansion bolt in bedrock ~2 m downstream of station
	73	100.376	Concrete expansion bolt in bedrock in line with station
	74	100.247	Concrete expansion bolt in bedrock ~1 m upstream of station
Telkwa-Hydro (2017-2019)	69	100.000	Spike in the base of tree ~5 m downstream of station
	70	100.068	Spike in the base of tree ~1 m upstream of station
	71	100.416	Spike in the base of tree ~3 m upstream of station

¹ Elevation is height (m) relative to the gauge datum.

To allow for continuity in the elevation of the recorded water levels at existing hydrometric stations, benchmarks installed in 2017 were used in 2018 and 2019 as survey control points for each station. The exception to this was at the Tenas Creek stations (Tenas-Hydro and Tenas-Hydro B) where new benchmarks were established in 2018 when the station was relocated and were then also used in 2019 at the new location. In order to check the accuracy and consistency of the recorded data, it is necessary to periodically verify the surveyed elevations in relation to the established station datum. Throughout the 2017, 2018 and 2019 open water monitoring periods, hydrometric levelling surveys were conducted during site visits at each station. The survey included checking and verifying pressure transducer readings to determine the reliability of the water level data that were recorded between site visits.

7.4.5 Discharge Measurements

Manual flow measurements were completed during each site visit during the 2017-2019 monitoring period to obtain a range of measured discharges under different flow conditions. Flow measurements were conducted a minimum of five times during each of the 2017 and 2018 open water seasons and three times during the 2019 open water season to provide a range of flows for rating curve development. Additionally, flow was measured monthly during winter periods to obtain estimates of baseflow within the monitored streams.

Manual flow measurements were carried out at each site using one of two methods, depending on flow conditions and stream morphology: i) when stream channels could be safely waded, a hand-held current velocity meter was used to complete velocity-area measurements; and ii) when the stream channels were too deep or swift to wade safely, tracer dilution was used to measure discharge. In all cases, the methods followed the provincial standard operating procedures for British Columbia (RISC 2018).

7.4.5.1 Velocity-Area Measurements

The location of the measured section at each site was determined based on channel geometry and flow conditions at the time of measurement. Generally, the stream was measured along a straight reach near the monitoring station where the bed and flow conditions were relatively uniform. Areas with highly turbulent flow and/or immovable rocks were avoided where feasible. Current velocities were measured using a Hach FH950™ handheld electromagnetic current meter (velocity measurement accuracies of $\pm 2\%$ of reading and ± 0.015 m/s through a range 0 to 3.04 m/s). A fixed sampling interval of 40 seconds was selected for each velocity measurement, during which an average velocity was determined.

Measurements of water current velocity, depth of flow, and distance across the channel were obtained (Photo 7.4-5) to determine the total stream discharge during each station visit. Typically, a minimum of 20 current velocity measurements were taken across the width of a channel, with the aim of having each vertical or observation interval account for less than 10% of the total discharge (RISC 2018). This method assumes that the velocity measured at each vertical represents the mean velocity in a segment. During the velocity measurements, if the observed water depth was less than 0.75 m, the water velocities were measured at 60% of the water depth, measured from the water surface. The measurement at 60% of the water depth is generally accepted as representing the mean velocity of the vertical water column (Herschy 2009). If water depth was greater than 0.75 m, the water velocities were measured at 20% and 80% of the water depth, with the average of the two readings taken to represent the mean velocity for the vertical water column. In all cases, where feasible, the methodologies employed adhered to the *British Columbia Manual of Standard Operating Procedures for Hydrometric Surveys* (RISC 2018) and Water Survey of Canada (WSC) operating procedures (Terzi 1981).

7.4.5.2 Tracer Dilution Measurements

Tracer dilution is a simple and reliable method of calculating discharge in channels that are steep and turbulent (Hudson and Fraser 2002; Moore 2004). This method can yield results that are comparable to the conventional velocity-area procedure when used appropriately. In settings where high gradient and turbulent flow conditions exist along mountain streams, it has been reported that tracer dilution procedures produce better results than the velocity-area method (Elder and Kattelman 1990; Spence and McPhie 1997).



Photo 7.4-5. Velocity-area discharge measurement on Tenas Creek. June 18, 2018.

Flow measurements conducted using tracer dilution followed the standard slug injection methodologies (Moore 2004; Hudson and Fraser 2005). This method consists of injecting a known mass of dry salt (sodium chloride, NaCl) into the stream at an upstream release point. For a given mass of salt injected, greater stream discharges will result in greater salt dilution and lower concentrations measured at the downstream site (i.e., the higher the flow, the greater the dilution).

The concentration of salt was measured as specific conductivity. The specific conductivity of the stream water was measured using WTW 3410 conductivity probes (MultiLine® Intelligent Digital Systems). The reported accuracies were 0.5% of conductivity reading and ± 0.15 °C of the temperature reading. Measurement of the salt slug was conducted sufficiently far downstream of the injection (approximately 4 km) to ensure complete lateral mixing of the salt slug. For each measurement, two conductivity probes were used. Probes were placed at two locations approximately 450 m apart and separated by a bend and sections of converging and diverging flow to confirm complete mixing was achieved. Specific conductivity measured in the field was related to the concentration of salt within the mixing reach through the use of a calibrated coefficient. The average of the measurements obtained from each probe was taken to be the average discharge. The deviation of the measured value, from the average value, provides the range of error for the calculated flow.

7.4.6 Rating Curve Development

Empirical relationships between measured stage and discharge (i.e., rating curves) were developed (ISO 2010) to provide a continuous record of the discharge at hydrometric monitoring sites. Once the rating curve is established for a monitoring site, continuous stage data (i.e., stage data recorded at 10 minute intervals) can be converted into continuous discharge data and presented as a discharge hydrograph.

The quality of the rating curve, and therefore the quality of the discharge hydrograph, depends on the number, accuracy, and distribution of the data points used to generate the curve, as well as the hydraulic characteristics of the monitoring location. Although a rating curve can theoretically be developed with as few as two points, to properly produce a reliable rating curve, a minimum of ten (RISC 2018) or 15 (ISO 2010) stage and discharge measurements, well distributed through the range of flows, is recommended. Once a rating curve has been established at a site, a minimum of five discharge measurements per year is recommended to meet “Grade A” standards for discharge data based on the Manual of British Columbia Hydrometric Standards (RISC 2018). Each additional stage-discharge measurement at varying flow conditions increases the range and robustness of the rating curve. Discharge measurements at the higher end of the discharge range are especially important as they help define the upper end of the rating curve. These measurements are important since high discharges often require extrapolation beyond the range of the field data used to generate the rating curve. The rating curve can also change from low flow periods to high flow periods due to seasonal influences, such as vegetation (Hersch 2009), or because of different channel geometries or hydraulic controls at low and high flow conditions.

Rating curves are hydraulic functions expressed as an equation of the form:

$$Q = C (h - a)^b \quad (1)$$

where Q is the discharge (m^3/s), C and b are dimensionless coefficients, h is the stage (water level; m), and a is the stage at zero flow (datum correction; m).

The rating curves were developed using Aquarius™ Time Series Hydrologic Software (Aquatics Informatics Inc.). The software uses standard methods outlined by the United States Geological Survey and the International Organization for Standardization (Kennedy 1984, ISO 2010). The Aquarius™ interface allows the user to draw the rating curve in a logarithmic plot. Equation (1) is logarithmically transformed to:

$$\log Q = \log C + b \log (h - a) \quad (2)$$

which is in the form of the equation of a straight line. The hydrometric technician can then determine characteristics that are evident in logarithmic plots and relate these to the type of hydraulic control, the stream cross section, cross section shape changes, and shifting control patterns (Sauer 2002). Root Mean Square (RMS) error, used by the Aquarius™ software as an overall measure of error of the stage discharge relationship, is provided as an indicator of uncertainty. RMS error is a statistical parameter that describes how well the values predicted by the stage-discharge relationship fit or represent the observed data.

Rating curve uncertainty is critical in interpreting discharge records, and much of the uncertainty is associated with the extrapolation of the rating curve beyond field measurements. Guidelines suggest that 1.5 times (ISO 2010) or 2 times (Rantz et al. 1982) of the greatest manually measured discharge is the recommended limit of reliable extrapolation. All discharges obtained from curves extrapolated beyond twice the highest manually measured discharge are noted as having higher uncertainty in the daily discharge tables provided in Appendix 7-A of this report.

7.4.7 Hydrograph Generation

Annual hydrographs, presented as mean daily discharge, were generated for each hydrometric monitoring station operated in 2017-2019. For the operational period at each hydrometric station, water discharges were calculated at ten minute intervals by applying the developed rating curve equation to the recorded stage data. The ten minute discharge data were averaged over a 24-hour period to calculate mean daily discharge.

For periods when stations were demobilized for winter (pressure transducers were removed to protect them from damage due to freezing), daily discharges were calculated by interpolating between discrete point measurements using a standard linear or logarithmic growth or decay function. When gaps were observed in the stage data recorded due to water level going below the sensor height or data loss due to data logger malfunctions, discharges was estimated by correlating discharge time series from nearby hydrometric stations in the watershed with similar characteristics.

7.4.8 Hydrologic Indices

Observed and estimated discharge values were used to generate a series of hydrologic indices, including annual runoff, monthly runoff distribution, unit discharge, mean annual discharge, and annual peak and low flows.

Annual runoff represents the proportion of precipitation, snowmelt and glacial melt that becomes stream flow. Runoff is valuable for obtaining gross estimates of the water available in a watershed. Runoff is normalized to drainage area, expressed as a depth of water, and thus is a useful index for comparing the hydrological response of watersheds of different sizes.

Monthly runoff distribution was determined by summing the daily runoff by month for each watershed. Monthly runoff was calculated and presented to illustrate the spatial and temporal distribution of runoff in the Project area.

Unit discharge is a calculation of discharge, normalized by drainage area, and is an indicator of a drainage basin's ability to convey water, irrespective of drainage area.

Mean annual discharge, computed as an average discharge over the year, gives an indication of the potential amount of water a watershed can provide as a function of drainage area, geology, and climate.

Peak flows represent the maximum stream discharges that were produced from a drainage area over the year in response to precipitation events, snowmelt, and glacial melt. Conversely, low flows provide an estimate of baseflow conditions for the year (annual low flow) and during the open water season (summer low flow), which is important for the sustained health of a stream's aquatic community. The annual and summer low flows were calculated using a 7-day average from the calculated daily discharge.

7.4.9 Quality Assurance/Quality Control

Data collection for this study was conducted in compliance with the BC guidelines for water and air baseline monitoring (BC MOE 2016). The hydrotechnical standards and methods employed on the

Project are consistent with standards published by the British Columbia Ministry of Environment (RISC 2018). These standards complement the national standards developed by the Environment Canada's Water Survey of Canada (WSC 1999).

RISC (2018) outlines three criteria for both water level data and discharge data that are used to assess and grade (i.e., A, B, C, E [estimated], and U [unknown]) the overall quality of hydrometric data. The criteria are: i) instrumentation; ii) field procedures; and iii) data calculation and assessment. The list provided below details the methods that were used in the hydrometric monitoring program, with the aim to achieve high quality data based on the standards in each of the three criteria.

1. Instrumentation

All instrumentation used and calibration/verification procedures complied with the highest quality data collection outlined by in the RISC manual (i.e., Grade A). Data loggers and pressure transducers used for the recording and calculation of continuous water level at the hydrometric stations met the required accuracy (3 mm or 0.2% of effective stage, whichever is greater) and were checked, and if necessary calibrated by the manufacturer, prior to each field season.

2. Field Procedures

The field procedures were designed to meet the high/mid range of standards outlined by RISC (Grade A and B). These included the use of a minimum of three bench marks at each station, more than two level checks per year, 20 or more verticals (each accounting for <10% of the total discharge) in manual stream flow measurements, and five or more manual flow measurements per year in 2017 and 2018 (Grade A) and three manual flow measurements in 2019 (Grade B).

3. Data Calculation and Assessment

Data calculations met the high/mid-range of standards. Results were compared to other stations and years and reviewed for anomalies/deficiencies (Grade A). Discharge rating accuracy varied across the hydrometric monitoring network (between Grade A and B). Due to the unstable nature of natural channels, rating curves often shift and rating points that were <15% (Grade B) from established curves were considered valid, although many of the points were within 5% (Grade A).

Additionally, RISC (2018) states that, "hydrometric data should be graded as E (i.e., Estimated) when stations are operated using RISC standards (i.e., water level or discharge data could be Grade A/RS, A, B, or C) but data were estimated because of instrument anomalies, shift correction, missing data, or rating curve extrapolation beyond maximum or minimum measured discharge levels." Some of the data collected for the Project as described above falls in this category and thus should be considered Grade E for discrete periods at each station (e.g., when stations are deactivated for winter periods, for discharge calculated from rating curves extrapolated beyond measured values).

7.5 DATA SUMMARY

Results from the 2017-2019 hydrometric monitoring program are presented as follows: i) stage-discharge field measurements; ii) stage-discharge rating curves; iii) daily discharge hydrographs; and iv) hydrologic indices.

7.5.1 Stage-Discharge Measurements

A total of 73 manual discharge measurements were conducted across the hydrometric network over the 2017-2019 monitoring period. During the open water season, while automated stations were recording continuous stage data and stage were not affected by ice in the channel, measurements of both stage and discharge were made to support rating curve development. Additionally once ice formed in the channels and stations were removed to prevent freezing, winter low flow measurements were completed on each stream to obtain the baseflow conditions for the 2017/2018 and 2018/2019 winter periods (Table 7.5-1).

Table 7.5-1. Summary of 2017 to 2019 Stage-Discharge Measurements

Station	Date	Stage (m)	Discharge (m ³ /s)	Difference From Curve ¹ (%)	Method	Instrument ²
Tenas-Hydro and Tenas-Hydro B	May 18, 2017	98.223	2.502	0.47	Velocity-Area	Hach FH950
	Jun 20, 2017	98.155	1.841	1.63	Velocity-Area	Hach FH950
	Jun 20, 2017	98.155	1.790	1.19	Velocity-Area	Hach FH950
	Aug 16, 2017	97.862	0.159	1.97	Velocity-Area	Hach FH950
	Sep 21, 2017	97.908	0.283	1.85	Velocity-Area	Hach FH950
	Oct 18, 2017	97.952	0.263	42.5	Velocity-Area	Hach FH950
	Nov 28, 2017	N/A ³	0.251	N/A ³	Velocity-Area	Hach FH950
	Dec 14, 2017	N/A ³	0.153	N/A ³	Velocity-Area	Hach FH950
	Jan 17, 2018	N/A ³	0.079	N/A ³	Velocity-Area	Hach FH950
	Feb 19, 2018	N/A ³	0.056	N/A ³	Velocity-Area	Hach FH950
	Mar 20, 2018	N/A ³	0.051	N/A ³	Velocity-Area	Hach FH950
	May 2, 2018	97.646	1.999	0.10	Velocity-Area	Hach FH950
	Jun 18, 2018	97.596	1.543	1.98	Velocity-Area	Hach FH950
	Jul 23, 2018	97.416	0.367	1.42	Velocity-Area	Hach FH950
	Sep 24, 2018	97.320	0.093	7.32	Velocity-Area	Hach FH950
	Oct 15, 2018	97.349	0.145	-1.81	Velocity-Area	Hach FH950
	Nov 19, 2018	97.343	0.123	-7.83	Velocity-Area	Hach FH950
	Dec 10, 2018	N/A ³	0.065	N/A ³	Velocity-Area	Hach FH950
	Jan 22, 2019	N/A ³	0.062	N/A ³	Velocity-Area	Hach FH950
	Feb 20, 2019	N/A ³	0.039	N/A ³	Velocity-Area	Hach FH950
	Mar 12, 2019	N/A ³	0.035	N/A ³	Velocity-Area	Hach FH950
	Apr 23, 2019	97.469	0.602	-1.20	Velocity-Area	Hach FH950
	Jun 18, 2019	97.544	1.074	-1.27	Velocity-Area	Hach FH950
	Nov 4, 2019	97.467	0.573	-4.30	Velocity-Area	Hach FH950

(continued)

Table 7.5-1. Summary of 2017 to 2019 Stage-Discharge Measurements (continued)

Station	Date	Stage (m)	Discharge (m ³ /s)	Difference From Curve ¹ (%)	Method	Instrument ²
Goathorn-Hydro	May 17, 2017	98.986	5.777	2.54	Velocity-Area	Hach FH950
	Jun 19, 2017	98.868	3.871	0.15	Velocity-Area	Hach FH950
	Jun 19, 2017	98.868	3.945	1.76	Velocity-Area	Hach FH950
	Aug 1, 2017	98.591	1.221	6.32	Velocity-Area	Hach FH950
	Aug 15, 2017	98.558	0.930	1.32	Velocity-Area	Hach FH950
	Sep 21, 2017	98.599	1.022	15.0	Velocity-Area	Hach FH950
	Oct 19, 2017	98.494	0.647	6.39	Velocity-Area	Hach FH950
	Nov 20, 2017	N/A ³	0.743	N/A ³	Velocity-Area	Hach FH950
	Dec 11, 2017	N/A ³	0.525	N/A ³	Velocity-Area	Hach FH950
	Jan 16, 2018	N/A ³	0.291	N/A ³	Velocity-Area	Hach FH950
	Feb 13, 2018	N/A ³	0.247	N/A ³	Velocity-Area	Hach FH950
	Mar 19, 2018	N/A ³	0.153	N/A ³	Velocity-Area	Hach FH950
	May 1, 2018	98.883	5.337	-0.80	Velocity-Area	Hach FH950
	Jun 18, 2018	98.867	5.125	0.86	Velocity-Area	Hach FH950
	Jul 23, 2018	98.688	2.265	-4.56	Velocity-Area	Hach FH950
	Sep 24, 2018	98.463	0.510	4.35	Velocity-Area	Hach FH950
	Oct 15, 2018	98.513	0.715	-7.48	Velocity-Area	Hach FH950
	Nov 19, 2018	98.412	0.302	11.4	Velocity-Area	Hach FH950
	Dec 10, 2018	N/A ³	0.230	N/A ³	Velocity-Area	Hach FH950
	Jan 21, 2019	N/A ³	0.164	N/A ³	Velocity-Area	Hach FH950
	Feb 20, 2019	N/A ³	0.170	N/A ³	Velocity-Area	Hach FH950
	Mar 11, 2019	N/A ³	0.123	N/A ³	Velocity-Area	Hach FH950
	Apr 24, 2019	98.639	1.865	2.16	Velocity-Area	Hach FH950
	Jun 18, 2019	98.798	3.876	-0.67	Velocity-Area	Hach FH950
	Nov 4, 2019	98.610	1.407	-8.56	Velocity-Area	Hach FH950
Telkwa-Hydro	May 16, 2017	99.022	67.083	5.48	Salt Dilution	WTW 3410
	Jun 19, 2017	99.092	69.008	5.12	Salt Dilution	WTW 3410
	Aug 1, 2017	98.612	22.913	0.43	Salt Dilution	WTW 3410
	Aug 15, 2017	98.549	18.563	0.55	Salt Dilution	WTW 3410
	Sep 21, 2017	98.489	14.944	0.22	Salt Dilution	WTW 3410
	Oct 19, 2017	98.518	17.528	0.82	Salt Dilution	WTW 3410
	Nov 20, 2017	N/A ³	9.776	N/A ³	Velocity-Area	Hach FH950
	Dec 13, 2017	N/A ³	7.458	N/A ³	Velocity-Area	Hach FH950
	Jan 16, 2018	N/A ³	6.471	N/A ³	Velocity-Area	Hach FH950
	Feb 13, 2018	N/A ³	2.526	N/A ³	Velocity-Area	Hach FH950
	Mar 19, 2018	N/A ³	1.650	N/A ³	Velocity-Area	Hach FH950
	May 1, 2018	98.868	52.598	12.60	Salt Dilution	WTW 3410
	Jun 18, 2018	99.281	101.083	-1.67	Salt Dilution	WTW 3410
	Jul 23, 2018	98.735	36.618	9.31	Salt Dilution	WTW 3410
	Sep 24, 2018	98.297	5.602	-4.51	Velocity-Area	Hach FH950
	Oct 15, 2018	98.34	7.653	1.57	Velocity-Area	Hach FH950

(continued)

Table 7.5-1. Summary of 2017 to 2019 Stage-Discharge Measurements (completed)

Station	Date	Stage (m)	Discharge (m ³ /s)	Difference From Curve ¹ (%)	Method	Instrument ²
Telkwa-Hydro (cont'd)	Nov 19, 2018	98.298	5.924	0.36	Velocity-Area	Hach FH950
	Dec 10, 2018	N/A ³	4.056	N/A ³	Velocity-Area	Hach FH950
	Jan 21, 2019	N/A ³	3.223	N/A ³	Velocity-Area	Hach FH950
	Feb 20, 2019	N/A ³	3.419	N/A ³	Velocity-Area	Hach FH950
	Mar 11, 2019	N/A ³	2.433	N/A ³	Velocity-Area	Hach FH950
	Apr 23, 2019	98.601	22.270	-0.99	Salt Dilution	WTW 3410
	Jun 18, 2019	99.088	69.883	-5.21	Salt Dilution	WTW 3410
	Nov 4, 2019	98.719	38.464	20.00	Salt Dilution	WTW 3410

Notes:

¹ Difference from curve indicates how far the rating point discharge was from the established rating curve.

² <http://www.hach.com/fh950-portable-velocity-meter-with-20-cable/product?id=10379735623>:

<https://www.wtw.com/en/products/product-catalog/lab-products/multi-parameter-measurement/sensors-and-probes.html>

³ N/A Stage measurement was not conducted due to snowpack/ice affecting measurement. Not used in rating curve.

7.5.2 Stage-Discharge Rating Curves

In 2017, the relationships between stage and discharge were established for the three monitoring stations. In 2018 and 2019, stage-discharge measurements were compared to the existing rating curves to determine if the relationships were still valid. Where geomorphic changes to the channel occurred and rating points did not plot along the existing rating curve, an updated curve was developed.

For station Tenas-Hydro B, a new rating curve was developed for the new location established in 2018. At Goathorn-Hydro, a new curve was developed in 2018 as points did not plot along the 2017 curve; this is likely a result of changes that occurred in the channel geometry late in the 2017 season, when a peak flow event produced visible changes at the monitoring location. At Telkwa-Hydro, the points plotted well with the 2017 rating points; a slightly revised curve was developed using the 2017 and 2018 stage-discharge measurements. In 2019 all rating points plotted along the established 2018 rating curves and no revisions were made to the curves.

The rating equations expressing the stage-discharge relationship for each hydrometric station are summarized in Table 7.5-2. Included in the table are the number of stage-discharge field measurements used to construct the rating equations, the Root Mean Square Error (an index to describe the relative fit of the rating equation to the stage-discharge measurements) and the years of measurements included in the rating equation.

7.5.3 Discharge Hydrographs

Annual discharge hydrographs were generated for each hydrometric station for 2017-2019. Hydrographs are presented in Figures 7.5-1 through 7.5-3, and include daily precipitation data from the *Tenas Deposit* meteorological station, located in the Project deposit area (UTM 616,847 E; 6,051,099 N; Zone 9U; NAD 83). Hydrographs are presented in tabular form in Appendix 7-A. The hydrographs were generated for the entire 2017, 2018 and 2019 years, and include both observed data from the periods of operation at each station, and estimated data for periods without recorded data.

Table 7.5-2. Preliminary Stage-Discharge Rating Equations

Station	Year	Rating Equation $Q = C(h - a)^b$	Root Mean Square - Error	Number of Measurements Used	Rating Period
Tenas-Hydro	2017	$Q = 11.221(h - 97.720)^{2.191}$	1.5	5	2017
Tenas-Hydro B	2018	$Q = 13.233(h - 97.210)^{2.278}$	4.5	6	2018
	2019	$Q = 13.233(h - 97.210)^{2.278}$	4.0	9	2019
Goathorn-Hydro	2017	$Q = 9.383(h - 98.180)^{2.361}$	6.7	7	2017
	2018	$Q = 14.628(h - 98.240)^{2.265}$	6.2	6	2018
	2019	$Q = 14.628(h - 98.240)^{2.265}$	5.8	9	2018-2019
Telkwa-Hydro	2017	$Q = 52.566(h - 97.930)^{2.160}$	3.7	6	2017
	2018	$Q = 56.634(h - 97.955)^{2.113}$	5.4	12	2017-2018
	2019	$Q = 56.634(h - 97.955)^{2.113}$	5.2	14	2017-2019

Note:

Equation $Q = C(h - a)^b$: Q is the discharge (m^3/s), C and b are regression coefficients, h is the stage (m), and a is the stage at zero flow (m).

7.5.4 Discharge Estimates

Discharge estimates were, at times, required in place of measured field data. In regions where streams freeze during the winter months, it is common practice to deactivate stations to ensure pressure transducers are not damaged by ice. Additionally, recorded stage data are often unreliable when streams are frozen or partially frozen, and therefore discharge data need to be estimated.

Gaps in the flow data caused by station deactivation, malfunctioning pressure transducers, water levels dropping below the sensor elevation, or unreliable data caused by snow and ice buildup, were filled with modelled or estimated data using one, or a combination of several methods. Regression models (Maidment 1992) were used to fill data gaps during the open water season (April – November). Prior to the initiation of monitoring in 2017, regression models were used during winter period before stations were installed in May. In 2018 and 2019, both linear and logarithmic growth and decay curves (Herschly 2009) were used during winter low flow periods to interpolate between discrete manual measurements made while hydrometric stations were not active.

7.5.4.1 Tenas-Hydro and Tenas-Hydro B Discharge Estimates

In 2017, daily discharge values for the missing periods of data at Tenas-Hydro were required from January 1, 2017 to May 18, 2017 when the station was installed, and from August 18, 2017 to December 31, 2017 due to a data logger malfunction and the winter ice affected period. The station was paired with a reference station (Goathorn-Hydro), based on having comparable watershed characteristics resulting in similar hydrologic response. Concurrent periods of record from each station were used to determine the regression equations (two equations selected, one for low flow estimates and one for high flow estimates). The equations were then applied to the data from the reference station to model daily discharge for the station with missing data (Table 7.5-3).

Figure 7.5-1
Discharge Hydrograph for Tenas Hydro and Tenas-Hydro B

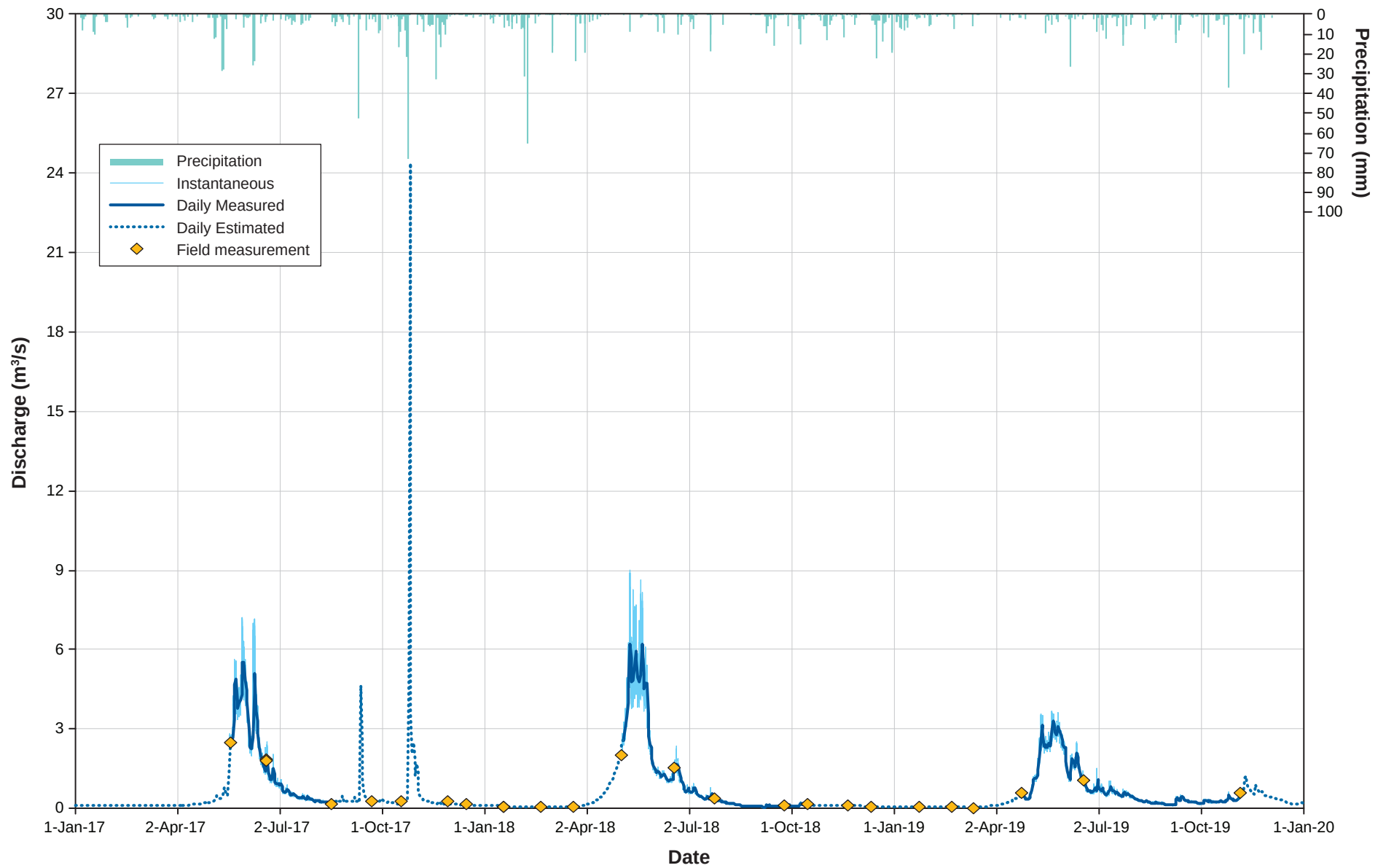


Figure 7.5-2
Discharge Hydrograph for Goathorn-Hydro

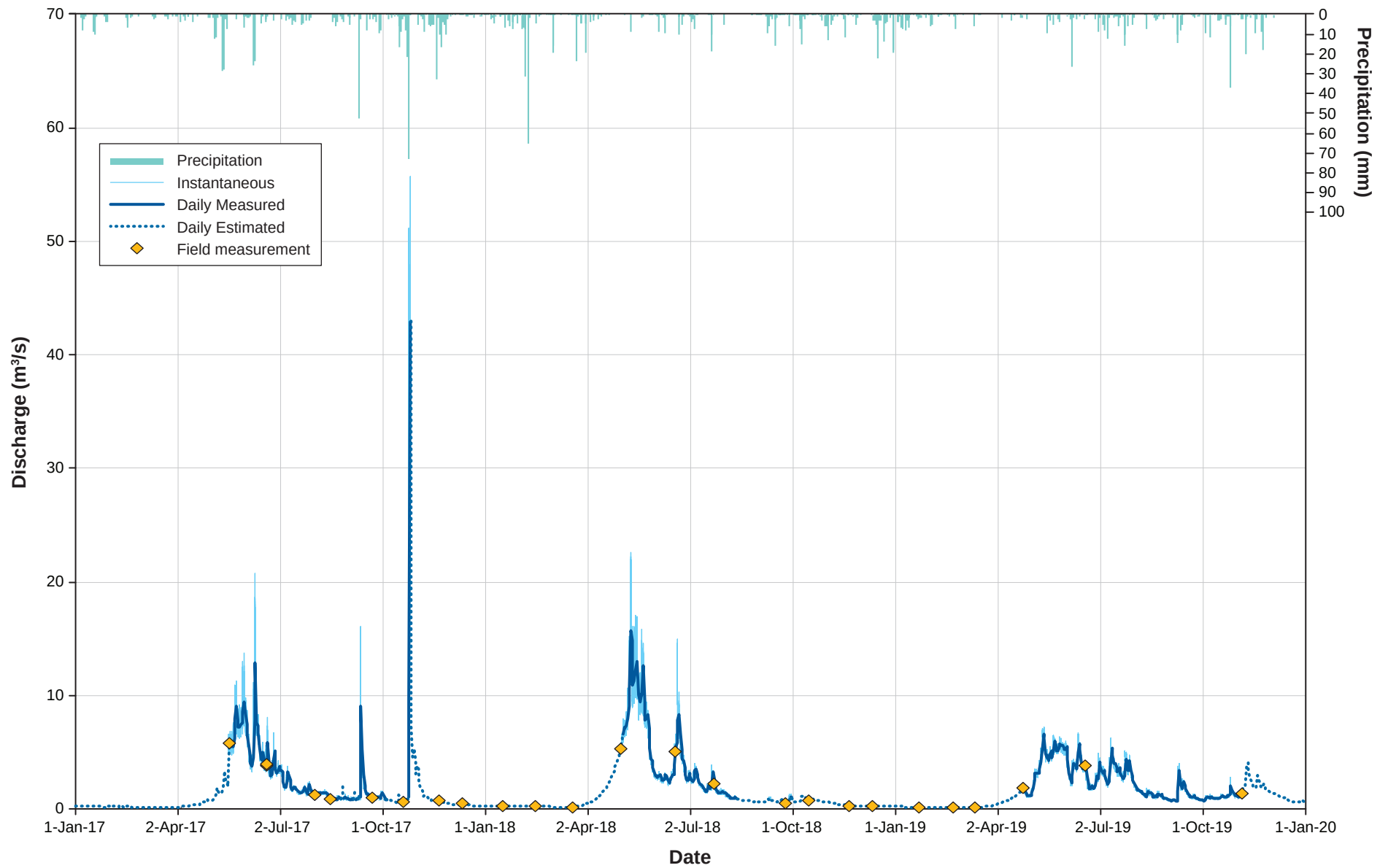


Figure 7.5-3
Discharge Hydrograph for Telkwa-Hydro

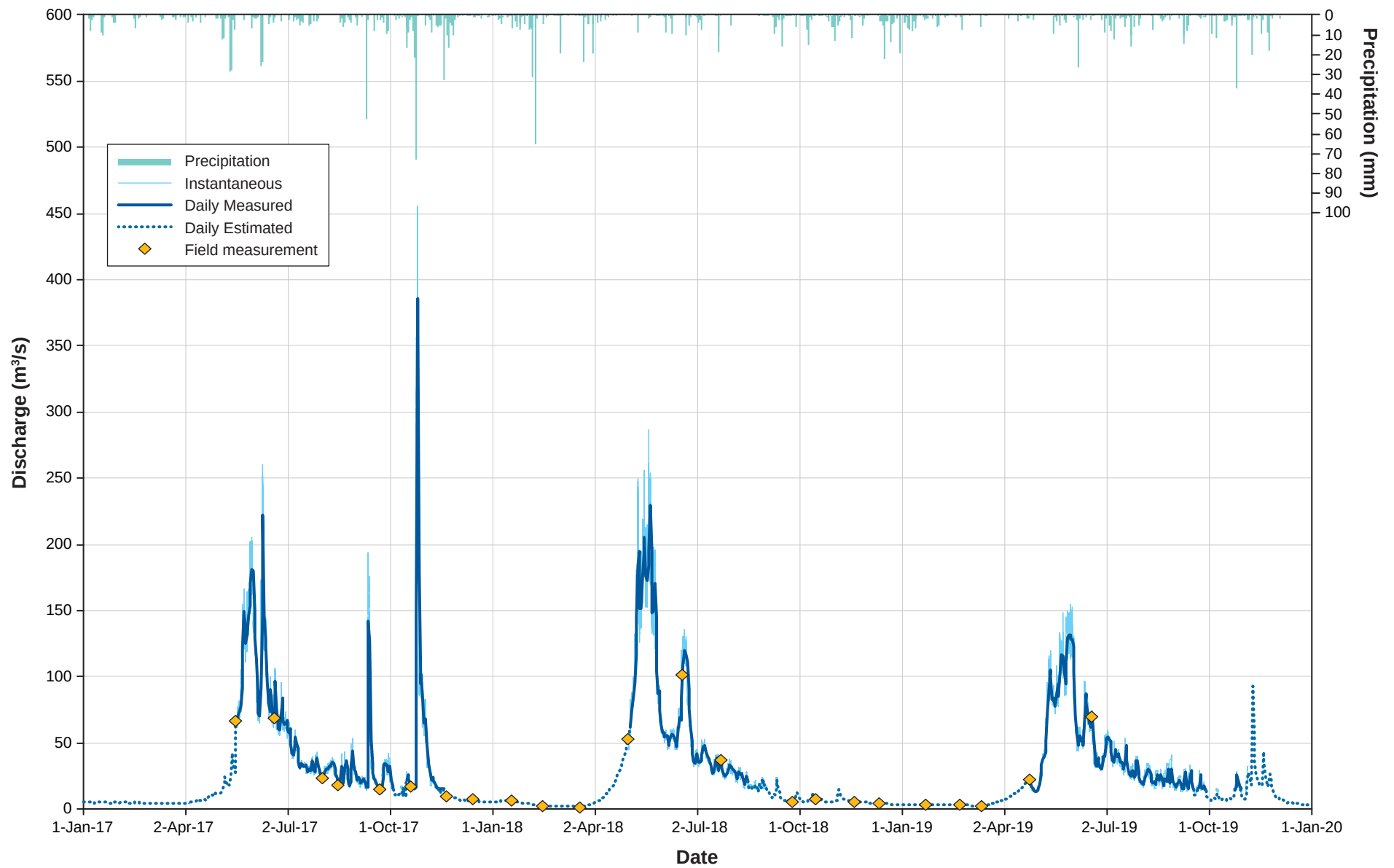


Table 7.5-3. Correlation Analysis Summary for Hydrograph Estimation in 2017

Station	Reference Station	Concurrent Period	Regression Equation	R ²	Estimated Periods
Tenas-Hydro	Goathorn-Hydro	Jul 4 – Aug 2	$Y = 0.2186(X) + 0.068$; Low Flow: $Q < 1 \text{ m}^3/\text{s}$	0.78	Jan 1 – May 18 Aug 18 – Sep 11 Sep 15 – Oct 24 Nov 3 – Dec 31
		May 19 – Aug 17	$Y = 0.5815(X) - 0.5925$; High Flow: $Q > 1 \text{ m}^3/\text{s}$	0.93	Sep 12 – Sep 14 Oct 25 – Nov 2
Goathorn-Hydro	08EE020	Sep 14 – Sep 24	$Y = 0.1065(X) + 0.0494$	0.98	Jan 1 – May 17 Aug 26 – Aug 27 Sep 6 Sep 10 Oct 6 – Oct 16 Oct 20 – Oct 23 Oct 27 – Dec 31
Telkwa-Hydro	08EE020	Jul 15 – Sep 11	$Y = 1.2648(X) + 1.8394$	0.78	Jan 1 – May 16 Sep 23 Oct 5 – Oct 11 Oct 13 Oct 15 Nov 15 Nov 19 – Dec 31

Note:

Regression Equation $Y = mX + b$: Y is the mean daily discharge (m^3/s) for the station with the missing data, m and b are regression coefficients and X is the mean daily discharge (m^3/s) for the reference station.

For 2018, daily discharge was estimated for ice affected periods prior to installation in the spring (January 1 to May 2, 2018), and after it was removed late in the fall (October 15 to December 31, 2018). Daily discharge data were estimated by means of linear growth and decay between discrete manual winter discharge measurements and logarithmic growth between the last winter measurement and when the station was re-installed for the open water season.

Similarly for 2019, daily discharge was estimated for the ice affected period prior to installation in the spring (January 1 to April 23, 2019) using the same method as described above. After the station was removed on November 4, 2019, discharge was modelled up until December 31, 2019 (with the exception of the period from November 28 to December 14) using correlation analysis with WSC station 08EE008 (*Goathorn Creek Near Telkwa*) as a reference station (see Table 7.5-5). The provisional data from WSC station 08EE008 were deemed unreliable for the period from November 28 to December 14 and therefore, discharge was estimated for that period using linear decay between the modelled data generated for the day prior and the day following the period of unreliable data.

7.5.4.2 Goathorn-Hydro Discharge Estimates

Daily discharge estimates at Goathorn-Hydro in 2017 required modelled data for the ice affected periods prior to installation and after removal of the station, as well as a few short periods when water levels dropped below the transducer elevation (see Table 7.5-3 for specific dates). The data gaps were modelled with a correlation analysis using WSC station 08EE020 (*Telkwa River Below Tsai Creek*) on the Telkwa River as a reference station (Table 7.5-3).

For 2018, daily discharge was estimated for ice affected periods prior to installation in the spring (January 1 to May 2, 2018) and after it was removed late in the fall (October 15 to December 31, 2018). Daily discharge data were estimated by means of linear growth and decay between discrete manual winter discharge measurements and logarithmic growth between the last winter measurement and when the station was re-installed for the open water season. Additionally, a few periods during the operational period when water level dropped below the transducer elevation (see Table 7.5-4 for specific dates) were modelled with a correlation analysis using the station Tenas-Hydro B as a reference station (Table 7.5-4).

Table 7.5-4. Correlation Analysis Summary for Hydrograph Estimation in 2018

Station	Reference Station	Concurrent Period	Regression Equation	R ²	Estimated Periods
Goathorn-Hydro	Tenas-Hydro B	Jul 1 – Aug 12	$Y = 3.9107(X) + 0.367$	0.93	Aug 13 – Sep 28 Oct 1 – Oct 15
Telkwa-Hydro	08EE020	Jul 28 – Aug 12	$Y = 1.1242(X) - 0.1$	0.92	Aug 17 – Aug 22 Aug 24 – Aug 26 Aug 28 Aug 31 – Sep 10

Note:

Regression Equation $Y = mX + b$: Y is the mean daily discharge (m^3/s) for the station with the missing data, m and b are regression coefficients and X is the mean daily discharge (m^3/s) for the reference station.

Similarly for 2019, daily discharge was estimated for the ice affected period prior to installation in the spring (January 1 to April 24, 2019) using the same method as described above. After the station was removed on November 4, 2019 discharge was modelled up until December 31, 2019 (with the exception of the period from November 28 to December 14) with a correlation analysis using WSC station 08EE008 (*Goathorn Creek Near Telkwa*) as a reference station (Table 7.5-5). The provisional data from WSC station 08EE008 were deemed unreliable for the period from November 28 to December 14 and therefore, discharge was estimated for that period using a linear decay between the modelled data generated for the day prior and the day following the period of unreliable data.

7.5.4.3 Telkwa-Hydro Discharge Estimates

In 2017, daily discharge estimates at Telkwa-Hydro required modelled data for the ice affected periods prior to installation and after removal of the station, as well as a few short periods when water level dropped below the transducer elevation (see Table 7.5-3 for specific dates). The data gaps were modelled with a correlation analysis using WSC station 08EE020 (*Telkwa River Below Tsai Creek*) on the Telkwa River as a reference station (Table 7.5-3).

Table 7.5-5. Correlation Analysis Summary for Hydrograph Estimation in 2019

Station	Reference Station	Concurrent Period	Regression Equation	R ²	Estimated Periods
Tenas-Hydro B	08EE008	Oct 3 - Nov 4	$Y = 0.296(X) - 0.0215$	0.87	Nov 5 - Nov 27 Dec 15 - Dec 31
Goathorn-Hydro	08EE008	Apr 26 - Nov 4	$Y = 0.9923(X) - 0.0552$	1.00	Nov 5 - Nov 27 Dec 15 - Dec 31
Telkwa-Hydro	08EE020	Jul 1 - Sep 17	$Y = 1.5111(X) - 2.3656$	0.90	Sep 18 - Sep 20 Sep 29 - Oct 23 Oct 30 - Dec 31

Note:

Regression Equation $Y = mX + b$: Y is the mean daily discharge (m³/s) for the station with the missing data, m and b are regression coefficients and X is the mean daily discharge (m³/s) for the reference station.

For 2018, daily discharge was estimated for ice affected periods prior to installation in the spring (January 1 to May 2, 2018) and after it was removed late in the fall (October 15 to December 31, 2018). Daily discharge data were estimated by means of linear growth and decay between discrete manual winter discharge measurements, and logarithmic growth between the last winter measurement and when the station was re-installed for the open water season. Additionally, a few periods during the operational period when water level dropped below the transducer elevation (see Table 7.5-4 for specific dates) were modelled with a correlation analysis using WSC station 08EE020 (*Telkwa River Below Tsai Creek*) on the Telkwa River as a reference station (Table 7.5-4).

Similarly for 2019, daily discharge was estimated for the ice affected period prior to installation in the spring (January 1 to April 23, 2019) using the same method as described above. After the station was removed on November 4, 2019 discharge was modelled up until December 31, 2019 with a correlation analysis using WSC station 08EE020 (*Telkwa River Below Tsai Creek*) as a reference station (Table 7.5-5). Additionally, a few periods during the operational period when water level dropped below the transducer elevation (see Table 7.5-5 for specific dates) were also modelled using WSC station 08EE020 (*Telkwa River Below Tsai Creek*) on the Telkwa River as a reference station (Table 7.5-5).

7.5.5 Annual Runoff and Monthly Runoff Distribution and Unit Discharge

Annual and monthly runoff values and unit discharge for 2017-2019 are presented in Table 7.5-6. Across the monitoring network, annual runoff and unit discharge was greatest in 2017 and lowest in 2019. Annual runoff in 2017 for the three monitored watersheds ranged from approximately 450 mm at Tenas and Goathorn stations to 981 mm at Telkwa-Hydro. Unit discharge in 2017 ranged from approximately 170 to 370 L/s/km² at Tenas and Goathorn stations, and at Telkwa-Hydro, respectively. In 2018, annual runoff ranged from 399 mm at Tenas-Hydro B to 864 mm at Telkwa-Hydro. Unit discharge ranged from 150 L/s/km² at Tenas-Hydro B to 326 L/s/km² at Telkwa-Hydro. In 2019, annual runoff ranged from 349 mm at Tenas-Hydro B to 769 mm at Telkwa-Hydro. Unit discharge ranged from 132 L/s/km² at Tenas-Hydro B to 291 L/s/km² at Telkwa-Hydro.

Table 7.5-6. Monthly Runoff Distribution and Unit Discharge

Station	Runoff (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tenas-Hydro (2017)	7	6	6	9	117	122	29	15	30	85	19	8	452
Tenas-Hydro B (2018)	5	3	4	37	228	65	26	7	5	7	7	4	399
Tenas-Hydro B (2019)	4	2	3	17	124	69	35	15	14	16	35	15	349
Goathorn-Hydro (2017)	5	4	4	9	96	109	44	25	33	98	23	7	457
Goathorn-Hydro (2018)	6	5	5	42	191	79	47	19	16	18	8	5	442
Goathorn-Hydro (2019)	4	3	5	22	98	72	75	30	27	24	45	20	426
Telkwa-Hydro (2017)	14	12	12	20	202	252	104	78	85	134	49	17	981
Telkwa-Hydro (2018)	16	7	6	51	376	177	96	59	28	18	18	11	864
Telkwa-Hydro (2019)	9	8	10	38	225	158	103	65	47	28	64	14	769
Station	Unit Discharge (L/s/km ²)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tenas-Hydro (2017)	2.5	2.4	2.2	3.4	43.6	46.9	10.9	5.6	11.7	31.7	7.3	2.9	171.1
Tenas-Hydro B (2018)	1.9	1.3	1.4	14.3	85.2	25.1	9.6	2.8	1.95	2.8	2.5	1.5	150.4
Tenas-Hydro B (2019)	1.3	0.9	1.2	6.4	46.3	26.8	13.1	5.4	5.3	6.1	13.4	5.7	131.9
Goathorn-Hydro (2017)	1.9	1.7	1.4	3.4	35.9	41.9	16.5	9.3	12.8	36.8	8.7	2.7	173.0
Goathorn-Hydro (2018)	2.3	2.0	1.8	16.2	71.4	30.4	17.7	7.2	6.1	6.6	3.2	1.9	166.9
Goathorn-Hydro (2019)	1.5	1.4	1.7	8.5	36.7	27.7	28.2	11.0	10.5	9.1	17.4	7.6	161.3
Telkwa-Hydro (2017)	5.3	5.1	4.6	7.6	75.3	97.1	38.9	29.3	32.8	50.1	19.0	6.5	371.7
Telkwa-Hydro (2018)	5.9	2.9	2.4	19.6	140.2	68.4	35.9	22.2	10.7	6.7	7.1	4.2	326.1
Telkwa-Hydro (2019)	3.5	3.4	3.9	14.5	84.0	60.8	38.5	24.1	18.3	10.5	24.6	5.1	291.1

The higher annual runoff values observed for the Telkwa River compared to Goathorn and Tenas creeks are supported by regional streamflow data presented in *Streamflow in the Skeena Region* (Obedkoff 2001). Although the Project monitoring stations are in relative close proximity to each other, the Telkwa River Watershed extends farther west into the Coast Mountain range where, there is typically greater precipitation (deeper winter snowpack and summer rainfall) as well as a small glacial

influence. Obedkoff (2001) delineates regional streamflow by *Hydrologic Zones* and *Hydrologic Subzones* which relate to the hydrologic characteristics of the areas. The Telkwa River watershed lies predominantly in *Zone 8, Subzone U* whereas, Goathorn Creek and Tenas Creek watersheds are in *Zone 8 Subzone m*. Normal annual runoff from regional data are reported at 1,231 mm for Telkwa Below Tsai Creek, and 381 mm for Goathorn Creek (Obedkoff 2001).

The majority of runoff in 2017 occurred in May and June as a result of snowmelt, and in October due to a large storm event near the end of the month (Figure 7.5-4). In 2018, runoff was predominantly driven by snowmelt, with over 40% occurring in May at all stations and very little during the late summer and fall period. (Figure 7.5-5). In 2019, runoff was again predominantly driven by snow melt, but distributed more evenly across May, June and July relative to what was observed in 2018 (Figure 7.5-6). Fall rains in November of 2019 also produced increased streamflow, accounting for approximately 10% of the annual runoff in the monitored watersheds.

7.5.6 Mean Annual Discharge

Mean annual discharge (MAD) for 2017, 2018 and 2019 is presented in Table 7.5-7. MAD increased with watershed area for the three monitoring locations, ranging from 0.68 m³/s at Tenas-Hydro to 29.98 m³/s at Telkwa-Hydro in 2017, from 0.59 m³/s at Tenas-Hydro B to 26.40 m³/s at Telkwa-Hydro in 2018, and from 0.52 m³/s at Tenas-Hydro B to 23.57 m³/s at Telkwa-Hydro in 2019. Across the three years of monitoring MAD was highest in 2017 and lowest in 2019 for each of the monitored streams.

Table 7.5-7. Mean Annual Discharge

Station	Watershed Area (km ²)	Mean Annual Discharge (m ³ /s)		
		2017	2018	2019
Tenas-Hydro and Tenas-Hydro B	47	0.68	0.59	0.52
Goathorn-Hydro	122	1.76	1.70	1.64
Telkwa-Hydro	967	29.98	26.40	23.57

7.5.7 Annual Peak Flows

Annual peak flows for 2017-2019 are present in Table 7.5-8. For 2017, instantaneous and daily peak flows were determined for the Goathorn and Telkwa monitoring stations. However, at the Tenas Creek station, only estimated daily peak flows are available as the data gap caused by the data logger malfunction occurred during the October peak event. Estimated discharges through correlation analysis were completed at a daily time step. In 2017, daily peak flows ranged from 24.83 m³/s at Tenas-Hydro to 385.51 m³/s at Telkwa-Hydro. Annual peak flows were driven by a high intensity, short duration precipitation event at the end of October. The daily rainfall total that resulted in the annual peak flows was the highest on record (74 mm daily total) at the regional meteorological station in Smithers (Smithers A) since data collection began in 1942 (ECCC 2018). In 2018, annual peak flows occurred in May and ranged from 6.22 m³/s at Tenas-Hydro B to 230.12 m³/s at Telkwa-Hydro. In 2019, peak flows were lower than both of the previous monitoring years and the ranged from 3.30 m³/s at Tenas-Hydro B to 131.47 m³/s at Telkwa-Hydro.

Figure 7.5-4
Monthly Runoff (%) Distribution 2017

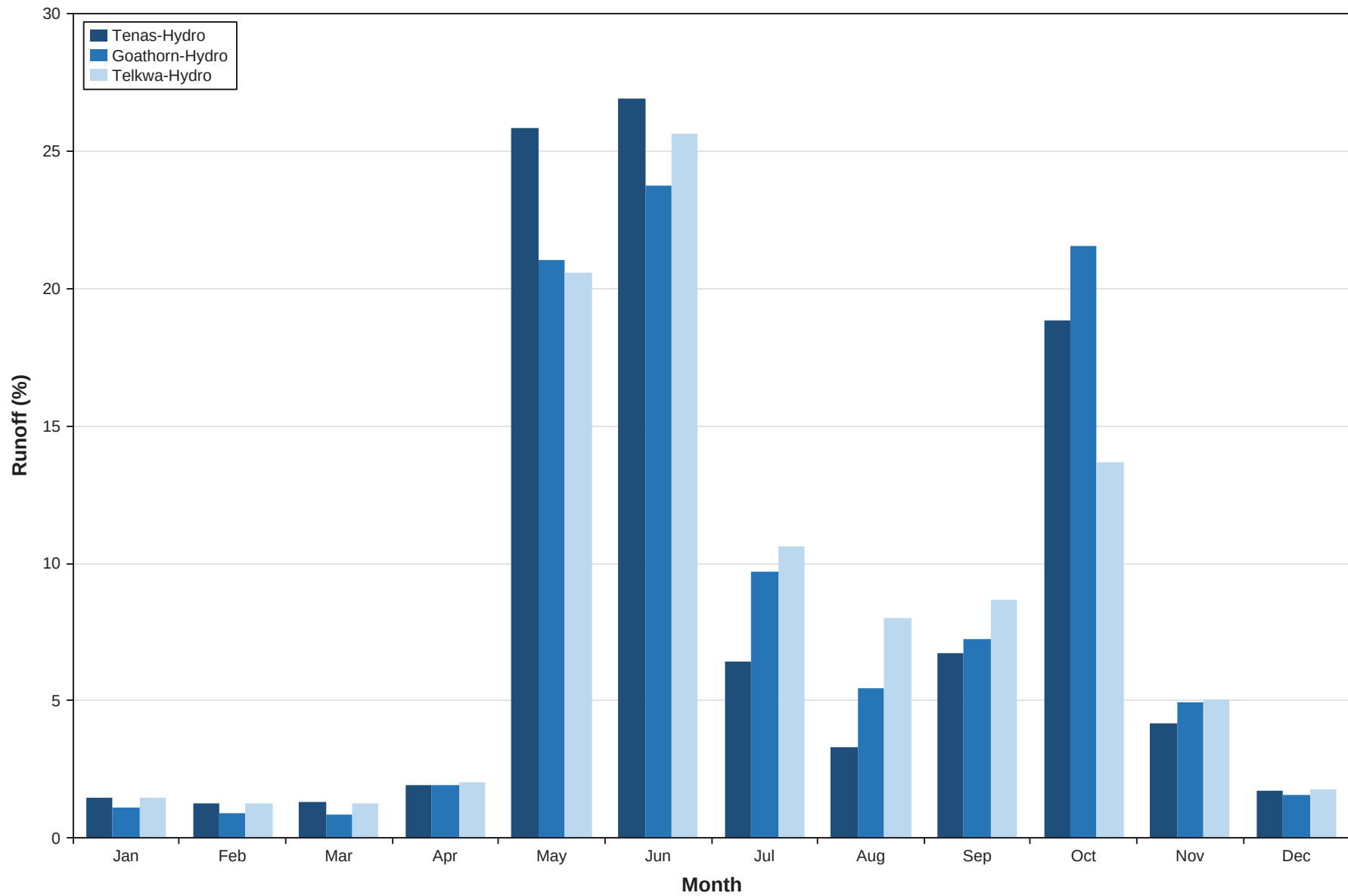


Figure 7.5-5
Monthly Runoff (%) Distribution 2018

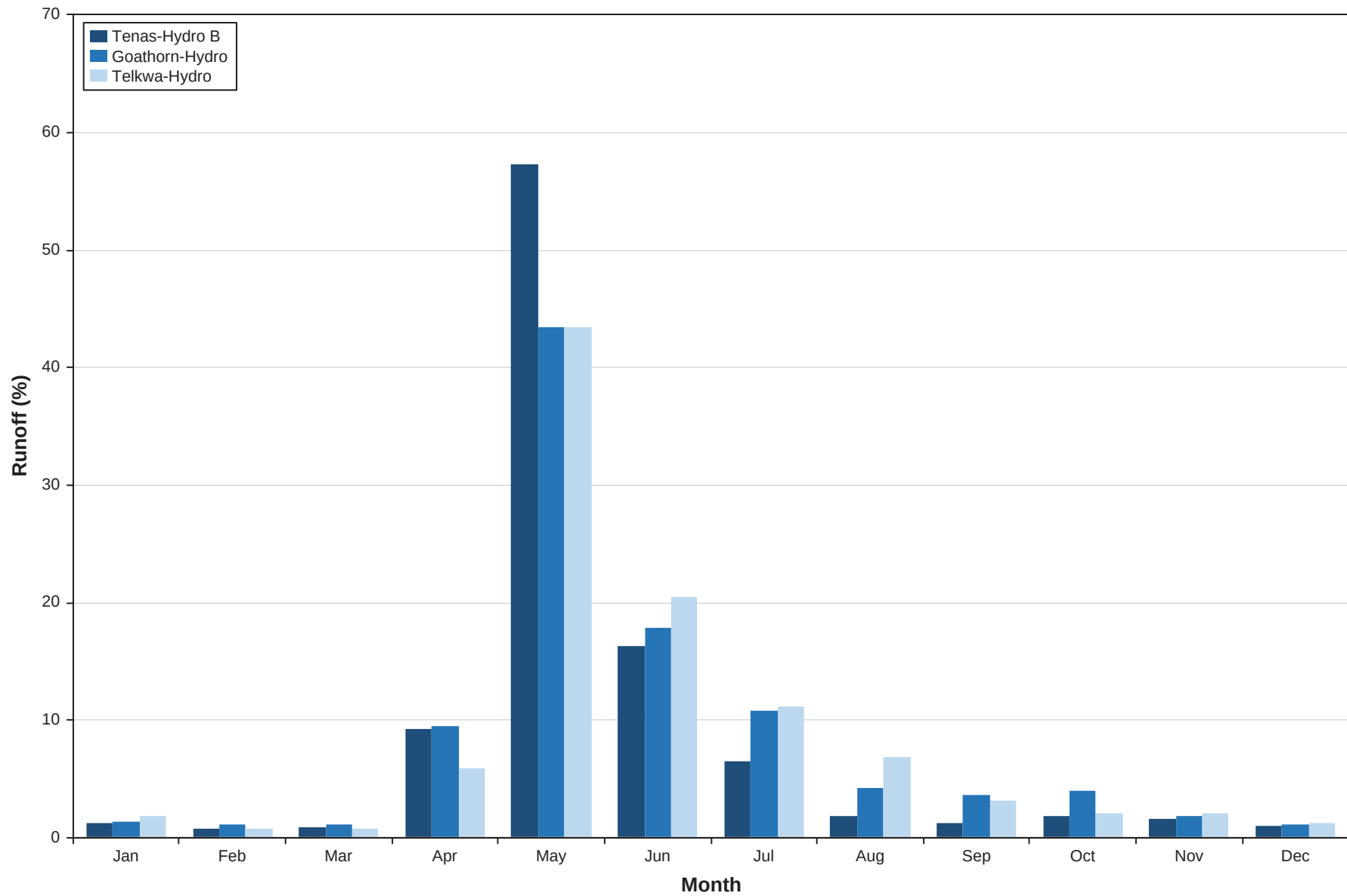


Figure 7.5-6
Monthly Runoff (%) Distribution 2019

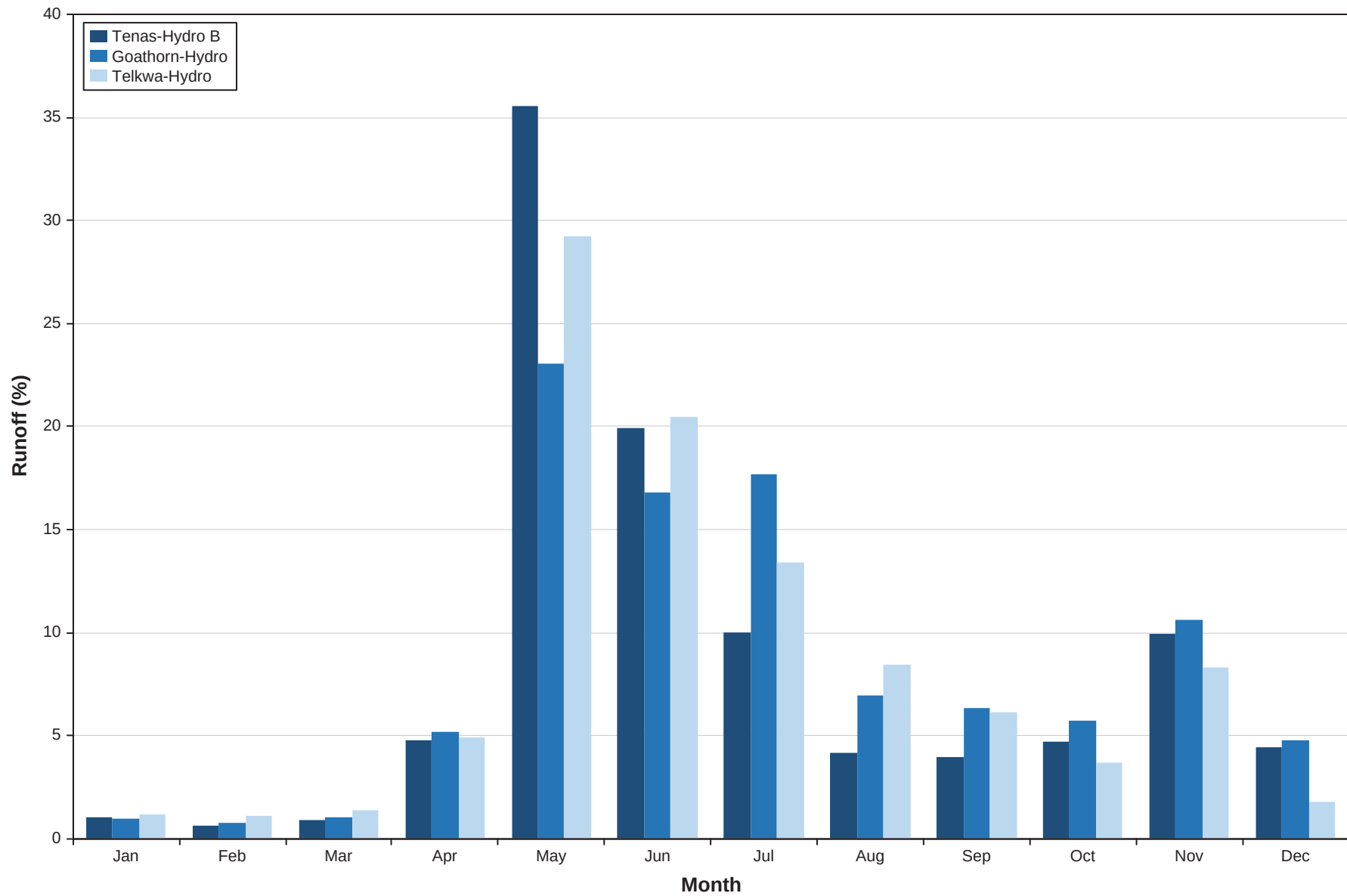


Table 7.5-8. Instantaneous and Daily Peak Flow

Station	Timing	Peak Flow (m ³ /s)					
		2017	Date	2018	Date	2019	Date
Tenas-Hydro and Tenas-Hydro B	Instantaneous	N/A ¹	N/A	9.02	May-9	3.69	May-20
	Daily	24.38 ¹	Oct-26	6.22	May-20	3.30	May-22
Goathorn-Hydro	Instantaneous	55.72	Oct-25	22.57	May-9	7.19	May-11
	Daily	42.94	Oct-25	15.65	May-9	6.66	May-12
Telkwa-Hydro	Instantaneous	455.71	Oct-25	286.85	May-20	154.51	May-29
	Daily	385.51	Oct-25	230.12	May-20	131.47	May-29

Note:

¹ Instantaneous data not available during the October 2017 peak flow event, as it eroded the bank and washed away the hydrometric monitoring station. Data was estimated at a daily time step for the same period.

7.5.8 Low Flows

Low flows were calculated using a 7-day average from the daily discharge. Summer (June through September) and annual low flows are presented in Table 7.5-9. Summer low flows in 2017 ranged from 0.20 m³/s at Tenas-Hydro to 17.19 m³/s at Telkwa-Hydro, and occurred between mid-August and late September. In 2018, summer low flows were lower than in 2017, ranging from 0.07 m³/s at Tenas-Hydro B to 6.01 m³/s at Telkwa-Hydro, and occurred in September. Similarly in 2019, summer low flows occurred in September and were lower than in 2017 but substantially higher than in 2018, ranging from 0.13 m³/s at Tenas-Hydro B to 14.36 m³/s at Telkwa-Hydro.

Table 7.5-9. Summer and Annual 7-Day Low Flows

Station	Timing	7-Day Low Flow (m ³ /s)					
		2017	Date	2018	Date	2019	Date
Tenas-Hydro and Tenas-Hydro B	Summer	0.20	Aug-16	0.07	Sep-5	0.13	Sep-8
	Annual	0.10	Mar-25	0.05	Mar-20	0.04	Mar-12
Goathorn-Hydro	Summer	0.87	Sep-6	0.62	Sep-6	0.76	Sep-8
	Annual	0.16	Mar-25	0.16	Mar-20	0.13	Mar-12
Telkwa-Hydro	Summer	17.19	Sep-22	6.01	Sep-23	14.36	Sep-30
	Annual	4.38	Mar-25	1.72	Mar-20	2.59	Mar-13

Annual low flows in 2017, 2018 and 2019 occurred in mid to late March when ground water discharge would typically be at its lowest, prior to the start of the open water season. Annual low flows in 2017 ranged from 0.10 m³/s at Tenas-Hydro to 4.38 m³/s at Telkwa-Hydro. In 2018, annual low flows ranged from 0.05 m³/s at Tenas-Hydro B to 1.72 m³/s at Telkwa-Hydro. In 2019, annual low flows ranged from 0.04 m³/s at Tenas-Hydro B to 2.59 m³/s at Telkwa-Hydro.

7.5.9 Summary

Streamflow patterns in observed over the 2017-2019 monitoring period were typical of the regional stream flow regime, with the majority of runoff resulting from snowmelt during the spring and early summer. The freshet was generally followed by a period of low flows through late summer into fall. In 2017, precipitation-driven peak flows occurred in late fall, whereas in 2018 and 2019, there was a lack of any substantial fall precipitation peak flow events. Flows receded to annual low flow in late winter, when precipitation generally falls as snow and is stored in the snowpack until the onset of freshet.

Across the monitoring network, 2017 produced greater runoff than 2018 and again it was lower in 2019. In 2017, freshet occurred in May and June with approximately equal runoff in both months (ranging from 21% to 27% per month); additionally, precipitation in October generated substantial runoff ranging from 14% to 22% of the annual runoff. In 2018, the majority of runoff was generated in May, ranging from 43% to 57% of the annual runoff. In 2019, the majority of runoff also occurred in May and June, ranging from 17% to 36% per month; there was also moderate runoff generated in November, ranging from 8% to 11% of the annual runoff. In contrast to 2017 and 2019, there was very little runoff produced in the 2018 late summer and fall period, after the freshet driven flows receded.

Annual peak flows in 2017 resulted from a high intensity rain event that occurred in late October. The October rain event was the largest daily rainfall event on record at the regional Smithers A meteorological station (see section 2.5 for details). The resulting peak flows were of short duration but very high, ranging approximately 45% to 80% higher than the observed freshet driven peak flows at the same locations. In 2018, peak flows occurred in May driven by snowmelt, and were much lower than those observed in 2017. In 2019, peak flows were the lowest of the monitored years and were driven by freshet occurring in mid to late May.

Summer low flows in 2017 were observed in August for Tenas Creek and in September at Goathorn Creek and the Telkwa River. In 2018, summer low flows were much lower than 2017. The observed low flow in 2018 were typical for the region, which experienced drought conditions with very dry to extremely dry levels from late July through October (BC Gov 2018). In 2019, summer low flows occurred in September and were lower than those observed in 2017, but well above the extreme low flows recorded in 2018. Annual low flows occurred in mid to late March throughout the Project area in all three years of monitoring.

8. SURFACE WATER QUALITY

This chapter presents the methods and results of the surface water quality baseline monitoring program. The purpose of the 2017 to 2019 water quality program was to collect Project-specific baseline surface water chemistry data. An understanding of the aquatic characteristics within and downstream of the Project area will contribute to engineering analysis and the design of water management features; support future development of water quality and water balance models, effects assessments, management plans, and closure planning; support permitting; support fisheries monitoring programs; and monitor changes in the local environment.

The objectives of the 2017 to 2019 program were to:

- collect water quality samples at select project locations; and
- upload project data to the British Columbia Environmental Monitoring System (EMS).

8.1 STUDY AREA

The study area for surface water quality included sites along the Telkwa and Bulkley rivers, as well sampling sites upstream and downstream of proposed Project infrastructure and activities, and focused on the three primary creeks that flow from the Tenas Project area - Tenas Creek, Goathorn Creek, and Four Creek. These creeks flow northward and into The Telkwa River. Four Creek lies east of the proposed Tenas Project, and enters Goathorn Creek before Tenas Creek. Tenas Creek is west of the proposed Tenas Project, and its confluence with Goathorn Creek is approximately 1.25 km upstream of where Goathorn Creek merges with the Telkwa River. The Telkwa River flows northeast for approximately 6 km before it empties into the Bulkley River. The Bulkley River is a tributary of the Skeena River, which empties into the Pacific Ocean.

The study area also included Helps Creek, which flows into the Bulkley River, southeast of the confluence of the Tenas and Bulkley rivers. The proposed Tenas bypass road originates from the Tenas Project area, and crosses Helps Creek before it reaches the proposed rail infrastructure.

The main objectives of the 2017 to 2019 surface water quality baseline program were to:

- characterize the spatial and temporal variability of surface water quality in creeks and rivers near the Project area; and
- establish surface water quality sites upstream and downstream of the proposed Project infrastructure to provide baseline data to support permitting and future monitoring programs.

Several surface water quality sites on creeks and rivers near proposed Project infrastructure were sampled from May 2017 to November 2019 (Table 8.1-1; Figure 8.1-1). Sampling sites were established upstream and downstream (i.e., near-, mid-, and far-field) of the proposed Project infrastructure. Samples were collected monthly. Additionally in 2018, weekly samples were collected at several sites during periods of elevated flow when water chemistry tends to be more variable (i.e., 5-in-30), including freshet (May/June) and fall rains (September/October).

Table 8.1-1. 2017 to 2019 Water Quality Sampling Sites and Historical Sites, Tenas Project

Waterbody	Site*	Easting (m)	Northing (m)	Sampling Period	Description
Tenas Creek	WQS01	615171	6050438	May 2017 to November 2019	Upstream reference for proposed Project infrastructure
	WQS02	616914	6053490	May 2017 to August 2019	Near-field downstream of deposits and proposed associated Project infrastructure
	WQS04	620499	6057020	May 2017 to September 2017	Mid-field downstream of deposits and proposed associated Project infrastructure
	WQS04B	620676	6057950	October 2017 to November 2019	Mid-field downstream of deposits and proposed associated Project infrastructure
	E242646	-	-	2006 to 2008	Unknown point in Tenas Creek (EMS UTM not in stream)
Four Creek	WQS03	619235	6049989	May 2017 to November 2019	Near-field upstream site of proposed Project infrastructure
	WQS03-DS	620034	6054076	May 2018 to November 2019	Immediately upstream of proposed bypass road, potentially influenced by historical workings
	WQS18	620071	6054130	October 2019	Downstream of mine hydrology and water quality influences (immediately downstream of proposed bypass road); sampled once.
Goathorn Creek	WQS15	620942	6047172	September 2018	Far upstream site sampled once. Sampled at the request of the Office of the Wet'suwet'en.
	WQS14	620476	6047262	September 2018	Far upstream site sampled once. Sampled at the request of the Office of the Wet'suwet'en.
	WQS13	621664	6051778	September 2018 to November 2019	Upstream reference site on Goathorn Creek. Upstream of historical workings
	WQS06-US	620587	6053711	May 2018 to October 2019	Upstream of WQS06 and of confluence with Four Creek; Potentially influenced by historical workings
	WQS07	620489	6053814	October 2019	Downstream of mine hydrology and water quality influences but upstream of proposed bypass road. Sampled once.
	WQS06	621100	6057441	May 2017 to November 2019	Downstream of project area, above confluence with Tenas Creek
	E242647	-	-	2004 and 2006 to 2008	Unknown point on Goathorn Creek (EMS UTM not in stream); description states above Tenas Creek confluence
	WQS05	620615	6058133	May 2017 to March 2019	Mid-field downstream of confluence with Tenas Creek
Helps Creek	WQS16	625906	6055851	September 2018 to October 2019	Upstream of proposed Tenas bypass road
	WQS17	625801	6055979	September 2018 to November 2019	Downstream of proposed Tenas bypass road
Telkwa River	WQS08	617964	6057860	May 2017 to November 2019	Upstream reference; above confluence with Goathorn Creek
	WQS09	621394	6058998	May 2017 to November 2019	Mid-field downstream of confluence with Goathorn Creek
	WQS10	624269	6061725	May 2017 to March 2019	Far-field downstream before confluence with the Bulkley River
	400187	625481	6062592	1974, 1975, 1985 to 1988, and 2006 to 2009	At mouth of river at village

(continued)

Table 8.1-1. 2017 to 2019 Water Quality Sampling Sites and Historical Sites, Tenas Project (completed)

Waterbody	Site	Easting (m)	Northing (m)	Sampling Period	Description
Bulkley River	WQS11-US	630472	6056723	November and December 2017 and May 2018 to November 2019	Upstream reference for proposed rail infrastructure
	WQS11	629601	6059221	May to December 2017 and June 2018 to November 2019	Near-field downstream of proposed rail infrastructure
	E246125	625477	6062748	2001 and 2002	Immediately downstream of Telkwa River confluence, likely not fully mixed; water intake for Telkwa
	WQS12	625021	6063831	May to December 2017 and March 2018 to November 2019	Mid-field downstream of proposed rail loadout and confluence with the Telkwa River
	400434	618410	6074024	1974, 1975, 1987 to 1992, and 2012	Far-field downstream of Project; downstream of Smithers and upstream of sewage discharge
	400435	617870	6074979	1974, 1975, 1987 to 1992, 2007, and 2012	Far-field downstream of Project; downstream of Smithers and downstream of sewage discharge

Notes:

WQS04 was moved approximately 1 km downstream to WQS04B for improved site access and safety.

WQS11-US was added in November 2017 to provide an upstream sampling site for the updated footprint of the rail loadout.

WQS03-DS was added in May 2018 to provide downstream monitoring site for proposed Project infrastructure on Four Creek.

WQS06-US was added in September 2018 to provide an upstream site on Goathorn Creek.

WQS13 was added in September 2018 to provide an upstream reference site on Goathorn Creek.

WQS16 and WQS17 were added in September 2018 to monitor Helps Creek upstream and downstream of the proposed Tenas bypass road.

WQS07 was added in October 2019 to monitor Goathorn Creek upstream of the proposed haul road (stakeholder input request).

WQS18 was added in October 2019 to monitor Four Creek immediately downstream of the proposed haul road (stakeholder input request).

Samples were not collected in January to April 2018 from the Bulkley River due to safety concerns.

Samples were collected by ERM with a few exceptions: WQS01, WQS02, WQS05, WQS04B, WQS08, WQS09, WQS11-US and WQS12 in August 2019 and WQS03-DS, WQS06-US, WQS07, WQS16, WQS17 and WQS18 in October 2019 were collected by Hemmera.

In October 2017, the mid-field downstream site on Tenas Creek (WQS04) was shifted downstream approximately 1 km (WQS04B) to allow for better and safer site access. In November 2017, a new site was established on the Bulkley River (WQS11-US) to provide a suitable upstream reference site for the proposed rail infrastructure. In May 2018, a downstream site on Four Creek (WQS03-DS) was added to capture the influence of historical mine workings. Two sites were added on Goathorn Creek in 2018 to capture the influence of historical mine workings: WQS13 (September 2018) and WQS06-US (May 2018). In addition, two sites were added on Helps Creek in September 2018, upstream and downstream of the proposed Tenas bypass road crossing (WQS16 and WQS17, respectively). In October 2019, WQS07 and WQS18 were added to monitor Goathorn Creek and Four Creek immediately upstream and downstream of the proposed bypass road, respectively. Samples were not collected from the Bulkley River between January and April 2018 due to substantial ice cover and unsafe sampling conditions. Additionally, no samples were taken during May to July, and September 2019. The sampling frequency of the 2017 to 2019 surface water quality baseline program is summarised in Table 8.1-2. In addition, the 2017 to 2019 surface water quality data set has been supplemented with publically available data (Table 8.1-2). Suitable public data was included in this report to improve the characterization of the study area. Further, there is now additional data available for the Bulkley River in Smithers (EMS E285129) that can supplement the Project's water quality baseline.

8.2 REGULATORY AND POLICY FRAMEWORK

This section provides an overview of the relevant provincial and federal statutory framework, guidance documents, and policies that apply to surface water quality. All provincial Environmental Assessment (EA) and Joint MA/EMA applications must include a detailed summary of water quality prior to project development, as water quality is a key component of the biological and physical environment which will strongly influence its suitability for aquatic life, wildlife, and human use and consumption.

At the provincial level, the *Environmental Management Act* (EMA; 2003) requires authorization of specified discharges to the environment, including the aquatic receiving environment. The legislation provides enforcement options to protect human health and the quality of water, land, and air in BC. Mines require authorization under the EMA to discharge mine effluent to receiving waters, and are required to register effluent (or have it included in the mine effluent permit) from sewage treatment facilities. Under the EMA, mines are also required to comply with requirements for the production, storage, treatment, or discharge of prescribed quantities of hazardous waste. The *BC Mines Act* (MA; 1996) and its associated Health, Safety and Reclamation Code for Mines in BC require mines to have programs for the environmental protection of land and watercourses throughout mine life, including plans for the prevention of erosion and sediment release. Watercourses are required to be reclaimed, and the Ministry of Energy, Mines and Petroleum Resources (BC MEMPR) has the authority to require monitoring and/or remediation programs to protect watercourses and water quality. Further, the British Columbia Ministry of Environment and Climate Change Strategy (BC ENV, formerly Ministry of Environment [BC MOE]) provides specific guidance for baseline programs (BC MOE 2016), field sampling methodologies (BC MOE 2013), and laboratory analyses (BC MOE 2015). There are surface water quality guidelines for the protection of aquatic life in BC (BC ENV 2019 and 2020), including some that are based on presently approved and working Canadian Council of Ministers of the Environment (CCME) guidelines (CCME 2014). The Bulkley River also has provisional water quality objectives (BC MOE 1986).

Figure 8.1-1
Surface Water, Sediment Quality, and Aquatic Resources Sampling Sites, Tenas Project

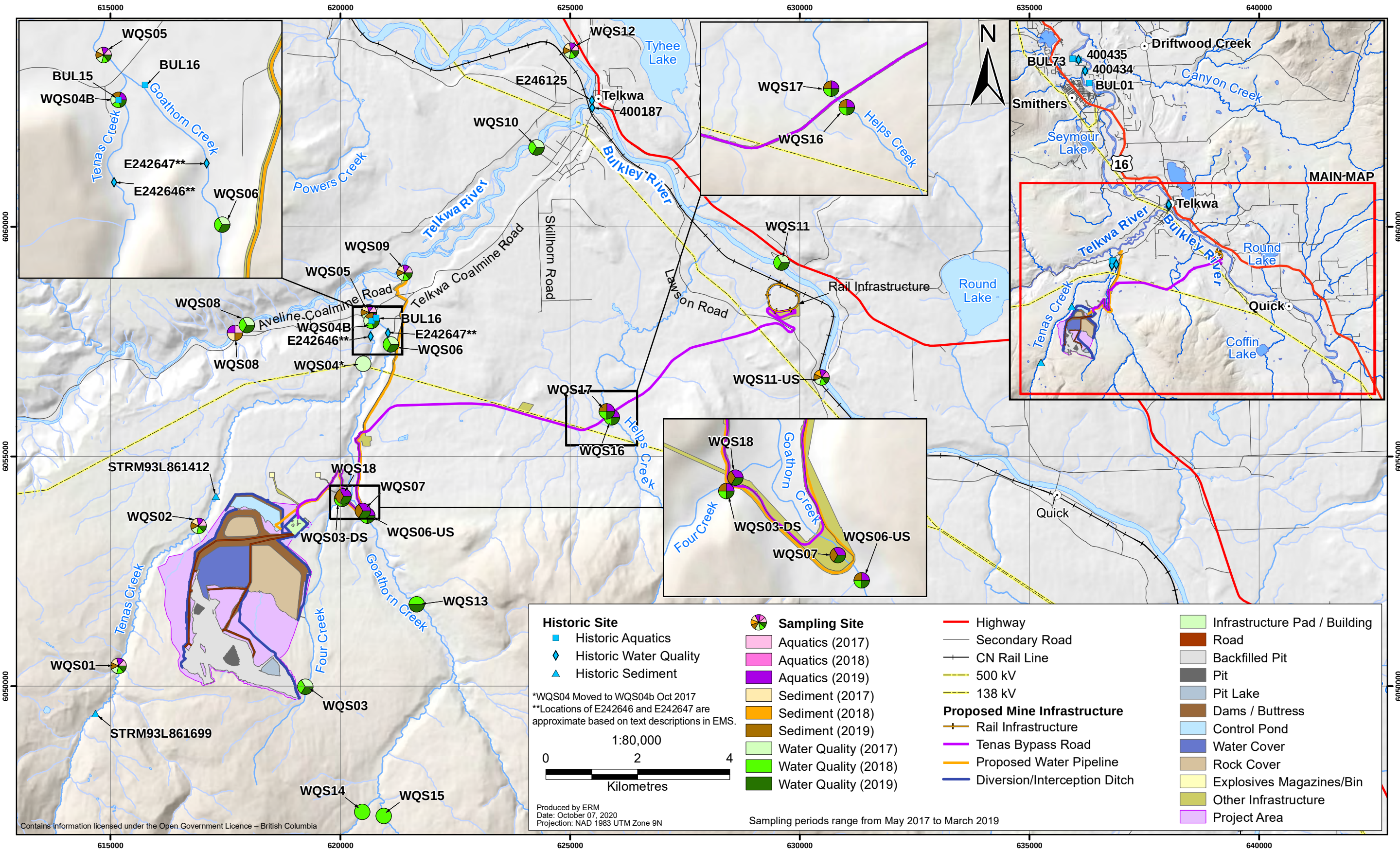


Table 8.1-2. 2017 to 2019 Water Quality Sampling Frequency, Tenas Project

Waterbody	Site	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tenas Creek	WQS01	2017					x	x	x	x	x	x	x	x
	WQS01	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS01	2019	x	x	x	x				x			x	
	WQS02	2017					x	x	x	x	x	x	x	x
	WQS02	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS02	2019	x	x	x					x				
	WQS04	2017					x	x	x	x	x			
	WQS04B	2017										x	x	x
	WQS04B	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS04B	2019	x	x	x	x				x			x	
Four Creek	WQS03	2017					x	x	x	x	x	x	x	x
	WQS03	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS03	2019	x	x	x	x							x	
	WQS03-DS	2018					x	x	x	x	x	x	x	x
	WQS03-DS	2019	x	x	x	x						x	x	
	WQS18	2019										x		
Goathorn Creek	WQS15	2018									x			
	WQS14	2018									x			
	WQS13	2018									x	x	x	x
	WQS13	2019	x	x	x	x							x	
	WQS06-US	2018					x	x	x	x	x	x	x	x
	WQS06-US	2019	x	x	x							x		
	WQS07	2019										x		
	WQS06	2017					x	x	x	x	x	x	x	x
	WQS06	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS06	2019	x	x	x	x							x	
Helps Creek	WQS05	2017					x	x	x	x	x	x	x	x
	WQS05	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS05	2019	x	x	x	x				x			x	
	WQS16	2018									x	x	x	x
	WQS16	2019	x	x	x							x		
	WQS17	2018									x	x	x	x
	WQS17	2019	x	x	x	x						x	x	
	WQS08	2017					x	x	x	x	x	x	x	x
	WQS08	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS08	2019	x	x	x	x				x			x	
Telkwa River	WQS09	2017					x	x	x	x	x	x	x	x
	WQS09	2018	x	x	x	x	x	x	x	x	x	x	x	x

(continued)

Table 8.1-2. 2017 to 2019 Water Quality Sampling Frequency, Tenas Project (completed)

Waterbody	Site	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Telkwa River (cont'd)	WQS09	2019	x	x	x	x				x			x	
	WQS10	2017					x	x	x	x	x	x	x	x
	WQS10	2018	x	x	x	x	x	x	x	x	x	x	x	x
	WQS10	2019	x	x	x									
Bulkley River	WQS11-US	2017											x	x
	WQS11-US	2018					x	x	x	x	x	x	x	x
	WQS11-US	2019	x	x	x	x				x			x	
	WQS11	2017					x	x	x	x	x	x	x	x
	WQS11	2018						x	x	x	x	x	x	x
	WQS11	2019	x	x	x	x							x	
	WQS12	2017					x	x	x	x	x	x	x	x
	WQS12	2018			x	x	x	x	x	x	x	x	x	x
	WQS12	2019	x	x	x	x				x			x	

Notes:

"X" indicates a site is sampled at least once during that month.

A site can be sampled more than once in a month for field duplicates and 5-in-30 samples.

At the federal level, surface water quality and aquatic habitat are subject to federal legislation including the *Fisheries Act* (1985) and the *Canadian Environmental Protection Act* (1999), and the regulations therein. Regulations designed to protect surface water quality, and, by extension, aquatic resources and fish and fish habitat, are premised on the avoidance of deleterious impacts to water quality and quantity, sediment quality, and aquatic organisms. CCME has developed consensus-based Canadian environmental quality guidelines for the protection of aquatic life (CCME 2014).

Surface water quality studies for the Project were designed to meet the *Environmental Assessment Act* requirements outlined in the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) and the requirements of the MA/EMA Permits Joint Application Information Requirements (AIR for MA/EMA Permits; BC MEM and MOE. 2016).

8.3 EXISTING INFORMATION

A review of existing information was undertaken for the Tenas Project, which included examining public sources of water quality data and historical reports (Table 8.3-1). Data were reviewed for quality, relevance (i.e., geographic), and compliance with requirements for Environmental Assessment and for Joint MA/EMA permit applications. Guidance was followed from The Joint AIR for MA/EMA Permits (BC MEM and MOE 2016), which recommends following the guidance outlined in the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) and the *BC Field Sampling Manual* (BC MOE 2013). The *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) provides detailed direction regarding the collection of baseline data for projects that trigger the Environmental Assessment process.

Table 8.3-1. Surface Water Quality Data Information Table

Documents Reviewed	Publicly available data - British Columbia Environmental Monitoring System (EMS). https://a100.gov.bc.ca/pub/ems/listDataFiles.do?userAction=mainmenu&electionIndex=0&x=55&y=12 - BC MOE. 2006. <i>Drinking Water Source Quality Monitoring 2002-03; Bulkley Valley Surface Water Sources: Smithers Lakes, Kirby Lake, Chicago Creek, Bulkley River, Tobaggan Creek, and Thompson Creek.</i> - BC MOE. 1986. <i>Skeena-Nass Area Bulkley River Basin Water Quality Assessment and Objectives.</i> Client-supplied consultant reports - AGRA Earth & Environmental. 1999. <i>Telkwa Coal Mine Surface Water Monitoring Program 1998.</i> - AGRA Earth & Environmental. 2000. <i>Telkwa Coal Project 1999 Baseline Surface Flow and Water Quality Final Data Report.</i> - Frontier Geosciences. 1999. <i>Report to Stephen Day: BC Research Selenium Results.</i> - Piteau Engineering. 1994. <i>Baseline Data, Surface Water and Groundwater, Telkwa Coal Project.</i> - SRK Consultants. 1996. <i>Summary of Fisheries, Aquatic Habitat and Water Quality Information for the Telkwa Project Area: A Literature Review.</i> - Telkwa Coal Project Approval Certificate Application: <i>Environmental Baseline.</i> Existing reports not obtained - Beaudry, P.G., J.W. Schwab and D. Septer. 1991. <i>Suspended Sediment: Telkwa River Watershed.</i> - Crows Nest Resources and READ Environmental & Planning Associates. 1983. <i>Telkwa Project: Stage I Application.</i> - MacLaren Plansearch Services. 1985. <i>Water Quality Investigation: Telkwa Coal Project.</i> Wilkes, B. and R. Lloyd. 1990. <i>Water Quality Summaries for Eight Rivers in the Skeena River Drainage, 1983 – 1987: the Bulkley, Upper Bulkley, Morice, Telkwa, Kispiox, Skeena, Lakelse, and Kitimat Rivers.</i>
General Remarks	The publicly available data in EMS (as described in the two BC MOE reports) does have relevant stations within the Project area. The client-supplied consultant reports contain older data available within the Project area. Many of these reports do not include raw data, or the site coordinates. It would require considerable effort to extract the raw data from the PDFs into electronic format. While not thoroughly reviewed, it is likely the historical data have higher detection limits and outdated laboratory methodologies.
Sampling Required for EA and by Joint AIR for Mines Act and Environmental Management Act Permits (Joint AIR for MA/EMA Permits and the Water and Air Baseline Monitoring Guidance (BC MOE 2016))	<i>“Minimum of monthly sampling for a period of two years is recommended, and more is preferred to assess trends and seasonal variation. To determine water quality guideline (WQG) or water quality objective (WQO) attainment, 5 samples in 30 days during critical flows (high and/or low) or biologically relevant periods are necessary. To assess inter-annual variation, or to prepare WQOs or science-based environmental benchmarks (SBEs), multiple years of water quality data are required.”</i> <i>“Conduct surface toxicity tests if required (this may be needed if WQGs are exceeded due to historic mining or site disturbance and should be discussed with Environmental Protection Division staff).” BC MOE 2016</i>

(continued)

Table 8.3-1. Surface Water Quality Data Information Table (completed)

Existing Data	The data sources listed below were deemed useful and included in the data summary: - EMS - E242646 – Tenas Creek; 2006-2008 - E242647 – Goathorn Creek above Tenas Creek confluence; 2004, 2006-2008 400187 – Telkwa River at village; 1974, 1975, 1985 to 1988, and 2006 to 2009 - E246125 – Bulkley River at Telkwa water system intake; 2001-2002 400434 – Bulkley River upstream from Smithers sewage; 1974-1975, 1987-1992, 2012 400435 – Bulkley River IDZ at Smithers; 1974-1975, 1987-1992, 2007, 2012 The data sources listed below were deemed not useful and were not included in the data summary: - EMS - E237472 – SW2 Bulkley River downstream STTS; one day of data - E242645 – Goathorn Creek (on Telkwa coalmine Creek); one sample - E242735 – Raymond Road backchannel; one day of data - E249692 – Bulkley River, upstream Fort Telkwa River; limited parameters (turbidity, bacteria) and only two months of data - E249693 – Bulkley River, Fort Telkwa River water intake; one day of data - E249694 – Bulkley River, 150 m upstream of Telkwa Bridge; limited parameters (turbidity, bacteria) and samples - E249733 – Bulkley River, George Frontage Road (RV Park); limited parameters (turbidity, bacteria) and samples 400436 – Bulkley River below Smithers sewage plant; old data (1974, 1975) and limited parameters 920088 – Bulkley River at Quick; old data (1966-1976, 1982-1990) and well upstream of Project area Client-supplied reports
Existing Data Issues	The EMS data had the following issues: - Concentrations that were below analytical detection limits were not clearly identified (i.e., not entered as “<” the detection limit); - Detection limits poor (i.e., high compared to modern detection limits) for metals data prior to 2002; - Potential sample contamination (anomalously high turbidity and metal content in some samples); and - Limited to no quality assurance/quality control (i.e., field duplicates, blanks).
Missing Data	None.
May 2017 to November 2019 Baseline Program	- The 2017–2019 baseline program collected monthly water quality samples from Tenas Creek, Four Creek, Goathorn Creek, Helps Creek, the Telkwa River, and the Bulkley River. - Additional sites were added to the monitoring program on Four, Goathorn, and Helps creeks and on the Bulkley River in 2018 and 2019, to improve the establishment of baseline conditions. 5-in-30 samples were collected in 2018 from sites on Tenas and Goathorn creeks, and on Telkwa and Bulkley rivers.
Key Issues	Two years of data and 5-in-30 sampling are listed as required components for the Joint AIR for MA/EMA Permits.
Other Comments	None.

8.4 METHODOLOGY

8.4.1 Sample Collection

The collection of water samples followed the *British Columbia Field Sampling Manual* (BC MOE 2013) and the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016). Water samples were collected in creeks by facing upstream and submersing the lab-certified clean sample bottles below the surface until filled. Where safety considerations allowed, water samples were collected mid-stream. Vinyl, (or nitrile prior to December 2018) gloves were worn during sampling. Surface water quality samples were collected for the analysis of:

- general parameters (pH, specific conductivity, total dissolved solids, total suspended solids, turbidity, color, total hardness);
- major anions (bromide, chloride, fluoride, and sulphate);
- alkalinity and acidity;
- nutrients (nitrate, nitrite, ammonia, total and dissolved orthophosphate);
- total and dissolved organic carbon;
- total metals (including total mercury);
- dissolved metals (including dissolved mercury);
- radium-226;
- selenium (April 2019 only) and iron speciation (only at WQS03 and WQS04B in November 2019);
- benzene, toluene, ethylbenzene, and xylene (BTEX) and phenols; and
- polycyclic aromatic hydrocarbons (PAH).

The listed analytes were chosen based on the requirements set out in BC MOE (2016). The sampling protocol was updated slightly beginning in December 2018 after discussions with ALS laboratories, based on current best practices. Sample bottles that were pre-charged with preservatives were used, as opposed to the previous protocol of adding preservative to the water sample after collection. All bottles were filled from the General Parameters bottle to ensure consistency in sample handling. In addition, samples requiring filtration (dissolved parameters) were filtered in the field instead of in the laboratory.

After collection and preservation, samples were kept cool (4°C) until analysis by ALS Environmental Laboratories (ALS; Burnaby, BC).

Field parameters (temperature, pH, conductivity) were measured in situ using a YSI ProPlus multiparameter probe or an Oakton PCS Tester multi-parameter probe. Collection of additional field parameters (ORP, turbidity, dissolved oxygen) began in October 2018 using a YSI ProDSS fitted with turbidity, dissolved oxygen and ORP sensors. The probes were placed in the water and allowed to stabilize for several minutes before data were recorded. Field parameters are summarised in Appendix 8-A.

8.4.2 Analysis

Water quality parameters were compared to BC ENV and CCME water quality guidelines for the protection of freshwater aquatic life (BC ENV 2019 and 2020; CCME 2014). Field duplicates were averaged prior to analysis and 5 in 30 samples collected in 2018 were treated as discrete samples. Hardness-, pH-, chloride-, temperature-, and DOC-dependent guidelines were calculated using site specific parameter values. Bulkley River water quality was also compared to the Skeena-Nass Area Bulkley River Basin Water Quality Assessment and Objectives (BC MOE 1986).

Screening of measured chromium concentrations employed both the trivalent chromium (Cr[III]) and the hexavalent chromium (Cr[VI]) guideline. Cr(VI) is the generally more mobile, bio-available and therefore more toxic form, and as such has a more stringent guideline (0.001 mg/L) compared to the trivalent form (Cr[III] guideline = 0.0089 mg/L). Screening measured total chromium concentrations against Cr(VI) guidelines is a conservative approach.

BC ENV updated the copper WQG for the protection of freshwater aquatic life in August 2019 (BC ENV 2019) and the updated BC WQG for dissolved copper is applied in this report. The bioavailability of copper to the biochemical receptors of aquatic organisms is determined by its concentration in water and the chemistry of that water (BC ENV 2019). The major factors influencing copper toxicity are dissolved organic carbon (DOC), water hardness, and pH. For instance, DOC binds to the toxic inorganic forms of copper in water forming organic compounds that are not bioavailable (BC ENV 2019). Biotic Ligand Models (BLM) incorporate metal speciation and the protective effects of competing cations to predict toxic concentrations. A copper BLM, named BC BLM, was developed for determining copper WQGs in BC (BC ENV 2019). Calculating a WQG using the BC BLM requires 11 essential water chemistry parameters. However, not all these water chemistry parameters are routinely measured. To overcome this issue, BC ENV also provides a “simplified” version of the BC BLM, which requires only four water chemistry parameters: temperature, DOC, pH, and hardness. This version considers the parameters most influential to dissolved copper toxicity. Based on these four water chemistry parameters, the other seven can be estimated (BC ENV 2019). The simplified approach was used to calculate dissolved copper WQGs as part of this report and the British Columbia median ion ratio values were adopted to estimate site characteristics. Inorganic carbon input was assumed to be controlled as an open system, using atmospheric partial pressure of CO₂. BC BLM options were set to “quick normalization - only the most sensitive organisms were normalized to site chemistry” for both the acute and chronic guidelines.

There were instances where temperature, hardness, DOC and pH data were not collected, especially for the historical data. In the absence of these data, assumptions were made according to the following practices.

Field temperature:

- the median temperature by site and season (two seasons: summer from May to September and winter from October to April) was applied to missing measurements; and
- for sites or seasons where too many measurements were missing to calculate a median value, the median by waterbody and season was used to substitute missing temperature. BC BLM sets a range for temperature (4.4 – 27 °C) and values outside of this range will be automatically

converted to the upper or lower limits. The effect of temperature on determining dissolved copper WQGs is minor (BC ENV 2019).

Hardness, DOC and pH:

- the median concentration by site was applied to missing measurements; and
- for sites where too many measurements were missing to calculate a median value, the median by waterbody was used to substitute these parameters.

Sample-specific assumptions for BC BLM copper guidelines are summarised in Appendix 8-B.

Sample concentrations that were below analytical detection limits were replaced with half the detection limit for the purposes of graphing and analyses. Parameters above BC and CCME guidelines were summarized as the percentage of samples that were greater than a specific guideline, and the average factor by which samples were above the guideline level. The average factor was calculated from only those samples that were above the guideline (i.e., samples below and equal to the guideline were excluded from the calculation). Data were excluded from guideline comparison summaries when sample concentrations were below analytical detection limits and the detection limits were above water quality guidelines (i.e., it was unclear whether actual concentrations were above guideline), or when data were missing.

Metals data prior to 2002 were excluded due to suspected poor detection limits. Some anomalous samples were also excluded due to suspected contamination, including 400187 (June 2, 1975 and September 4, 1986; high turbidity and metals) and E246125 (October 2001; high metals).

8.4.3 Quality Assurance/Quality Control

8.4.3.1 Field

Standard field quality assurance/quality control (QA/QC) procedures included the use of chain of custody forms (COCs) and the collection of sample blanks and replicates. A field blank and travel blank were collected during each sampling trip. Prior to December 2018, the field blank was pre-filled with distilled deionized water and was opened and exposed to the air at a randomly chosen sampling site for one minute. Beginning in December 2018, the field blank methodology changed according to recommendations made by ALS Laboratories. Field blanks were prepared in the field with laboratory supplied distilled deionized water at a randomly chosen sampling site. Field blanks gave an indication of potential contamination during field sampling (i.e., exposure to airborne particulates), and during transport and analysis at the laboratory. The travel blank was not opened and provided an assessment of potential contamination from travel or laboratory handling.

Field duplicate samples were also collected during each sampling trip. Field duplicate samples were used to provide an indication of the variability inherent in field sampling (environmental heterogeneity or sampler handling leading to contamination) by using the relative percent difference (RPD) calculation:

$$RPD = 100 \times |rep1 - rep2| / [(rep1 + rep2) / 2] \quad [Equation 1]$$

where:

rep = field duplicate water sample, or sediment splits

The *BC Field Sampling Manual* (BC MOE 2013) suggests that if both of the duplicate values are less than five times the analytical detection limit, they are not to be included in the RPD calculations. This is because the water quality measurement is more sensitive to variation as values approach the analytical detection limit. Thus, only the water quality variables with concentrations greater than five times the detection limit in at least one of two duplicate samples were considered. Overall, RPD values greater than 20% may indicate possible issues (i.e., high *in situ* variation, or sample contamination), while RPD values greater than 50% indicate definite issues that warrant further investigation.

8.4.3.2 Laboratory

The 2017 to 2019 laboratory QA/QC program included the examination of potential contamination (i.e., method blanks), analytical precision (i.e., laboratory replicates), and analytical accuracy (i.e., reference materials and matrix spikes). Method blanks were analyte-free matrices (i.e., distilled deionized water) that were prepared and analyzed using the same methodology as a regular sample. Laboratory replicates were field samples that were sub-sampled in the lab and analyzed separately to assess analytical precision. Reference materials were standards with known concentrations, analyzed using the same methods as a regular sample, to assess accuracy. Finally, matrix spikes were field samples to which known concentrations of a standard were added. These samples are used to measure the effect of the sample matrix (field sample) on a method's recovery efficiency and interference with the method.

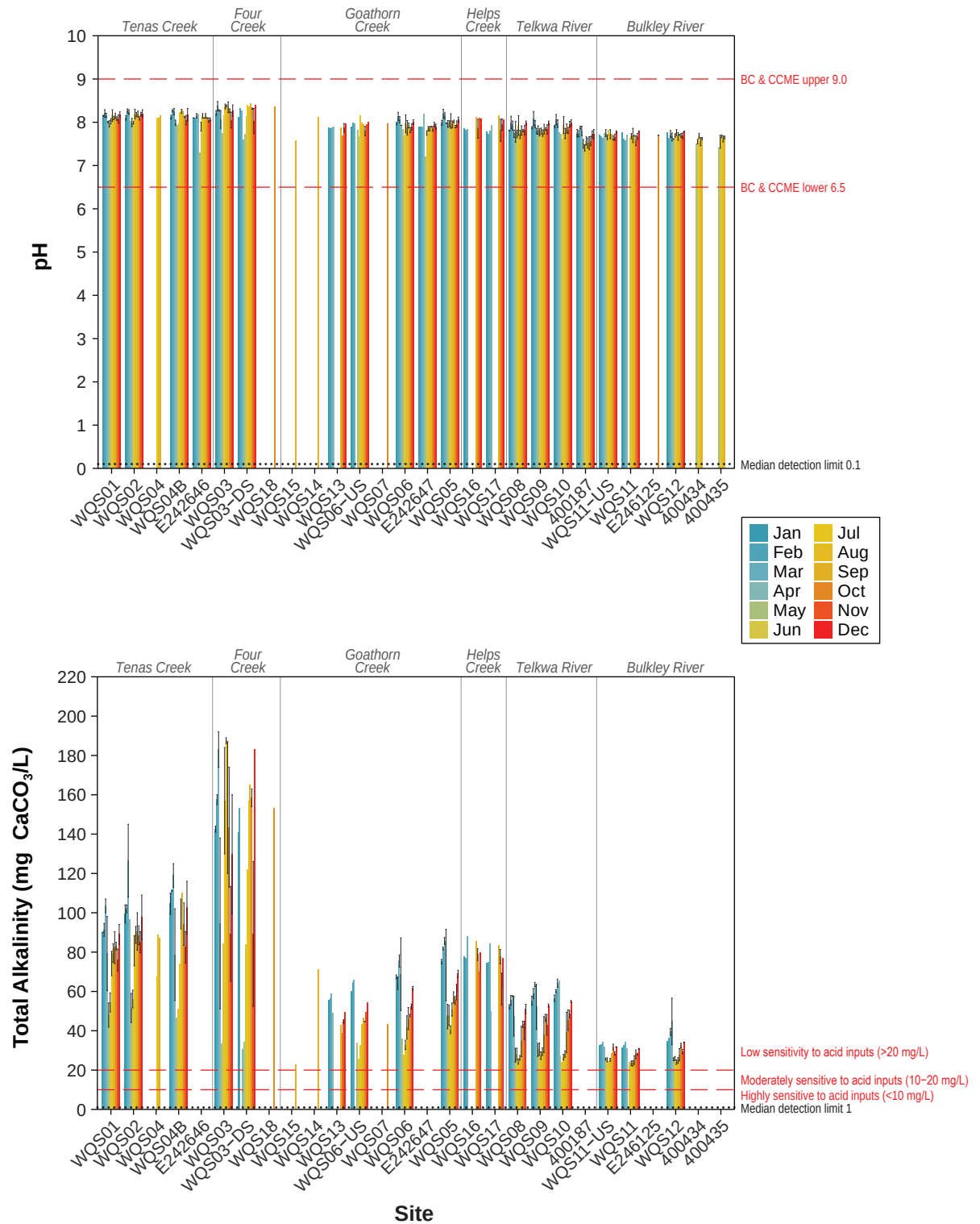
8.5 DATA SUMMARY

Water quality analytical results for May 2017 to November 2019 are provided in Appendix 8-A, with the associated QA/QC results in Appendices 8-C and 8-D. The historical data from EMS included in this data summary are provided in Appendix 8-E. Select water quality parameters are presented graphically in Figures 8.5-1 to 8.5-19, including available data collected from 1974 to 2019. Where applicable, BC and CCME guidelines are presented graphically. For guidelines that are hardness-dependent, the maximum and minimum guideline values were calculated for plotting on figures.

8.5.1 General Parameters

Project area streams had neutral to slightly basic pH (range: 6.9 to 8.48 pH), with low sensitivities to acid-inputs (total alkalinity >20 mg CaCO₃/L; Figure 8.5-1; Saffran and Trew 1996). In general, Four Creek had hard to very hard water (>120 mg CaCO₃/L), while Tenas, Goathorn and Helps creeks had moderately hard water (61 to 120 mg CaCO₃/L), and the Telkwa and Bulkley rivers had soft water (0 to 60 mg CaCO₃/L; Figure 8.5-2). Total alkalinity, conductivity, and hardness were generally higher in the streams or creeks than rivers, particularly in Four Creek (Figures 8.5-1 and 8.5-2). Alkalinity, pH, conductivity, and hardness all displayed strong seasonal patterns, with peak concentrations occurring in the winter during low flow (see Section 7) and lower concentrations occurring in the summer following May/June freshet.

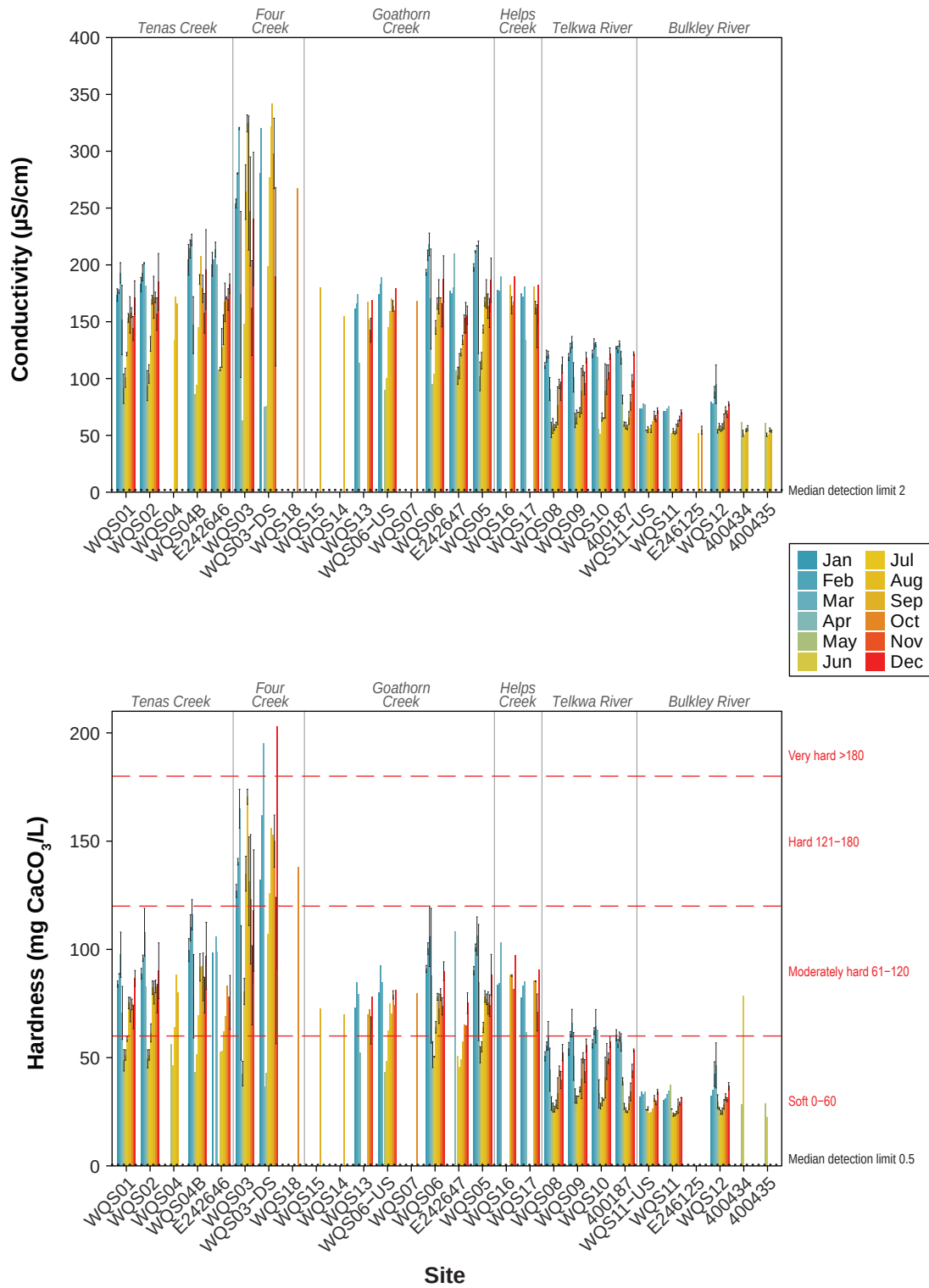
Figure 8.5-1
pH and Total Alkalinity in Tenas Project Streams, 1974 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.

Figure 8.5-2

Conductivity and Hardness in Tenas Project Streams, 1974 to 2019



Total suspended solids (TSS) and turbidity were generally low in Project area streams, except for peaks occurring during freshet (May/June) at all sites (Figure 8.5-3). Sites on the Tenas and Bulkley rivers also experienced elevated TSS levels in September during high rain and flow (see Section 7). Sporadically high TSS levels were measured during other months in the Telkwa River (Figure 8.5-3).

8.5.2 Anions

Sulphate was the dominant anion, exhibiting higher concentrations in Goathorn Creek and WQS03-DS in Four Creek, with concentrations in two to three times greater than at other sites within the same month (except in May; Figure 8.5-4). Sulphate concentrations were lowest at all sites in May during the spring freshet, low in the fall during high flow/rain events, and generally peaked in the winter during low flow months (Figure 8.5-4). Fluoride was slightly higher in Four Creek, with Project stream concentrations highest during September/October (fall rains) and in the winter, and lowest in the spring (Figure 8.5-4). Chloride concentrations (not shown) were below the detection limit (0.5 mg/L) in the majority of samples from 2017 to 2019 (95%; Appendix 8-A).

8.5.3 Nutrients

Nitrogen in the Project area streams was principally in the form of total Kjeldahl nitrogen (TKN; i.e., the sum of organic nitrogen and ammonia-nitrogen) and nitrate (Figure 8.5-5). TKN made up a larger proportion of total nitrogen concentrations in Tenas and Four creeks and the Telkwa and Bulkley rivers, while nitrate made up a larger proportion of total nitrogen in Helps creek. Nitrate concentrations were generally low in the summer and peaked in the winter, whereas TKN tended to be highest in May during freshet (Figure 8.5-5). Generally, concentrations of total nitrogen peaked during spring freshet (May), with a second peak occurring in the winter. TKN consisted primarily of organic nitrogen, as ammonia concentrations were below analytical detection limits in most samples (85% <0.005 mg/L; Appendix 8-A). Nitrite concentrations were usually below detection limits (97% <0.0010 mg/L; Appendix 8-A).

Like total nitrogen, total phosphorus concentrations peaked in the Project area streams in May (meso-eutrophic to eutrophic; 0.02 to 0.1 mg/L) and were low (ultra-oligotrophic to oligotrophic; <0.004 to 0.01 mg/L) over the summer (Figure 8.5-6). This likely reflects runoff during freshet contributing nutrients to streams, and biological uptake of nutrients in the summer. In contrast, total phosphorus concentrations in the Telkwa River remained elevated over the summer with a second peak in September.

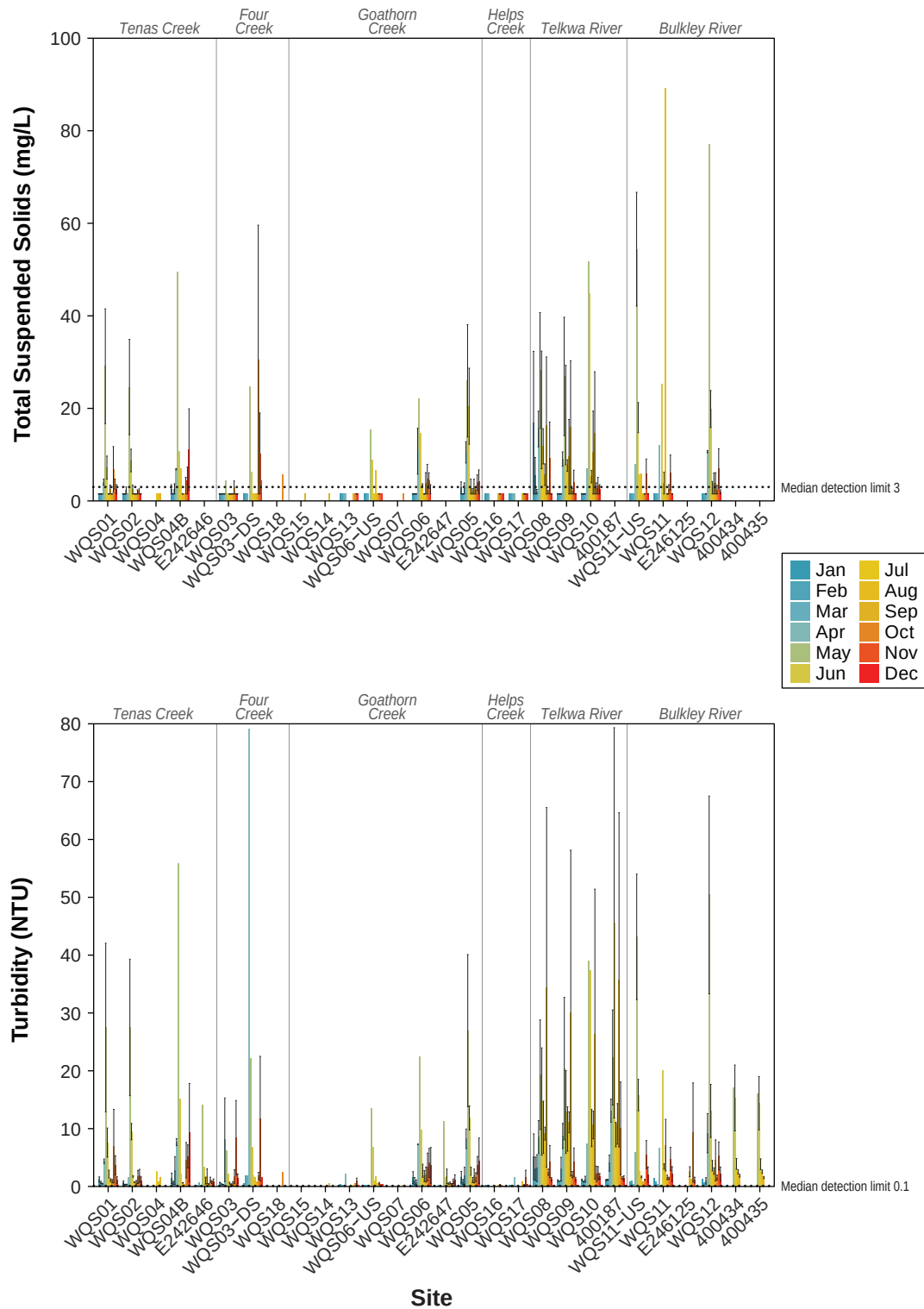
Total organic carbon (TOC) concentrations peaked during freshet in May, and to a lesser degree during the fall rains (Figure 8.5-6). Across sampled streams, concentrations were highest in Four Creek.

8.5.4 Cyanide

Total, free, and weak acid dissociable cyanides were measured in Project area streams in May, June, and August (no total) in 2017. Cyanides were below detection limits in all samples (Appendix 8-A).

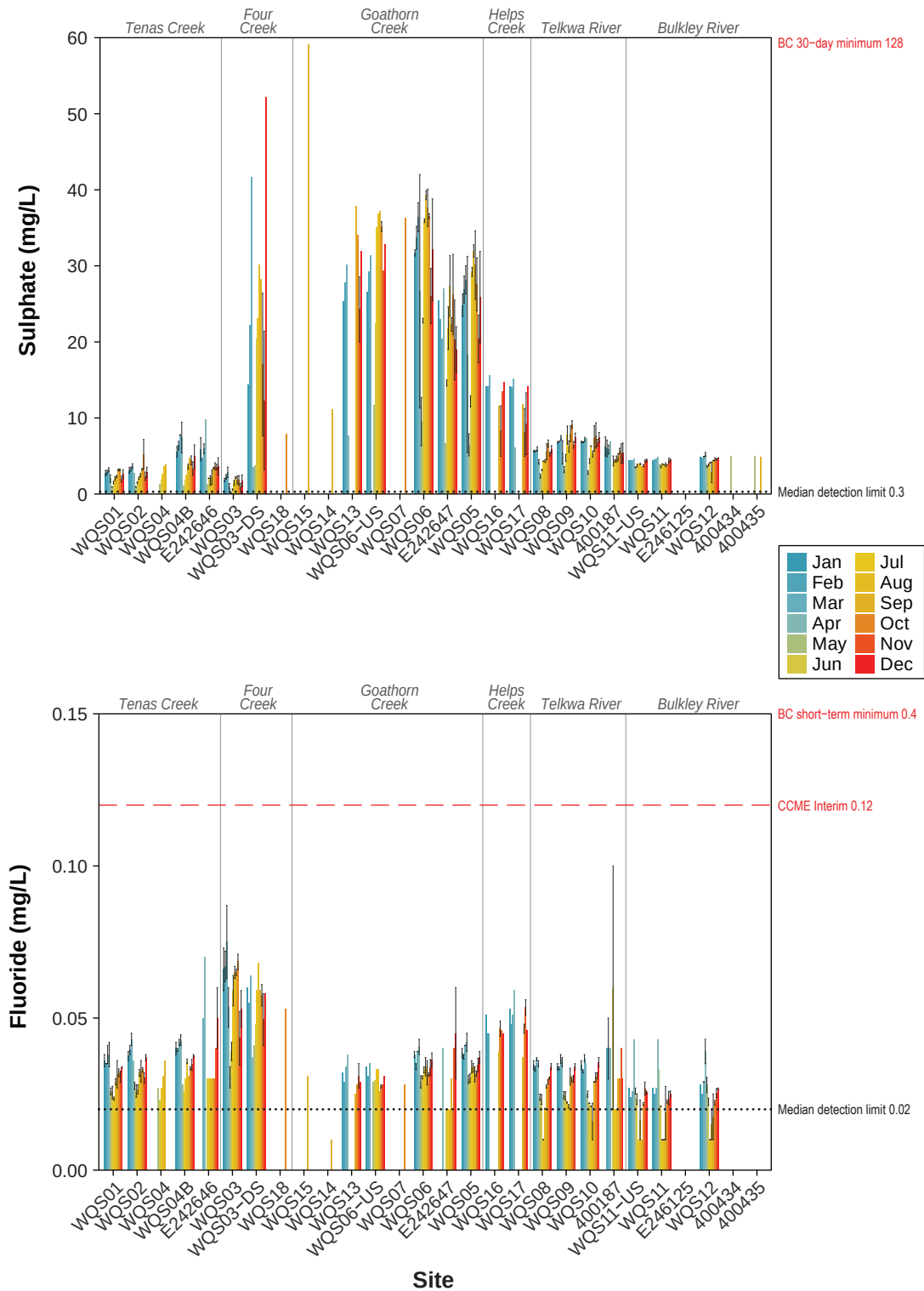
Figure 8.5-3

Total Suspended Solids and Turbidity in Tenas Project Streams, 1974 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME and BC guidelines for total suspended solids are dependent on background levels, see Appendix 8-A.
 CCME and BC guidelines for turbidity are dependent on background levels see Appendix 8-A.

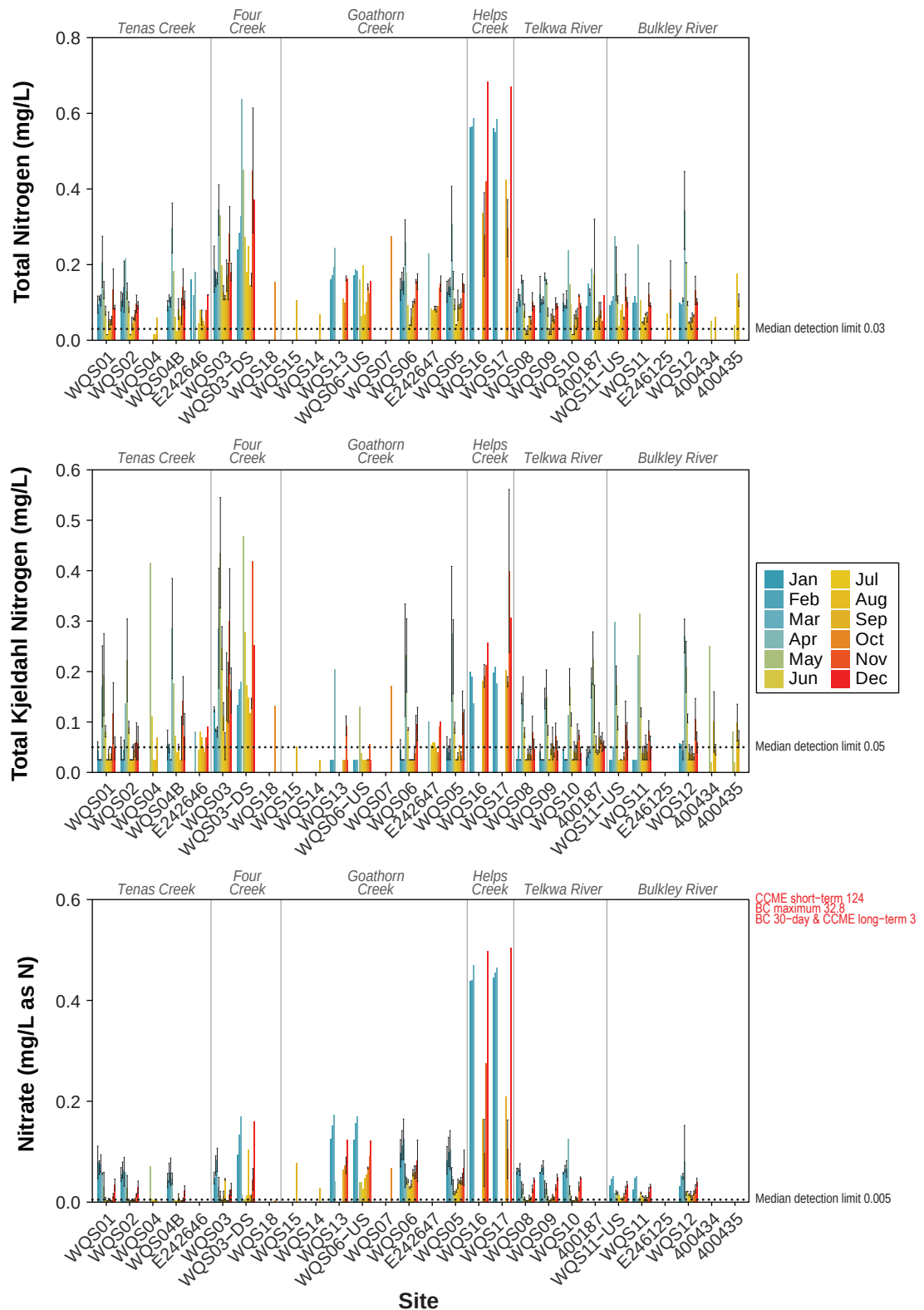
Figure 8.5-4
Sulphate and Fluoride Tenas Project Streams, 1974 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 BC sulphate guideline extends beyond the graph and is hardness dependent, see Appendix 8-A.
 BC fluoride guideline extends beyond the graph and is hardness dependent, see Appendix 8-A.

Figure 8.5-5

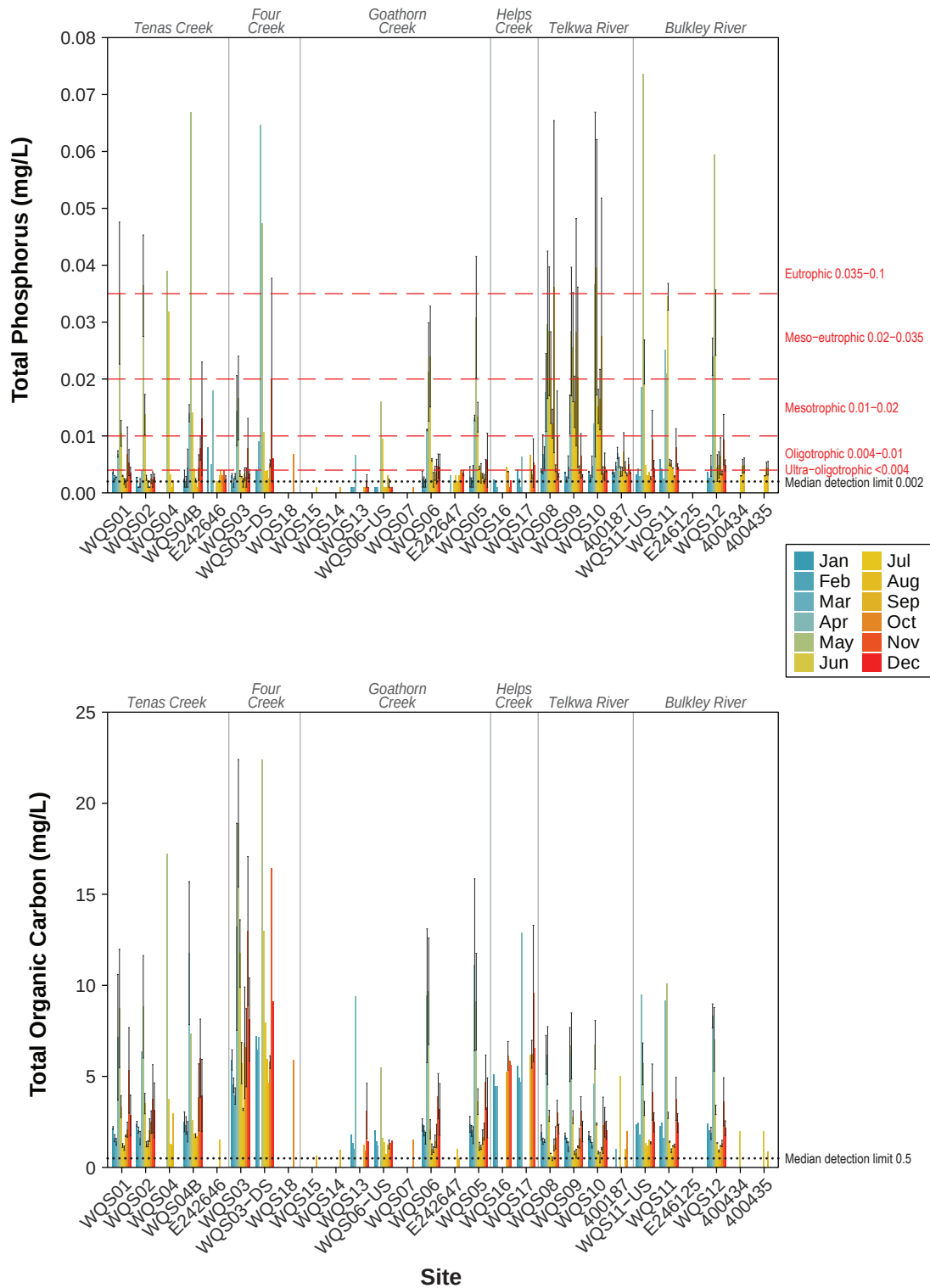
Total Nitrogen, Total Kjeldahl Nitrogen, and Nitrate in Tenas Project Streams, 1974 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.

Figure 8.5-6

Total Phosphorus and Total Organic Carbon in Tenas Project Streams, 1974 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 BC guideline for total organic carbon is dependent on background levels, see Appendix 8-A.

8.5.5 Metals

Metal (total and dissolved) concentrations displayed strong seasonal patterns in Project area streams (September; Figures 8.5-7 to 8.5-19). Peak concentrations of total and dissolved aluminum, total arsenic, total cadmium, total chromium, total and dissolved copper, total cobalt, total lead, total iron, total manganese, total nickel, total lead and total zinc typically occurred during freshet and were likely associated with elevated TSS levels. Telkwa River exhibited a second peak of total aluminum, total copper, total cadmium, total cobalt, total lead, total iron, and total manganese during the fall rains. In contrast, total antimony and total molybdenum concentrations typically peaked during low flow in the summer months, while total boron, total barium, total selenium, total uranium, and dissolved metals generally peaked during the winter.

Many metal concentrations were below or near detection limits across all sites, including total antimony, total beryllium, total boron, dissolved cadmium (except for sites on Goathorn Creek), dissolved chromium, dissolved lead, total mercury, total nickel, total selenium, total thallium, total silver, and total and dissolved zinc. Compared to other waterbodies:

- Tenas and Four creeks contained relatively higher concentrations of total arsenic and total uranium. In addition, Four Creek had elevated total barium;
- Goathorn Creek had elevated total and dissolved cadmium, although total cadmium was also high in the Telkwa River;
- Telkwa River had elevated concentrations of several metals compared to other sampled streams, including total and dissolved aluminum, total cadmium, total lead, total and dissolved iron, and total manganese; and
- sites on the Bulkley River were slightly higher in total manganese, which was also elevated in the Telkwa River.

Selenium speciation was collected in April 2019 only (Appendix 8-A). Selenium(IV), selenium(VI), selenocyanate and unknown selenium species were below the detection limits ($<0.10 \mu\text{g/L}$ or $<0.20 \mu\text{g/L}$) in all the samples.

Iron speciation was collected at WQS03 and WQS04B only in November 2019. Dissolved iron was comprised of 73% and 42% ferric iron, with the rest being ferrous iron at WQS03 and WQS04B, respectively.

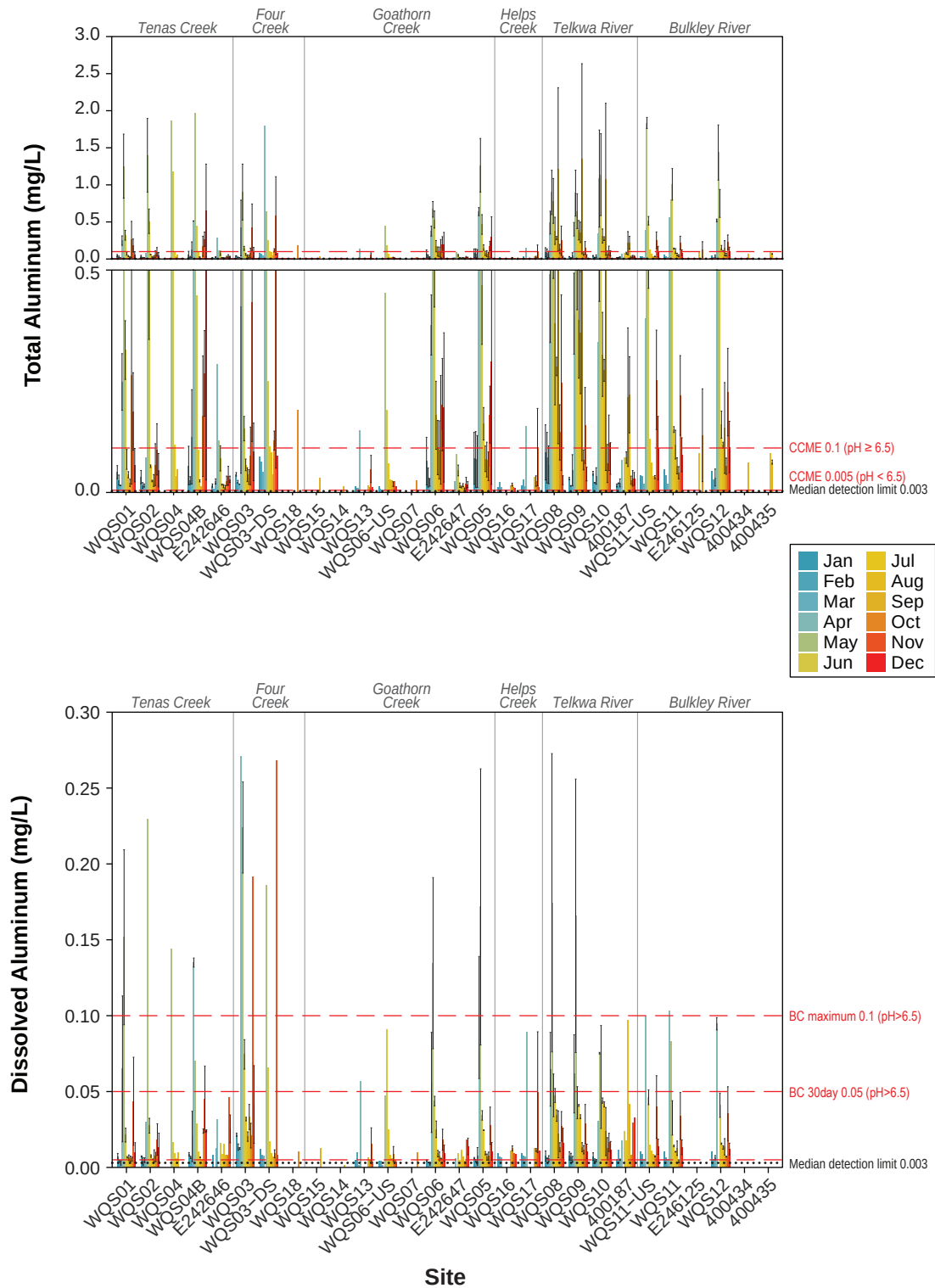
8.5.6 Hydrocarbons and Organic Compounds

Polycyclic aromatic hydrocarbons (PAHs) were measured monthly at all sampling stations. All PAH concentrations were below detection limits (Appendix 8-A). Benzene, toluene, ethylbenzene, and xylene (BTEX) were measured during nine sampling events (monthly from May to July 2017, then quarterly until October 2019), and all concentrations were below detection limits (Appendix 8-A).

Most samples were below detection limits for phenols ($68.6\% <0.0010 \text{ mg/L}$; Appendix 8-A). Concentrations ranged from 0.001 mg/L to 0.0199 mg/L , with the highest concentrations occurring during winter low flow conditions.

Figure 8.5-7

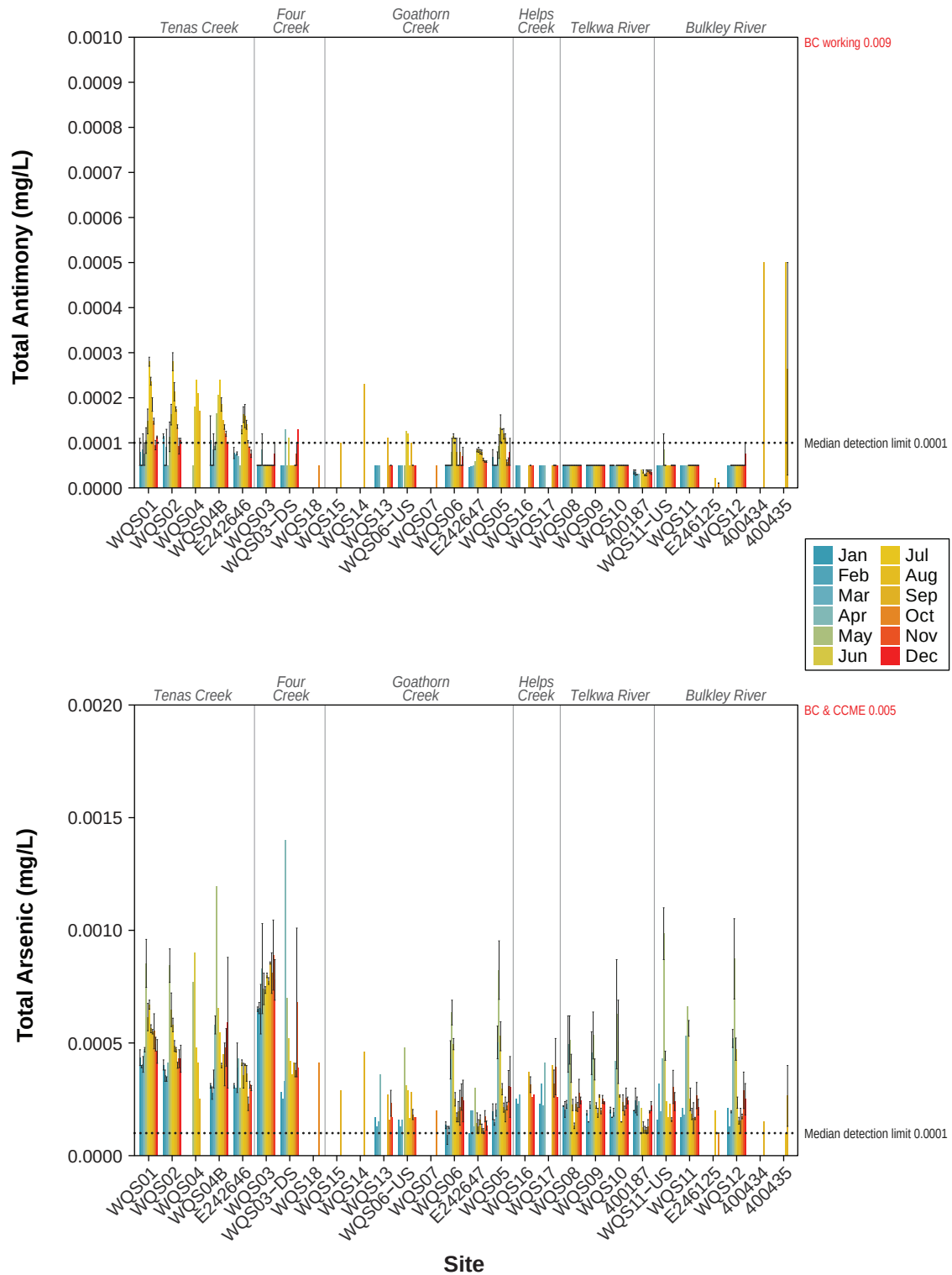
Total and Dissolved Aluminum in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 BC dissolved aluminum guidelines are pH dependent, see Appendix 8-A.

Figure 8.5-8

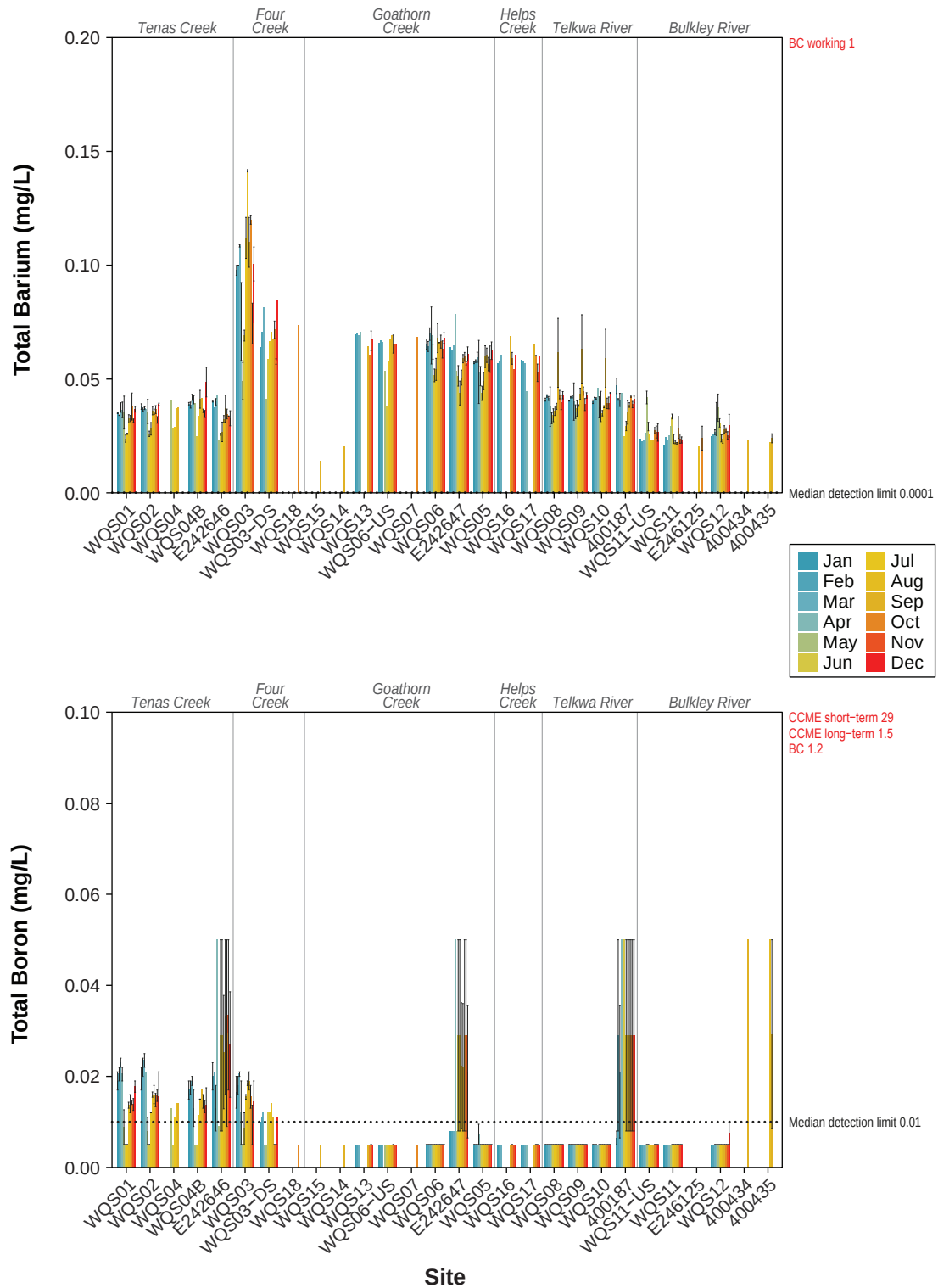
Total Antimony and Arsenic in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.

Figure 8.5-9

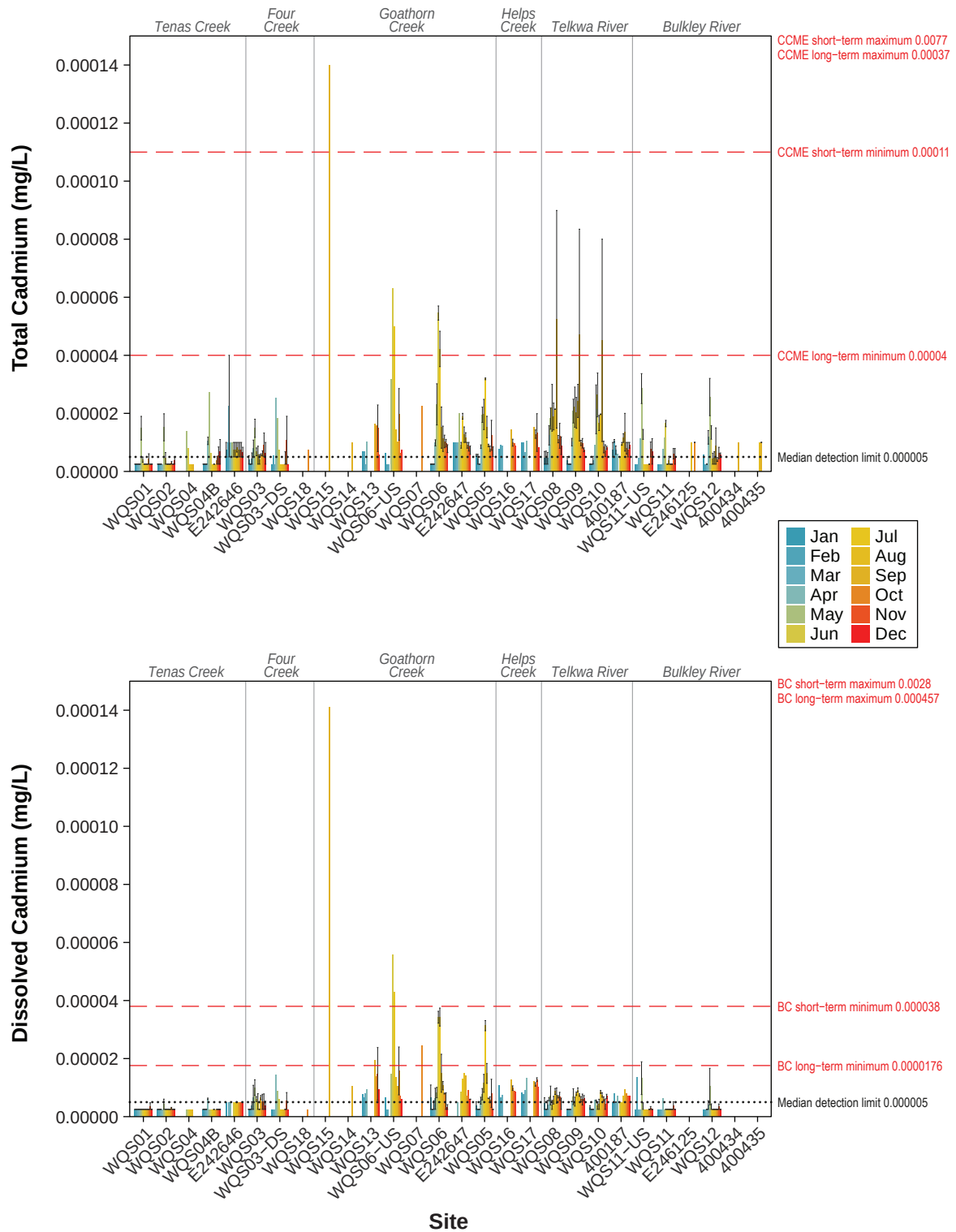
Total Barium and Boron in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.

Figure 8.5-10

Total and Dissolved Cadmium in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME cadmium guideline is hardness dependent, see Appendix 8-A.
 BC dissolved cadmium guidelines are hardness dependent, see Appendix 8-A.

Figure 8.5-11

Total and Dissolved Chromium in Tenas Project Streams, 2002 to 2019

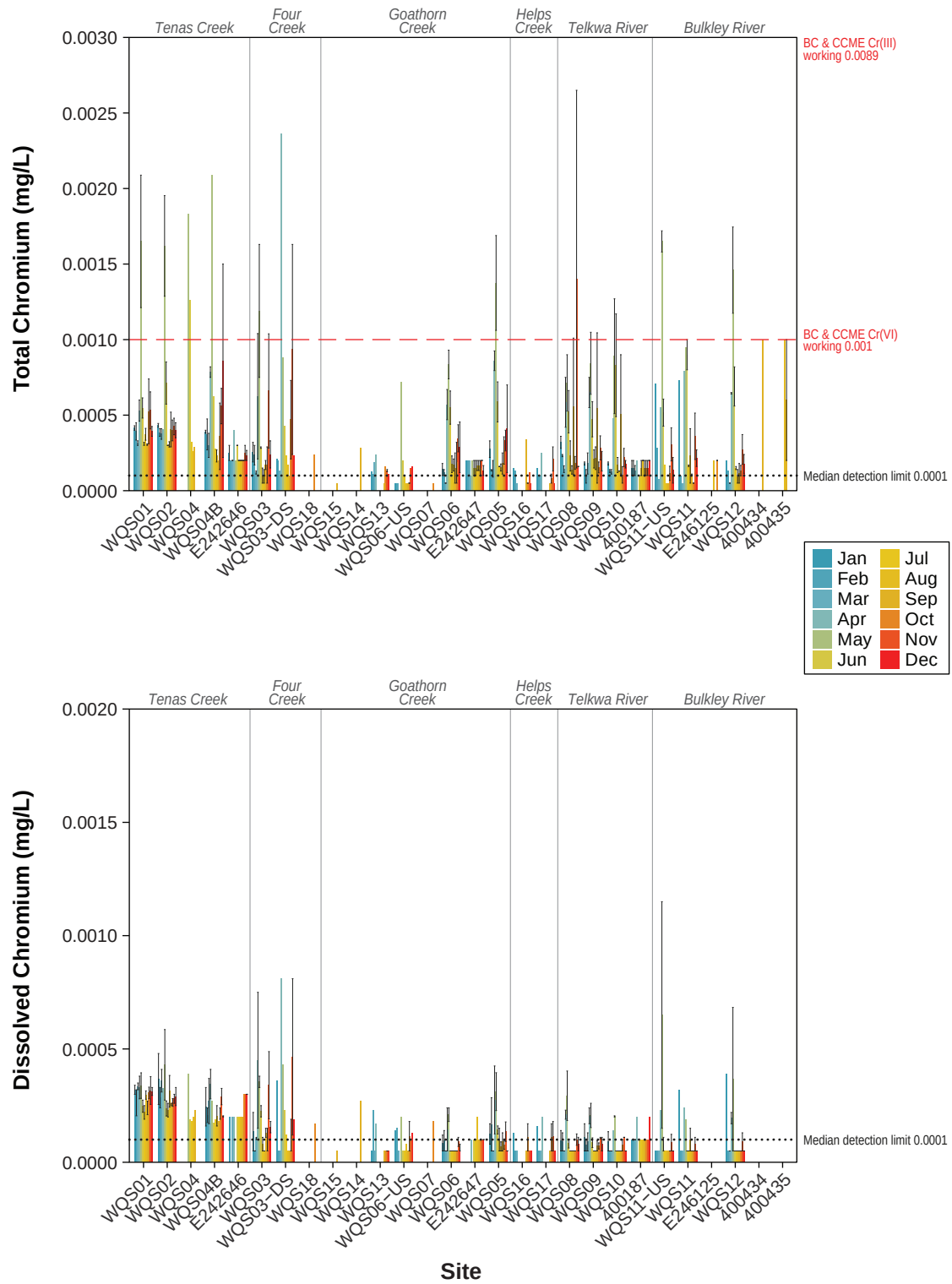
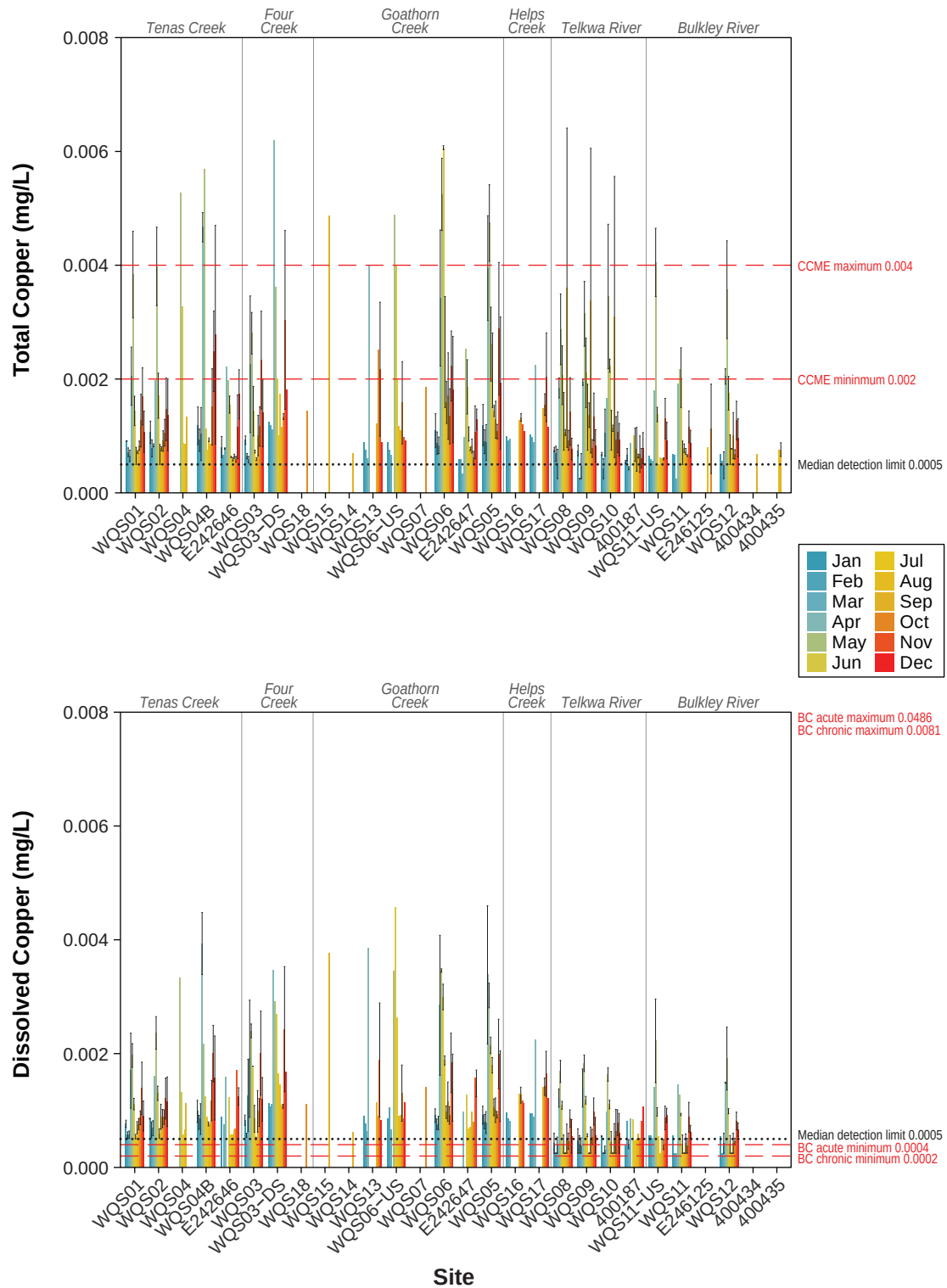


Figure 8.5-12

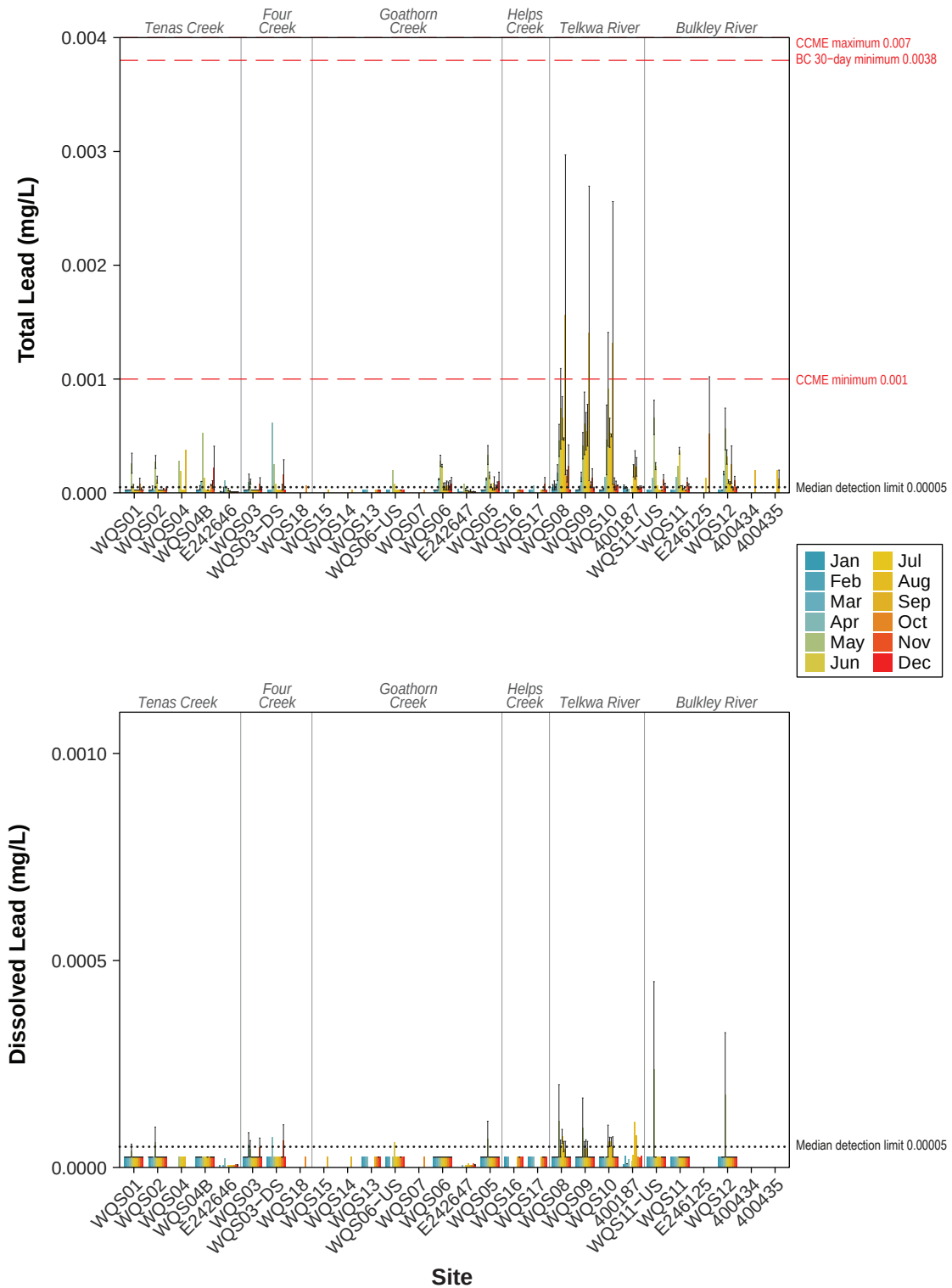
Total and Dissolved Copper Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME total copper guidelines are hardness dependent, see Appendix 8-A.
 BC dissolved copper guidelines are pH, hardness, DOC and temperature dependent

Figure 8.5-13

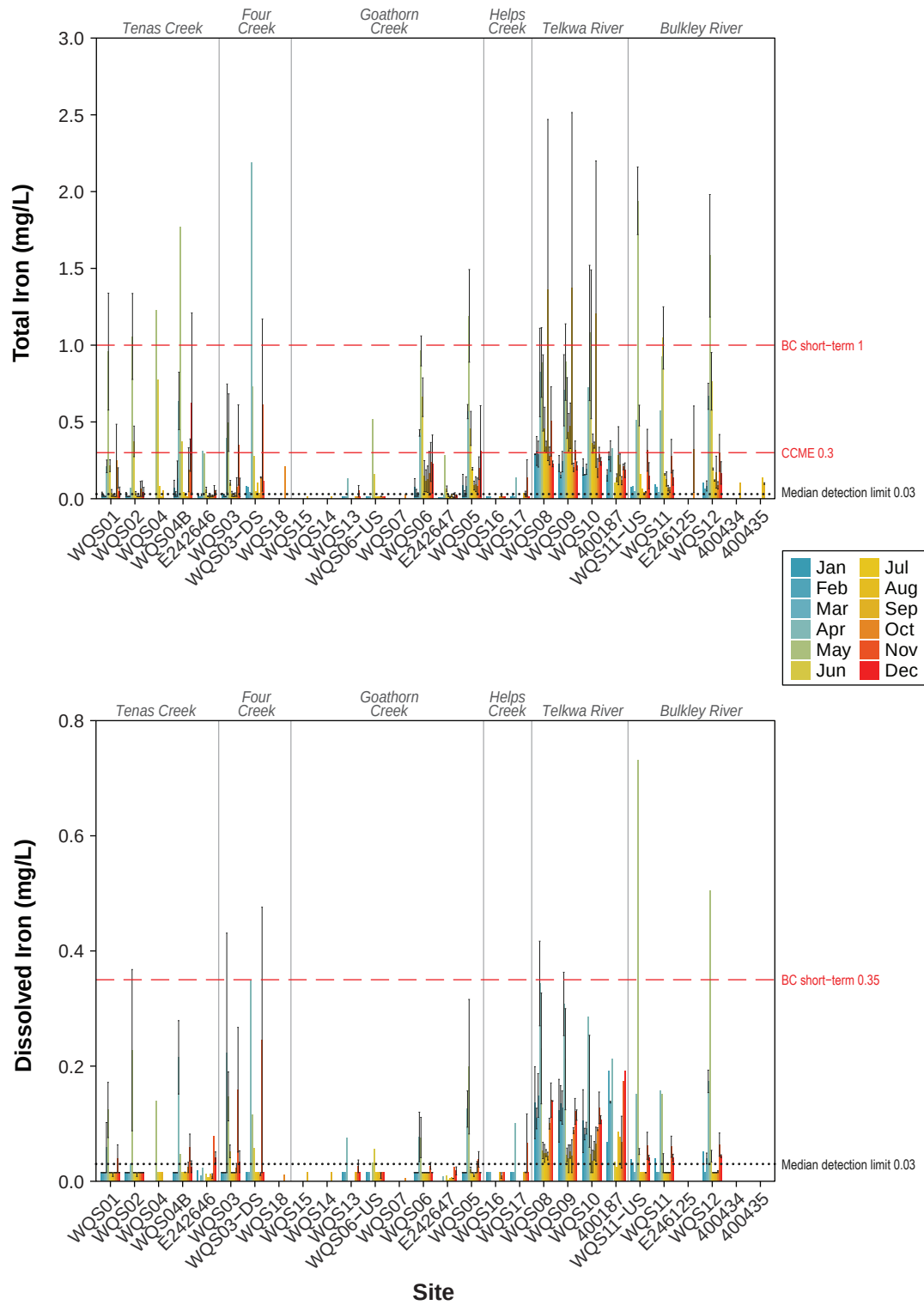
Total and Dissolved Lead in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 BC and CCME lead guidelines are hardness dependent, see Appendix 8-A.

Figure 8.5-14

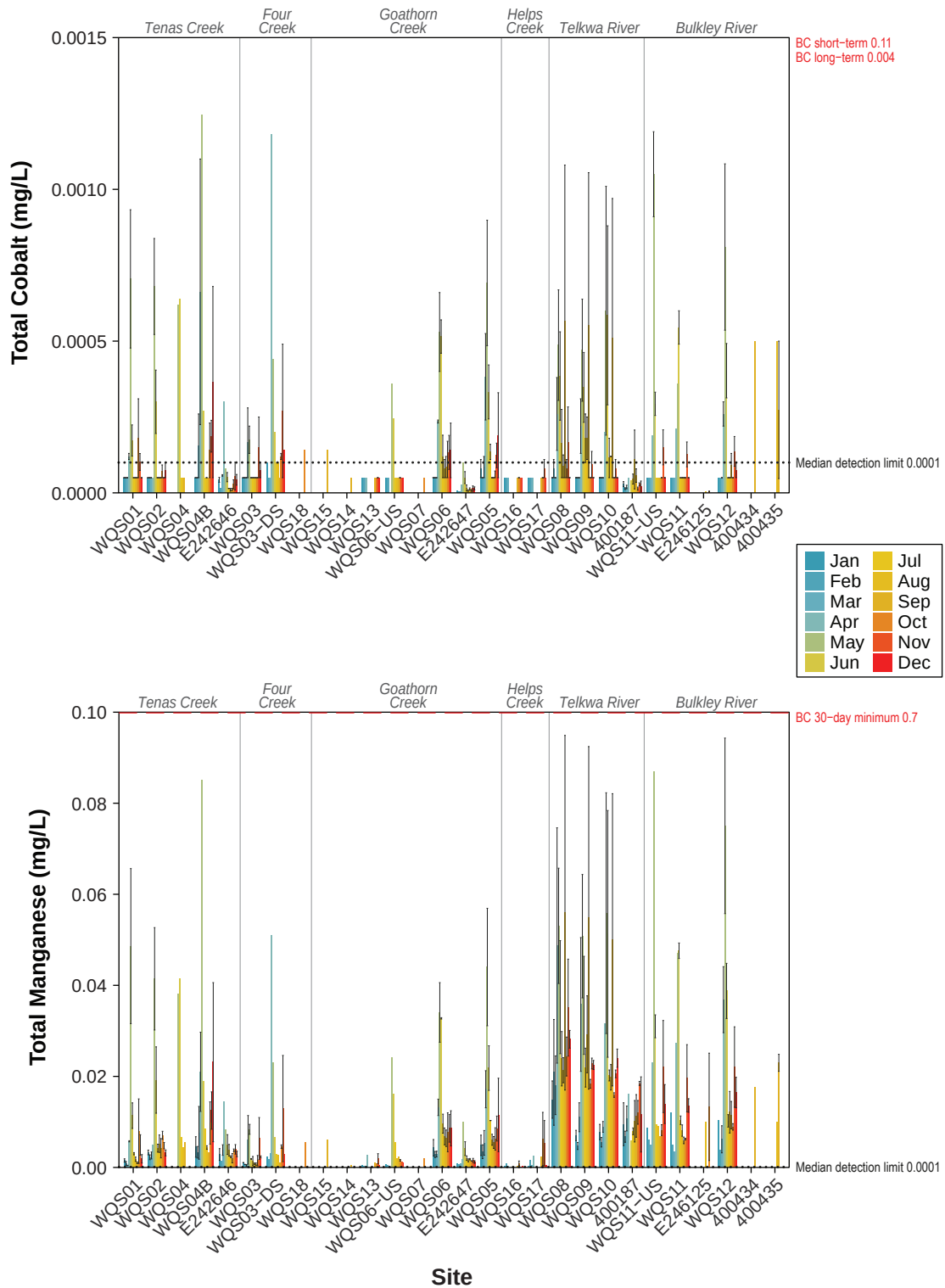
Total and Dissolved Iron in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.

Figure 8.5-15

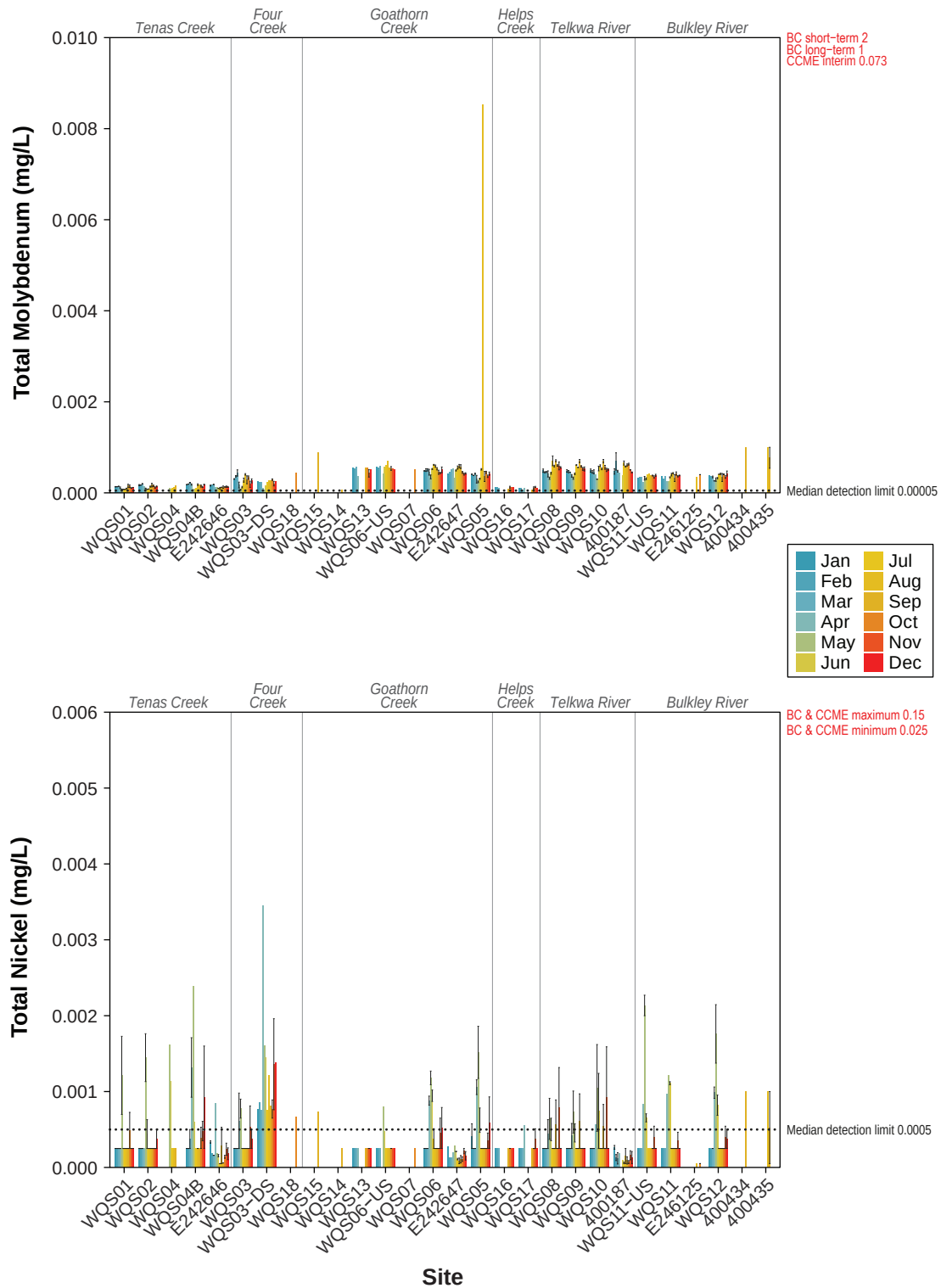
Total Cobalt and Manganese in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.
BC manganese guidelines are hardness dependent, see Appendix 8-A.

Figure 8.5-16

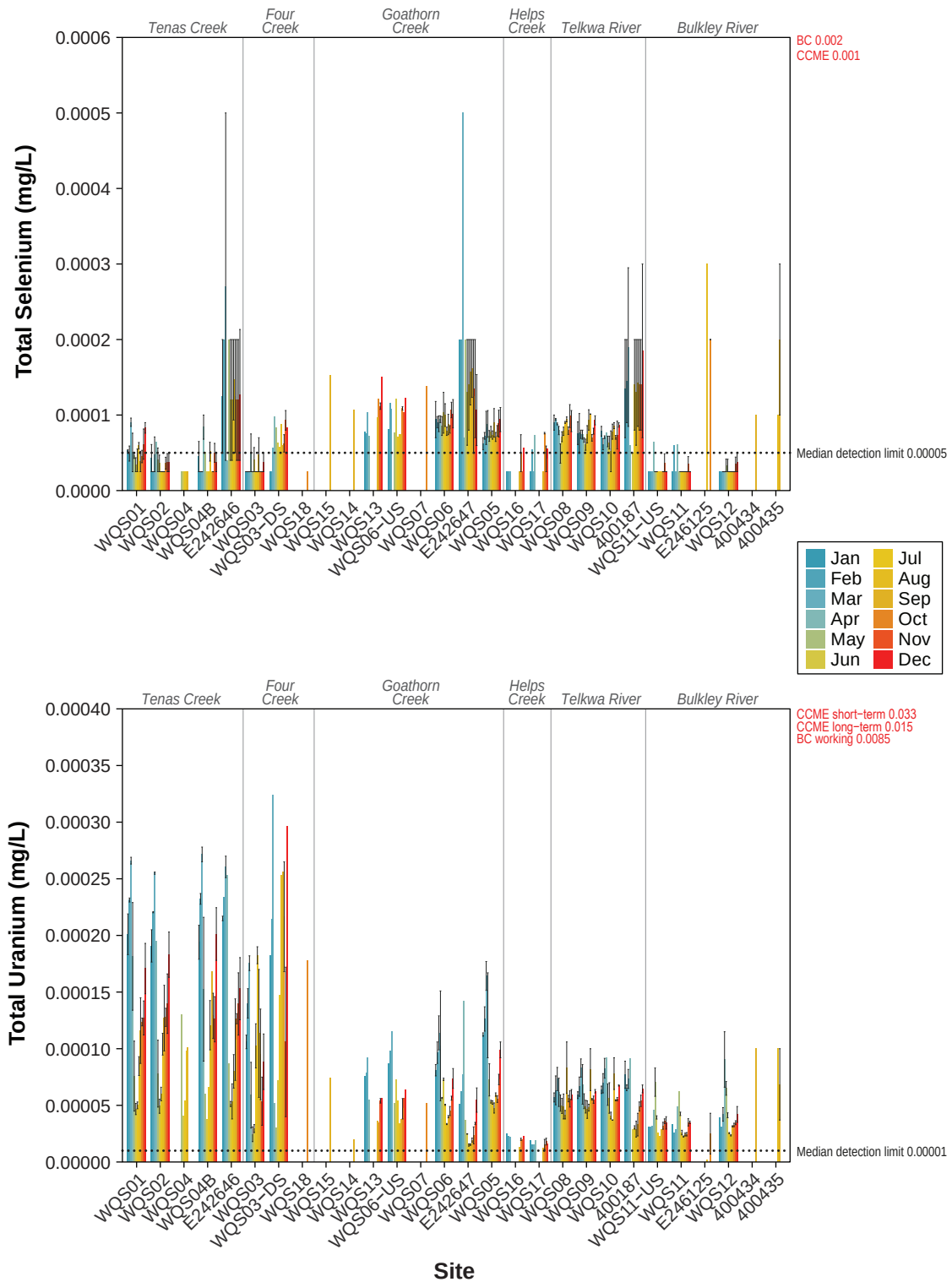
Total Molybdenum and Nickel in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.
BC and CCME nickel guidelines are hardness dependent, see Appendix 8-A.

Figure 8.5-17

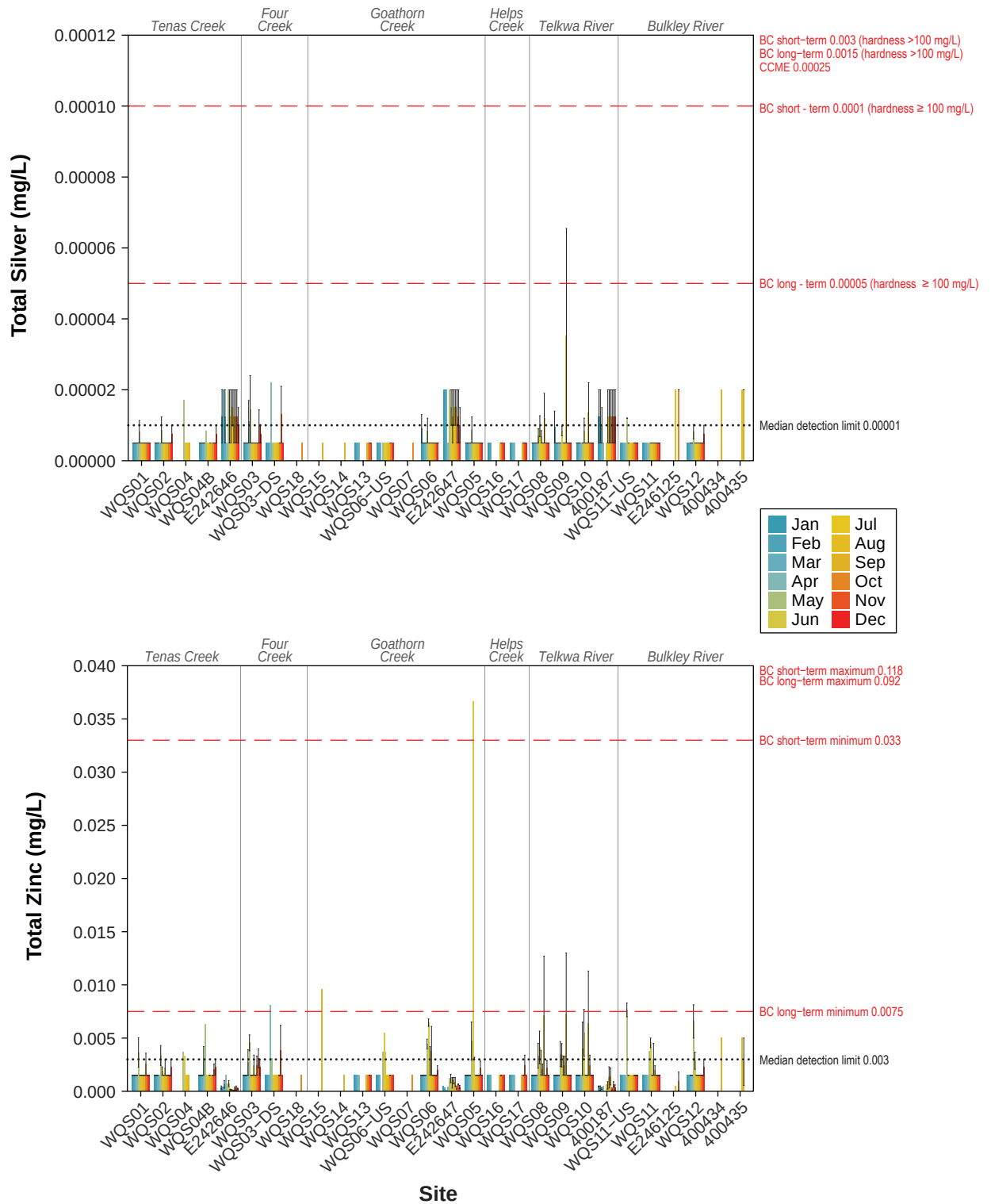
Total Selenium and Uranium in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.

Figure 8.5-18

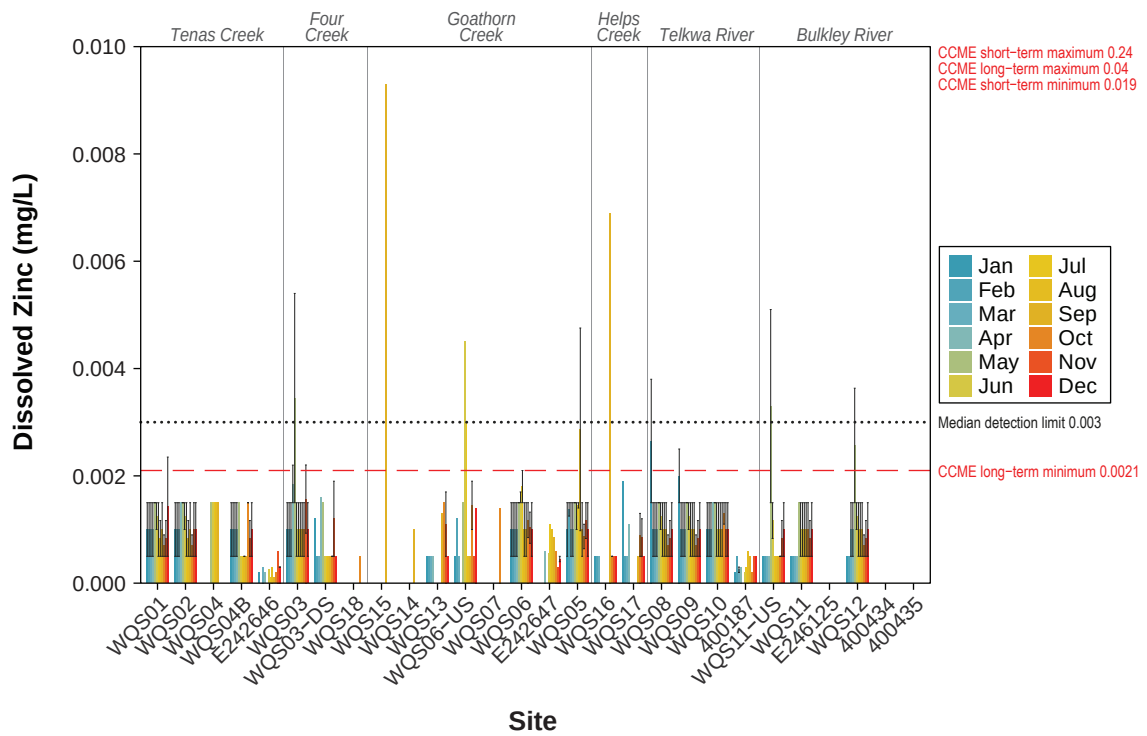
Total Silver and Zinc in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 BC total silver guidelines are hardness dependent, see Appendix 8-A.
 BC total zinc guidelines are hardness dependent, see Appendix 8-A.

Figure 8.5-19

Dissolved Zinc in Tenas Project Streams, 2002 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME dissolved zinc guidelines are hardness, pH and DOC dependent, see Appendix 8-A.

8.5.7 Isotopes

Radium-226 was measured in August 2017, and ranged from <0.0054 to 0.012 Bq/L (Appendix 8-A). Analysis of radium-226 was discontinued after August 2017.

8.5.8 Guideline Comparison

The concentrations of eight metals were above BC or CCME guidelines for the protection of freshwater aquatic life in at least one Project area creek and/or river between 2002 and 2019: total and dissolved aluminum, total cadmium, total chromium, total and dissolved copper, total and dissolved iron, total lead, total silver, and total zinc (Table 8.5-1). Elevated metal concentrations above guidelines occurred most frequently during freshet (May/June), except in the Telkwa River where they also commonly occurred in September.

Total and dissolved aluminum, and total copper were elevated in the Project area, as concentrations in creeks and rivers were frequently above the BC and/or CCME guidelines in all waterbodies (Table 8.5-1). Dissolved copper, total and dissolved iron, and total chromium were above BC and/or CCME guidelines in all creeks and rivers except for Helps Creek, and dissolved copper in Four Creek. Total cadmium, total lead, and total zinc were infrequently above guidelines in Four Creek, Goathorn Creek, the Telkwa River and the Bulkley River. Total silver was above guideline in only one sample at the Telkwa River site WQS09.

The Telkwa River had concentrations above guidelines for all eight metals, more than any other Project area stream. By contrast, Helps Creek demonstrated the best water quality, and was only above guidelines for total and dissolved aluminum, and total copper.

All anions and nutrients were below BC and CCME guidelines, and the Bulkley River samples were below provisional objectives (except for ammonia). Seven samples (9%) were greater than the 30-day average Bulkley River provisional objective for ammonia (0.007 mg/L). However, this objective is overly conservative compared to the BC ENV pH- and temperature- dependent long-term ammonia guidelines (0.227 – 1.34 mg/L). Ammonia is not likely to be a concern as no exceedance was found for the BC ENV long-term guidelines, or the Bulkley River provisional short-term objective for ammonia.

All PAHs and organics concentrations were below analytical detection limits. All concentrations were also below BC and CCME guidelines; however, for samples collected from May to August 2017, and in June 2018, detection limits for certain PAH parameters (anthracene, benzo[a]pyrene, benz[a]anthracene, fluoranthene, and pyrene) were above CCME guidelines, so these undetectable concentrations could not be assessed against BC and CCME guidelines.

Table 8.5-1. BC and CCME Water Quality for the Protection of Freshwater Aquatic Life Guideline Screening, Tenas Project

Site	"Total Phosphorus Trigger Range"	Total Aluminum		Dissolved Aluminum				Total Silver		Total Cadmium		Total Chromium	
		CCME		BC				BC		CCME		BC	
		- pH-dependent		Long-term pH-dependent		Short-term pH-dependent		Long-term Hardness-dependent		Long-term Hardness-dependent		Cr(VI)* 0.001	
		Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Tenas Creek													
WQS01	Ultra-oligotrophic - Eutrophic	6.08	37.5%	2.67	15.6%	1.53	12.5%	-	0%	-	0%	1.85	9.4%
WQS02	Ultra-oligotrophic - Eutrophic	7.38	30.0%	4.60	10.0%	3.16	6.7%	-	0%	-	0%	1.50	13.3%
WQS04	Ultra-oligotrophic - Eutrophic	10.49	60.0%	2.88	20.0%	1.44	20.0%	-	0%	-	0%	1.55	40.0%
WQS04B	Ultra-oligotrophic - Eutrophic	5.60	52.4%	2.14	19.0%	1.35	9.5%	-	0%	-	0%	1.80	9.5%
E242646	Ultra-oligotrophic - Mesotrophic	1.70	13.0%	-	0%	-	0%	-	0%	-	0%	-	0%
Four Creek													
WQS03	Ultra-oligotrophic - Meso-eutrophic	4.92	36.0%	4.33	32.0%	3.03	20.0%	-	0%	-	0%	1.36	12.0%
WQS03-DS	Ultra-oligotrophic - Eutrophic	6.74	42.9%	5.99	28.6%	3.77	21.4%	-	0%	-	0%	2.00	14.3%
WQS18	Oligotrophic	1.85	100.0%	-	0%	-	0%	-	0%	-	0%	-	0%
Goathorn Creek													
WQS15	Ultra-oligotrophic	-	0%	-	0%	-	0%	-	0%	1.15	100%	-	0%
WQS14	Ultra-oligotrophic	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS13	Ultra-oligotrophic - Oligotrophic	1.40	11.1%	1.14	11.1%	-	0%	-	0%	-	0%	-	0%
WQS06-US	Ultra-oligotrophic - Mesotrophic	3.17	16.7%	1.82	8.3%	-	0%	-	0%	-	0%	-	0%
WQS07	Ultra-oligotrophic	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS06	Ultra-oligotrophic - Meso-eutrophic	3.58	56.0%	2.39	12.0%	1.91	4.0%	-	0%	-	0%	-	0%
E242647	Ultra-oligotrophic - Oligotrophic	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS05	Ultra-oligotrophic - Eutrophic	4.56	62.5%	2.85	15.6%	1.99	9.4%	-	0%	-	0%	1.69	6.3%
Helps Creek													
WQS16	Ultra-oligotrophic - Oligotrophic	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS17	Ultra-oligotrophic - Oligotrophic	1.70	20.0%	1.79	20.0%	-	0%	-	0%	-	0%	-	0%
Telkwa River													
WQS08	Ultra-oligotrophic - Eutrophic	5.77	67.7%	2.51	19.4%	3.71	3.2%	-	0%	1.71	3.2%	1.99	9.7%
WQS09	Ultra-oligotrophic - Eutrophic	6.66	51.6%	2.37	19.4%	3.46	3.2%	1.31	3.2%	1.39	3.2%	1.14	6.5%
WQS10	Ultra-oligotrophic - Eutrophic	6.50	56.5%	1.63	13.0%	-	0%	-	0%	1.32	4.3%	1.22	8.7%
400187	Ultra-oligotrophic - Mesotrophic	2.70	14.3%	1.94	8.3%	-	0%	-	0%	-	0%	-	0%
Bulkley River													
WQS11-US	Ultra-oligotrophic - Eutrophic	6.62	47.6%	8.05	23.8%	8.90	9.5%	-	0%	-	0%	1.65	9.5%
WQS11	Ultra-oligotrophic - Eutrophic	4.54	50.0%	1.65	15.0%	1.03	5.0%	-	0%	-	0%	-	0%
E246125	-	2.33	33.3%	n/a	n/a	n/a	n/a	-	0%	n/a	n/a	-	0%
WQS12	Ultra-oligotrophic - Eutrophic	5.85	58.6%	3.81	27.6%	9.89	3.4%	-	0%	-	0%	1.35	13.8%
400434	Ultra-oligotrophic - Oligotrophic	-	0%	n/a	n/a	n/a	n/a	-	0%	n/a	n/a	-	0%
400435	Ultra-oligotrophic - Oligotrophic	-	0%	n/a	n/a	n/a	n/a	-	0%	n/a	n/a	-	0%

(continued)

Table 8.5-1. BC and CCME Water Quality for the Protection of Freshwater Aquatic Life Guideline Screening, Tenas Project (completed)

Site	Total Copper		Dissolved Copper				Total Iron				Dissolved Iron		Total Lead		Total Zinc			
	CCME		BC				CCME		BC		BC		CCME		BC			
	-		Chronic		Acute		-		Short-term		Short-term		-		Long-term		Short-term	
	Hardness-dependent		Hardness, pH, DOC and temperature-dependent		Hardness, pH, DOC and temperature-dependent		0.3		1		0.35		Hardness-dependent		Hardness-dependent		Hardness-dependent	
	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Tenas Creek																		
WQS01	1.65	20.0%	1.32	21.9%	-	0%	2.91	15.6%	1.42	6.3%	-	0%	-	0%	-	-	-	0%
WQS02	1.68	17.9%	1.82	16.7%	-	0%	3.20	13.3%	1.30	6.7%	1.43	3.3%	-	0%	-	-	-	0%
WQS04	2.14	40.0%	2.64	20.0%	-	0%	3.34	40.0%	1.23	20.0%	-	0%	-	0%	-	0%	-	0%
WQS04B	1.98	35.0%	1.07	9.5%	-	0%	2.59	33.3%	1.49	9.5%	-	0%	-	0%	-	0%	-	0%
E242646	1.29	4.3%	2.53	18.2%	-	0%	1.03	4.3%	-	0%	-	0%	-	0%	-	0%	-	0%
Four Creek																		
WQS03	1.63	16.0%	-	0%	-	0%	2.17	16.0%	-	0%	1.15	8.0%	-	0%	-	0.0%	-	0%
WQS03-DS	2.40	23.1%	-	0%	-	0%	4.54	21.4%	1.68	14.3%	1.36	7.1%	-	0%	1.08	7.1%	-	0%
WQS18	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
Goathorn Creek																		
WQS15	2.44	100.0%	18.80	100.0%	3.42	100.0%	-	0%	-	0%	-	0%	-	0%	1.28	100.0%	-	0%
WQS14	-	0%	1.55	100.0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS13	1.64	33.3%	1.61	77.8%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS06-US	1.86	27.3%	2.74	100.0%	1.90	8.3%	1.73	8.3%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS07	-	0%	2.01	100%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS06	2.07	41.7%	3.13	52.0%	1.41	8.0%	1.97	36.0%	1.06	4.0%	-	0%	-	0%	-	0%	-	0%
E242647	1.22	9.1%	2.09	66.7%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS05	1.91	37.9%	2.12	50%	-	0%	2.54	28.1%	1.48	6.3%	1.22	3.1%	-	0%	9.78	6.3%	4.21	3.1%
Helps Creek																		
WQS16	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
WQS17	1.27	20%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
Telkwa River																		
WQS08	1.65	24.1%	2.27	36.4%	1.22	3.3%	2.58	54.8%	1.41	16.1%	1.16	6.5%	1.88	9.7%	1.69	3.2%	-	0%
WQS09	1.79	20.7%	1.81	41.7%	1.08	3.3%	2.51	48.4%	1.46	12.9%	1.03	6.5%	1.95	6.5%	1.73	3.2%	-	0%
WQS10	1.82	18.2%	2.69	29.4%	-	0%	2.85	43.5%	1.74	13.0%	-	0%	1.99	8.7%	1.27	8.7%	-	0%
400187	-	0%	1.74	41.7%	-	0%	1.31	19.0%	-	0%	-	0%	-	0%	-	0%	-	0%
Bulkley River																		
WQS11-US	2.03	10.5%	1.49	50%	-	0%	2.87	38.1%	1.94	9.5%	3.94	4.8%	-	0%	1.11	4.8%	-	0%
WQS11	1.18	10.5%	1.58	38.5%	-	0%	2.42	30%	1.25	5.0%	-	0%	-	0%	-	0%	-	0%
E246125	-	0%	n/a	n/a	n/a	n/a	2.01	50%	-	0%	n/a	n/a	1.02	33.3%	-	0%	-	0%
WQS12	1.55	18.5%	1.55	45.5%	-	0%	3.02	37.9%	1.67	10.3%	3.69	3.4%	-	0%	1.28	3.4%	-	0%
400434	-	0%	n/a	n/a	n/a	n/a	-	0%	-	0%	n/a	n/a	-	0%	-	0%	-	0%
400435	-	0%	n/a	n/a	n/a	n/a	-	0%	-	0%	n/a	n/a	-	0%	-	0%	-	0%

Notes:

All units in mg/L; only parameters above guidelines are shown.

Canadian Council of Ministers of Environment water quality guidelines for the protection of aquatic life (CCME 2014).

British Columbia water quality guidelines for the protection of freshwater aquatic life (BC ENV 2019).

Half the detection limit was substituted for values below the detection limit.

Field duplicate samples were averaged before calculations.

Factor represents the factor by which average sample concentrations were greater than guideline concentrations.

Percent represents the percentage of samples collected at each site that were greater than guidelines.

Hardness-dependent guidelines were calculated according to the hardness of each sample.

Metals data prior to 2002 was excluded due to poor detection limits.

5-in-30 samples were collected at WQS01, WQS02, WQS05, WQS08, WQS09, WQS11-US, and WQS12 in 2018. As a conservative approach, these samples were screened against the BC and CCME water quality guidelines as discrete samples.

8.5.9 Quality Assurance/Quality Control

8.5.9.1 *Field*

Field and travel blanks were collected during each sampling trip from May 2017 to November 2019 except for trips conducted by Hemmera (Appendix 8-C). Overall, measured parameters in field and travel blanks were usually below the analytical detection limits, with a few exceptions. Detections of acidity were common in both the field and travel blanks, which reflects the slight acidic pH in equilibrium with atmospheric CO₂. There were sporadic detections of total phosphorus, ammonia, total alkalinity, dissolved organic carbon, total aluminum, total barium, total chromium, total magnesium, total manganese, and phenols in the field blanks. The travel blanks had irregular detections of total alkalinity, turbidity, ammonia, total and dissolved barium, total chromium, total molybdenum, total tin, Ra-226, phenols and PAHs. The detectable values were close to the detection limits, indicating sample contamination was low and that the water quality results were of good quality and reliable.

A total of 55 duplicate water quality samples were collected from May 2017 to November 2019 (Appendix 8-D). The RPD was calculated for parameters where at least one of the duplicates had concentrations at least five times greater than their detection limit, which was 21% (1586/7645) of the duplicate measurements. Of these, the calculated RPD was between 20% and 50% for 95 (6%) of the duplicate concentrations, and above 50% for 55 (3.5%) of the duplicate concentrations. Elevated RPDs were generally sporadic. The highest number of elevated RPDs occurred during high flow events (May/June and October). This elevated variability could be linked to the increased flow from freshet and precipitation events (see Section 7, Hydrology). The field duplicate results indicate that sampling heterogeneity was low, and the data are of good quality, but with increased variability noted in May and October that could have been linked to peak flow events.

8.5.9.2 *Laboratory*

Laboratory contamination was low, as method blanks were below detection limits with the exception of a few sporadic detections (acidity, alkalinity, total nitrogen, nitrate, fluoride, sulfate, dissolved aluminum, total arsenic, total antimony, total calcium, total and dissolved chromium, total and dissolved copper, total iron, total magnesium, total and dissolved manganese, total molybdenum, total and dissolved nickel, total silver, total sulfur, and total zinc). The limits of reporting were adjusted for all associated samples, and sample ranges were at or above the detections in the method blanks.

All reference materials and matrix spikes were within their target ranges except for one certified reference material sample which was slightly above the recovery limit for acidity. Some laboratory control samples were marginally outside (<10% total) of their target range for total alkalinity, total and dissolved bismuth, dissolved lithium, dissolved magnesium, total and dissolved sulphur, total thallium, anthracene, indeno(1,2,3-c,d)pyrene, EPH10-19, and EPH-19-32. The April 2018 laboratory control samples had a few high recoveries for PAHs that were marginally outside their control limits (<15%); however, all associated samples were below detection limits so this did not affect the results. There were some matrix spike recoveries that could not be determined due to high analyte background in the sample. Laboratory replicate concentration RPD values were low (<20%), and all within defined limits. In all cases where quality control samples were outside their target ranges, the results were examined by the laboratory personnel to determine acceptability of samples associated

with the QC batch. Overall, laboratory QA/QC measures demonstrated that analyses generally fell within data quality objectives, and data are of good quality.

All samples were analyzed within their recommended holding times, with the following exceptions: pH which has a short holding time (15 minutes) and was measured in the field (within the 15-minute holding time); several parameters with three day holding times (colour, BOD, turbidity, nitrate, nitrite, and dissolved orthophosphate). TSS and TDS were analyzed one day after the recommended 7-day holding time sporadically; and acidity, alkalinity, and PAHs were analyzed one to six days after the recommended 14 day holding time infrequently.

For metals results, the concentration of the dissolved fraction was compared to the concentration of the total fraction. There were several cases where the dissolved fraction was greater than the total fraction. For very low concentrations of metals (concentrations near detection limits), some variability of analytical results is generally acceptable (30% Relative Percent Difference). If the threshold of acceptability is not met, ALS laboratories confirms the results by re-analysis prior to issuing the data. ALS laboratories conducts these checks for all samples prior to issuing data.

9. SEDIMENT QUALITY

This chapter presents the methods and results of the sediment quality baseline monitoring program. The purpose of the 2017 to 2019 sediment quality program was to collect Project-specific baseline sediment chemistry data. An understanding of site-specific aquatic characteristics will contribute to engineering analysis and water management feature design; support future development of water quality/water balance models, effects assessments, management plans, and closure planning; support permitting; support aquatic monitoring programs; and monitor changes in the local environment.

The objectives of the 2017 to 2019 sediment quality baseline program were to:

- characterize the spatial variability of sediment quality in creeks and rivers near the Project area; and
- establish sediment quality sites upstream and downstream of proposed Project infrastructure to support permitting and future monitoring programs.

9.1 STUDY AREA

The study area for sediment quality was the same as for surface water quality, as described in Section 8.1.

Sediment quality was sampled from 14 sites in the Project area, which overlapped with water quality and aquatic resources sampling (Tables 9.1-1 and 9.1-2; Figure 8.1-1). Sampling was conducted in September 2017, September 2018, August 2019, and October 2019 concurrently with aquatic resources sampling. Historical information was also available within the Project area from two sites in Tenas Creek sampled in 1986 (Section 9.3).

Table 9.1-1. Sediment Quality Sampling Sites, Tenas Project, 1986, and 2017 to 2019

Waterbody	Site	Easting (m)	Northing (m)	Description
Tenas Creek	STRM93L861699	614672	6049404	Tenas Creek above confluence with unnamed tributary; ~1.4 km upstream of WQS01
	WQS01	615171	6050438	Upstream reference for proposed Project infrastructure
	WQS02	616914	6053490	Near-field downstream of deposits and proposed associated Project infrastructure
	STRM93L861412	617290	6054135	Near-field downstream of deposits and proposed associated Project infrastructure; ~800 m downstream of WQS02
	WQS04B	620676	6057950	Mid-field downstream of deposits and proposed associated Project infrastructure

(continued)

Table 9.1-1. Sediment Quality Sampling Sites, Tenas Project, 1986, and 2017 to 2019 (completed)

Waterbody	Site	Easting (m)	Northing (m)	Description
Four Creek	WQS03-DS	620034	6054076	Immediately upstream of proposed Project infrastructure; potentially influenced by historical workings
	WQS18	620071	6054130	Downstream of mine hydrology and water quality influences (immediately downstream of proposed haul road)
Goathorn Creek	WQS06-US	620587	6053711	Upstream of WQS06 and of confluence with Four Creek; potentially influenced by historical workings
	WQS07	620489	6053814	Downstream of mine hydrology and water quality influences (upstream of proposed haul road)
	WQS05	620615	6058133	Mid-field downstream of confluence with Tenas Creek
Helps Creek	WQS16	625906	6055851	Upstream of proposed Tenas bypass road
	WQS17	625801	6055979	Downstream of proposed Tenas bypass road
Telkwa River	WQS08	617702	6057686	Upstream reference; above confluence with Goathorn Creek; ~300 m upstream of water quality site
	WQS09	621394	6058998	Mid-field downstream of confluence with Goathorn Creek
Bulkley River	WQS11-US	630472	6056723	Upstream reference for proposed rail infrastructure
	WQS12	625021	6063831	Mid-field downstream of proposed rail infrastructure and confluence with the Telkwa River

Table 9.1-2. Sediment Quality Sample Replicates, Tenas Project

Waterbody	Site	1986	2017	2018	2019
Tenas Creek	STRM93L861699	1	-	-	-
	WQS01	-	3	-	1
	WQS02	-	3	-	1
	STRM93L861412	1	-	-	-
	WQS04B	-	-	-	1
Four Creek	WQS03-DS	-	-	-	5
	WQS18	-	-	-	5
Goathorn Creek	WQS06-US	-	-	-	5
	WQS07	-	-	-	5
	WQS05	-	3	-	1
Helps Creek	WQS16	-	-	-	5
	WQS17	-	-	-	5
Telkwa River	WQS08	-	3	-	1
	WQS09	-	3	-	1
Bulkley River	WQS11-US	-	-	3	1
	WQS12	-	3	-	1

Values represent the number of replicates; values exclude field splits.

9.2 REGULATORY AND POLICY FRAMEWORK

The provincial and federal policies and regulations discussed in Section 8.2 for surface water quality are also applicable to sediment quality. There are also federal and working provincial sediment quality guidelines for the protection of aquatic life (BC ENV 2019, CCME 2019).

9.3 EXISTING INFORMATION

A review of existing information was undertaken for the Tenas Project, which included examining public sources of sediment quality data and historical reports (Table 9.3-1). Data were reviewed for quality, relevance (i.e., geographic), and compliance with the requirements for Environmental Assessment and for the Joint MA/EMA permit applications. Guidance was followed from the Joint AIR for MA/EMA Permits (BC MEM and MOE 2016), which recommends following the guidance outlined in the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) and the *BC Field Sampling Manual* (Clark 2002, 2013 edition). The *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) provides detailed direction regarding the collection of baseline data for projects that trigger the Environmental Assessment Process.

Table 9.3-1. Sediment Quality Data Information Table

Documents Reviewed	Publically available data • Regional Geochemistry Survey (RGS) ▪ Stumpf. 2012. <i>Till Geochemistry and Clast Lithology Studies of the Bulkley River Valley, West-Central British Columbia (parts of NTS 093L)</i>. Geoscience BC 2008-012 ▪ Geoscience BC. 2009. <i>Quest-West Project Sample Reanalysis</i>. Geoscience BC 2009-05 Client-supplied consultant reports • Frontier Geosciences Inc. 1999. <i>Report to Stephen Day BC Research Selenium Results</i>
General Remarks	The RGS stream sediment data in the Quest-West sample reanalysis included data within the Project area; these were incorporated in the data summary below. Archived samples collected in 1986 were re-analyzed by inductively coupled plasma mass spectrometry (ICP-MS). The data presented in Stumpf (2012) and Frontier Geosciences (1999) are of limited use due to sampling focus or missing/incomplete data.
Sampling Required for EA and by Joint AIR for Mines Act and Environmental Management Act Permits (Joint AIR for MA/EMA Permits)	Minimum of once per year during summer low-flow periods during the entire baseline period.

(continued)

Table 9.3-1. Sediment Quality Data Information Table (completed)

Existing Data	The data sources listed below were deemed useful and included in the data summary: - Geoscience BC - STRM93L861699 – Tenas Creek upstream of WQS01; 1986 - STRM93L861412 – Tenas Creek downstream of WQS02; 1986 The data sources listed below were deemed not useful and were not included in the data summary: - Stumpf till geochemistry - Frontier Geosciences - HC3 to HC6, HC15 to HC18, and HC23; January 1999
Existing Data Issues	It is unclear from the Geoscience BC 2009 report whether the stream sediment metal analysis was performed on the <63 µm size fraction. Data are included in the summary below, but should be interpreted with caution. Further, no replicates were collected and no QA/QC data are available (i.e., field splits, lab results). The Bulkley River Valley focused on till geochemistry instead of stream sediment geochemistry. Frontier Geosciences collected samples in January instead of during the summer low-flow period (as recommended by the Joint AIR for MA/EMA guidance). No map or UTM coordinates were provided in the report, so it is uncertain where samples were collected. Further, samples were analyzed using hydride generation-atomic fluorescence spectrometry (HG-AFS). The report did not indicate if sediment samples were sieved to <63 µm prior to metals analysis.
Missing Data	None.
2017-2019 Baseline Program	The 2017-2019 baseline program collected sediment quality from Tenas Creek, Four Creek, Goathorn Creek, Help Creek, the Telkwa River, and the Bulkley River.
Key Issues	- An upstream reference site on the Bulkley River was identified as an important station for the <i>Joint Mines Act/Environmental Management Act</i> application, and for future monitoring programs; this site was added in 2018 - PAHs have not been analyzed in sediment samples, which are recommended parameters for coal projects where there may be naturally high PAH concentrations in sediments
Other Comments	None.

9.4 METHODOLOGY

9.4.1 Sampling

Sediment samples were collected from 14 sites in the Project area from August to October in 2017 to 2019, with three replicate samples collected from each site in 2017 and 2018, and 1 to 5 replicates collected in 2019 (Figure 8.1-1). Replicates were collected from distinct areas of each stream (e.g., different stretches of the main channel). For each replicate, sediment was spooned from the top 3 to 5 cm in depositional zones (areas of slow moving water). The subsamples were pooled until sufficient sample was obtained for a complete replicate. Excess water was drained and the sample was manually homogenized before being placed into pre-labelled containers. Samples were kept cool in the dark until analyzed by ALS Labs (ALS).

9.4.2 Analysis

Whole sediment samples from streams were analyzed for pH, particle size, nutrients, and TOC. In 2017 and 2018, metal analyses were conducted on the <63 µm fraction of the sample because this is more bioavailable to benthic organisms and fine grained material tends to contain greater concentrations of metals and other contaminants than the coarse sediment fraction (BC MOE 2016). In 2019, metals analysis was conducted on the <2 mm size fraction. As such, variations of metal concentrations between the 2017/2018 data set and the 2019 data set should be interpreted with caution.

Sediments were compared to the current BC ENV working sediment quality criteria (BC ENV 2019) and CCME sediment quality guidelines (CCME 2019). BC sediment quality criteria includes a lower guideline and an upper guideline that provide a flexible interpretive tool for evaluating the toxicological significance of sediment chemistry data (BC ENV 2019). Sediment chemical concentrations below the lower guideline are rarely associated with adverse effects on biological communities and concentrations between the lower and upper guideline are occasionally associated with adverse biological effects. Sediment concentrations above the upper guideline are frequently associated with adverse effects on biological communities (BC ENV 2019). Similarly, the CCME guidelines include the Interim Sediment Quality Guidelines (ISQG) and the Probable Effect Levels (PEL), analogous to the BC lower and upper guidelines.

The percentage of stream sediment samples with concentrations greater than BC and CCME guidelines and the mean factor by which concentrations were greater than guidelines were calculated. The mean factor and percentage of sediment concentrations greater than BC ENV and CCME guidelines are presented together in this report because many provincial and federal guidelines are identical.

9.4.3 Quality Assurance/Quality Control

9.4.3.1 Field

The sediment quality assurance/quality control (QA/QC) program in 2017 and 2018 included three sediment replicate samples collected at each stream site, and the 2019 program included 5 replicate samples at select sites. Chain of custody (COC) forms were used for all samples. To determine the effectiveness of sample homogenization, a proportion of samples in 2017 and 2019 were split in the field and submitted to ALS as a blind sample and analyzed separately. The relative percent difference (RPD) between each set of sediment splits was calculated if at least one of the parameter concentrations was greater than five times the analytical detection limit (Equation 1 in Section 8.4.3.1; Clark 2013).

9.4.3.2 Laboratory

The ALS sediment QA/QC program included method blanks, laboratory replicates, and reference material. Potential laboratory contamination was assessed using method blanks, where analyte-free matrices were prepared and analyzed using the same methods as regular samples. Laboratory replicates were used to assess analytical precision by taking subsamples of field samples that were subsequently analyzed separately using the same analytical methods. Finally, reference materials, which are standards with known concentrations, were analyzed using the same methods as regular samples to assess the methodological accuracy.

9.5 DATA SUMMARY

Sediment quality analytical results are presented in Appendix 9-A.

Project area sediments consisted mainly of sand (0.063 to 2.0 mm), that on average made up 40% to 96% of stream sediments, followed by gravel (1% to 37%) and silt (2% to 34%; Figure 9.5-1). The highest proportion of fine sediments occurred at the upstream Bulkley River site (WQS11-US), Four Creek, and WQS01 in 2019. Total organic carbon was low in the Project area sediments, with annual means ranging from 0.07% at WQS08 in 2017 to 2.26% at WQS05 in 2019 (Figure 9.5-1).

Sediment metal concentrations varied across Project area streams (Figures 9.5-2 to 9.5-7). Several sediment metal concentrations were highest in Goathorn Creek and Helps Creek, which both had elevated cadmium and zinc. Further, Goathorn Creek had high sediment copper, while Helps Creek had high arsenic and lead. Sediment chromium, iron, manganese, and nickel were elevated in Tenas Creek compared to other sampled streams, with higher concentrations typically observed in the upper portion of the creek (WQS01 and WQS02); however, only one sample was collected from WQS04B. Silver concentrations were low (<0.2 mg/kg), with higher concentrations generally measured in the Telkwa and Bulkley rivers. Selenium concentrations were low in Project area streams with the majority of samples below detection limits (66%, 0.1 to 0.2 mg/kg), and a maximum of 0.31 mg/kg in Goathorn Creek samples from WQS06-US and WQS07. Sediment mercury concentrations were also commonly below the detection limit (65%, 0.005 to 0.05 mg/kg).

Sediment arsenic, iron, manganese, and nickel concentrations appear to be elevated in the Project area as concentrations of these metals at all sites, including upstream of the Project, were above BC lower sediment quality guidelines (Table 9.5-1). Further, iron and manganese concentrations were greater than the BC upper sediment quality guideline in every stream (except iron in Helps Creek), while arsenic concentrations were above the upper guideline in Helps Creek. Sediment copper concentrations were above the BC lower guideline in Tenas Creek, Goathorn Creek, and the Telkwa River. Sediment cadmium and zinc concentrations in Goathorn Creek and Helps Creek were higher than the BC lower guidelines. Samples from upper Tenas Creek and the upstream Bulkley River site were marginally above the BC lower chromium guideline. Goathorn Creek sediment concentrations were above most sediment quality guidelines, followed by Helps Creek and upper Tenas Creek. All Project area stream sediment concentrations were below federal and provincial guidelines for lead, mercury, selenium, and silver.

9.5.1 Quality Assurance/Quality Control

Sediment quality assurance/quality control results are available in Appendix 9-B.

Figure 9.5-1

**Particle Size and Total Organic Carbon in
Tenas Project Stream Sediments, 1986, 2017 to 2019**

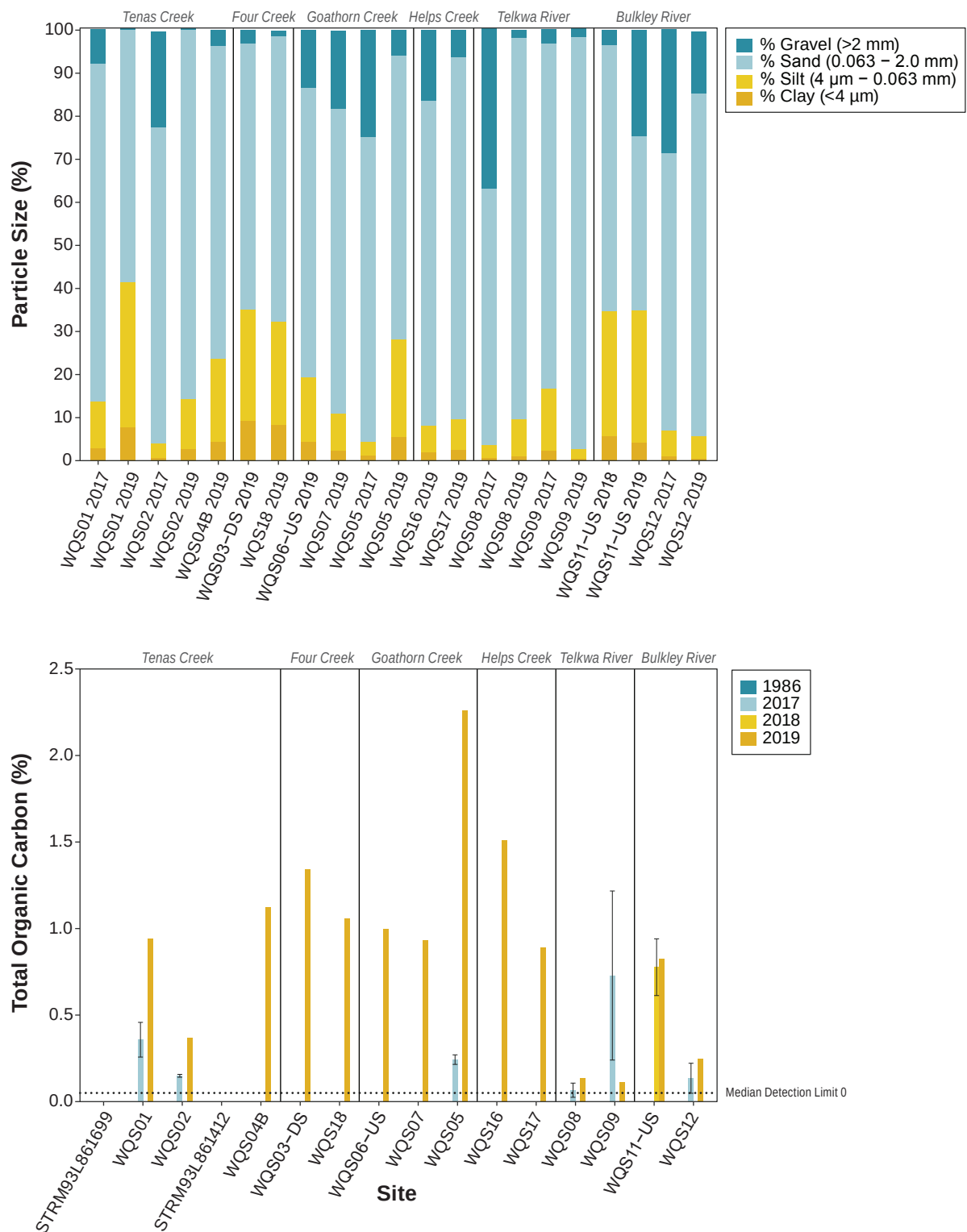
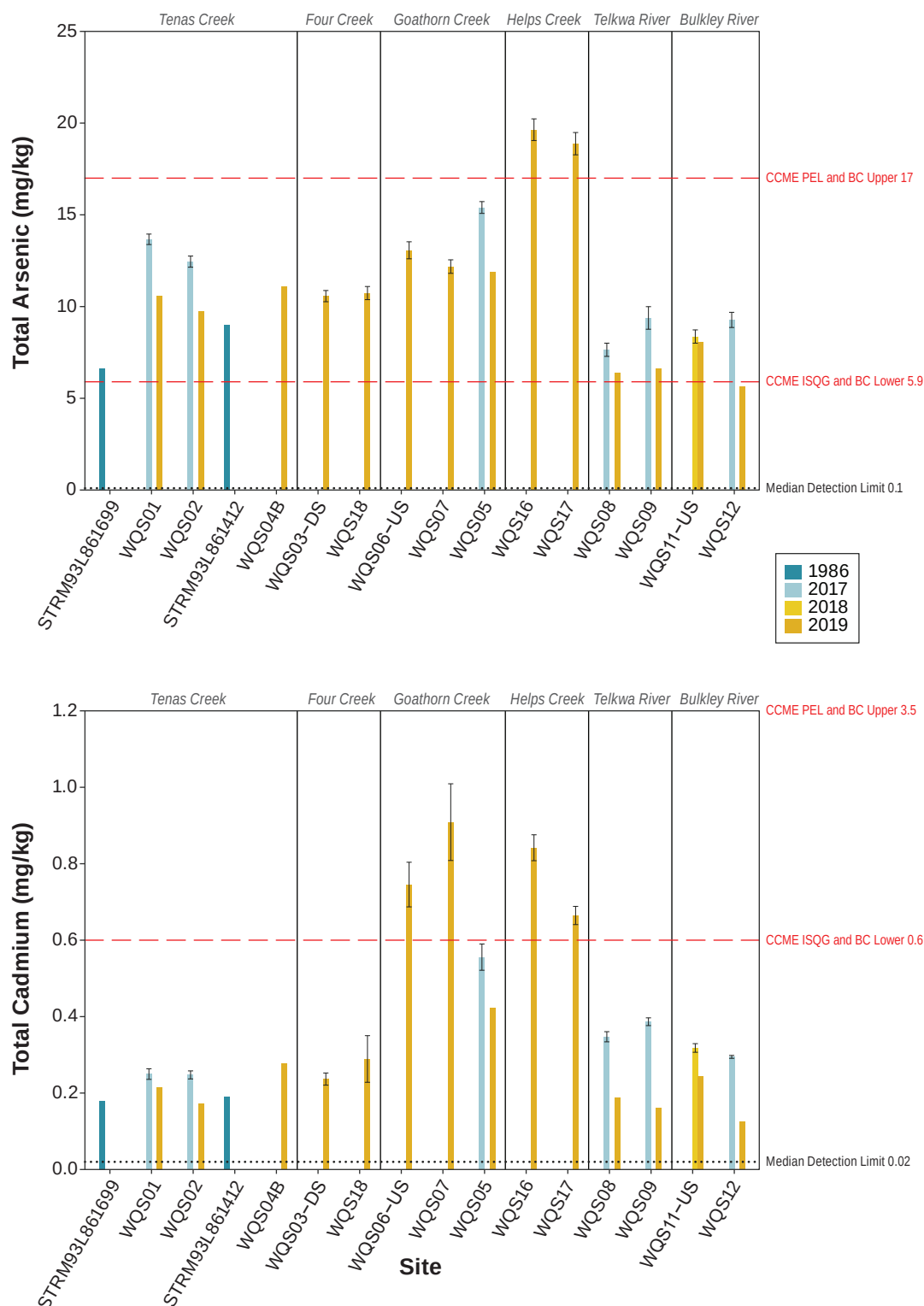


Figure 9.5-2

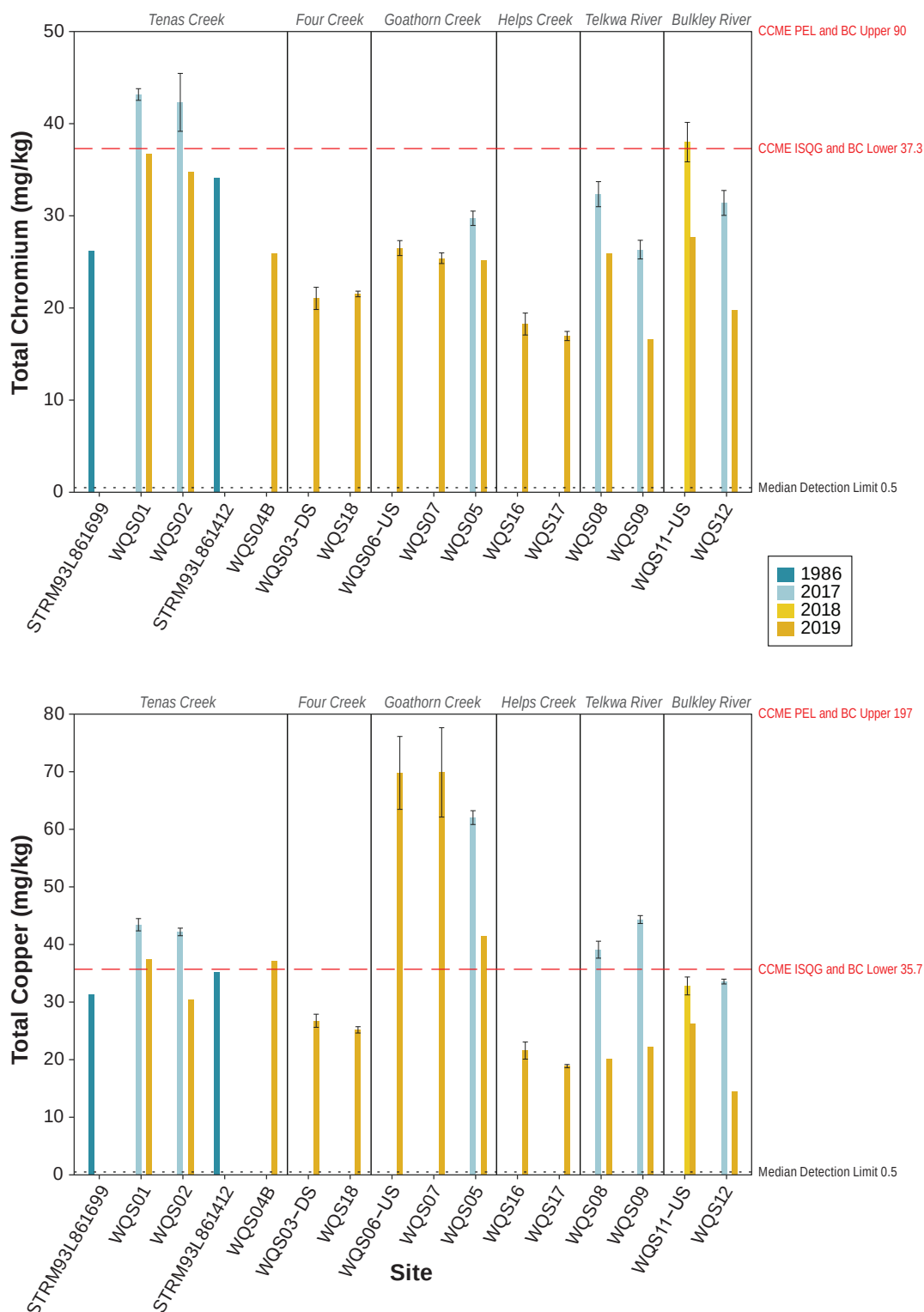
Arsenic and Cadmium in Tenas Project Stream Sediments, 1986, 2017 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME sediment quality guideline: PEL = probable effect level; ISQG = interim sediment quality guideline.

Figure 9.5-3

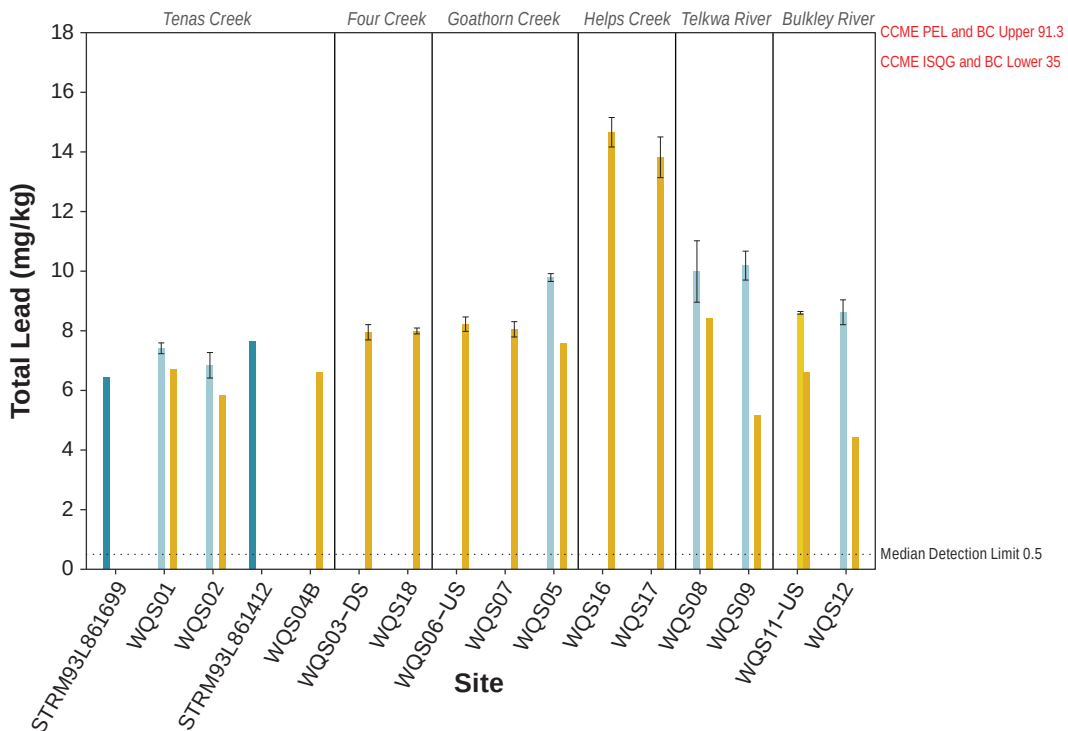
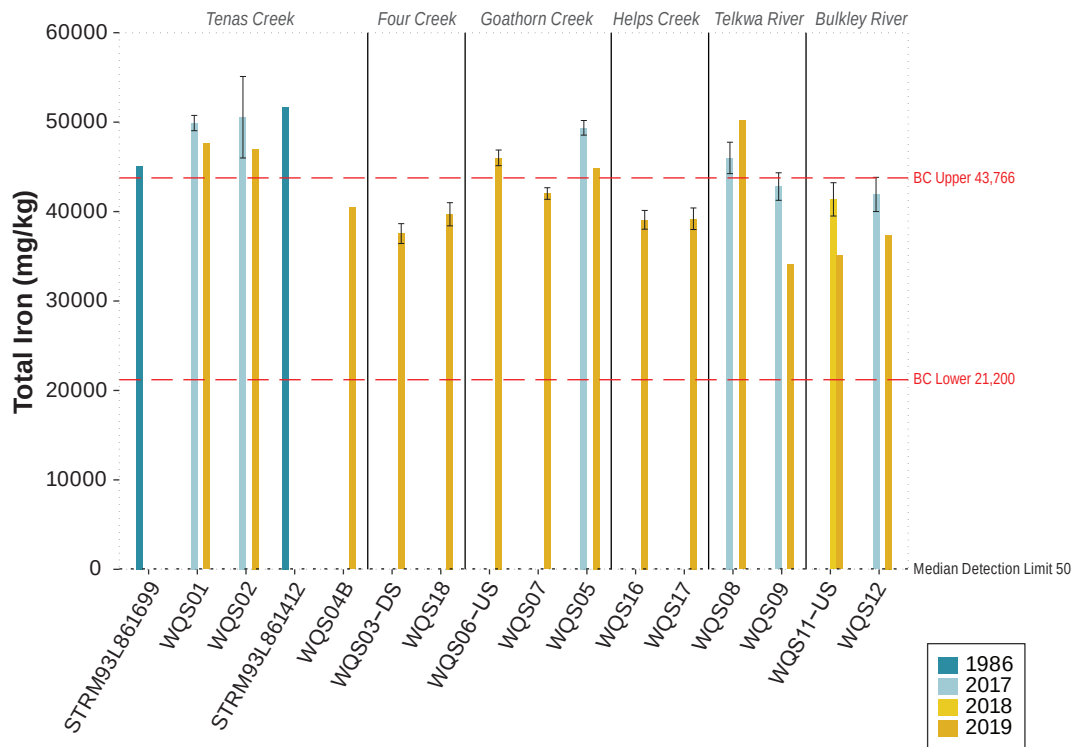
Chromium and Copper in Tenas Project Stream Sediments, 1986, 2017 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME sediment quality guideline: PEL = probable effect level; ISQG = interim sediment quality guideline.

Figure 9.5-4

Iron and Lead in Tenas Project Stream Sediments, 1986, 2017 to 2019



Notes: Error bars represent the standard error of the mean.
Values below the detection limit were plotted as half the detection limit.
CCME sediment quality guideline: PEL = probable effect level; ISQG = interim sediment quality guideline.

Figure 9.5-5

Manganese and Mercury in Tenas Project Stream Sediments, 1986, 2017 to 2019

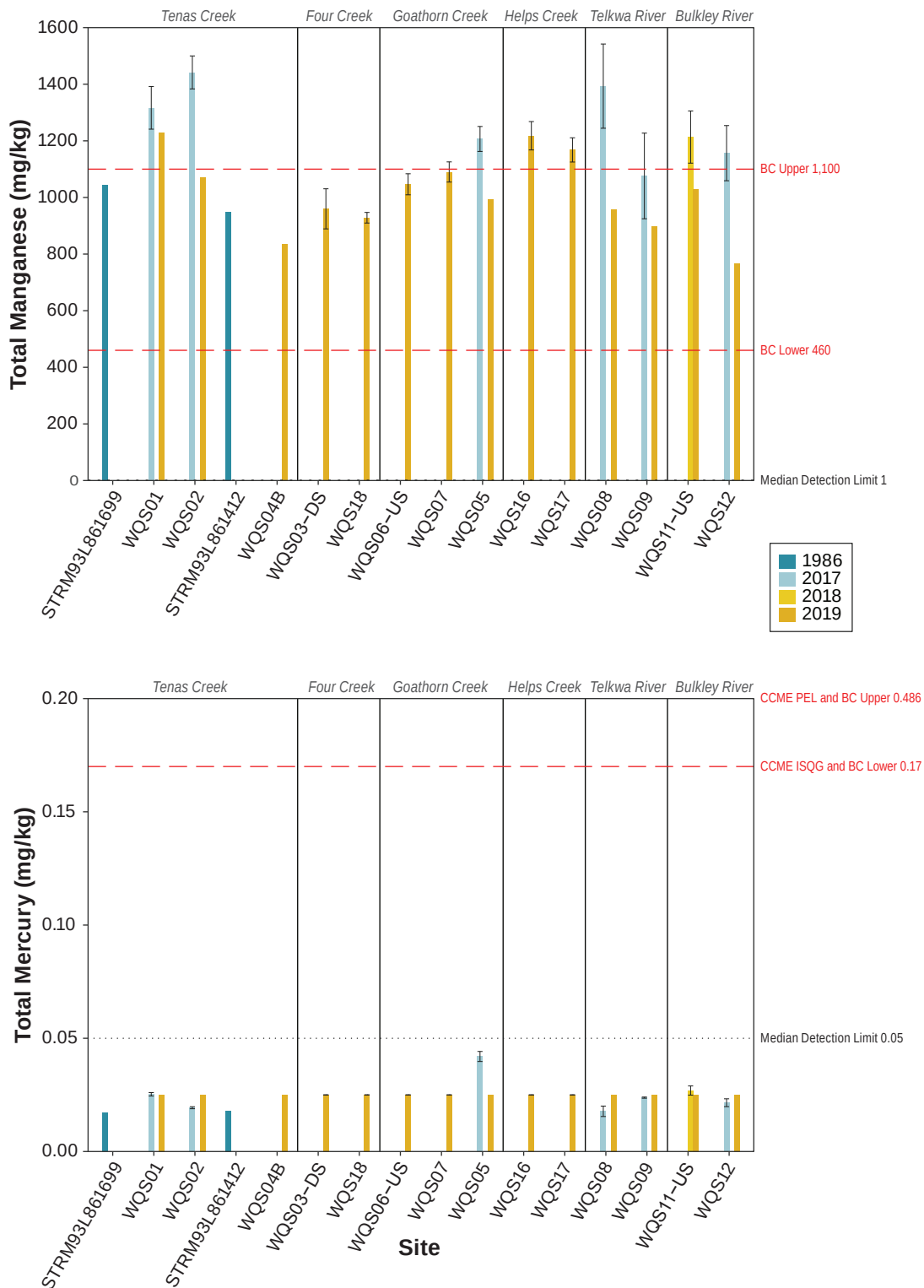


Figure 9.5-6

Nickel and Selenium in Tenas Project Stream Sediments, 1986, 2017 to 2019

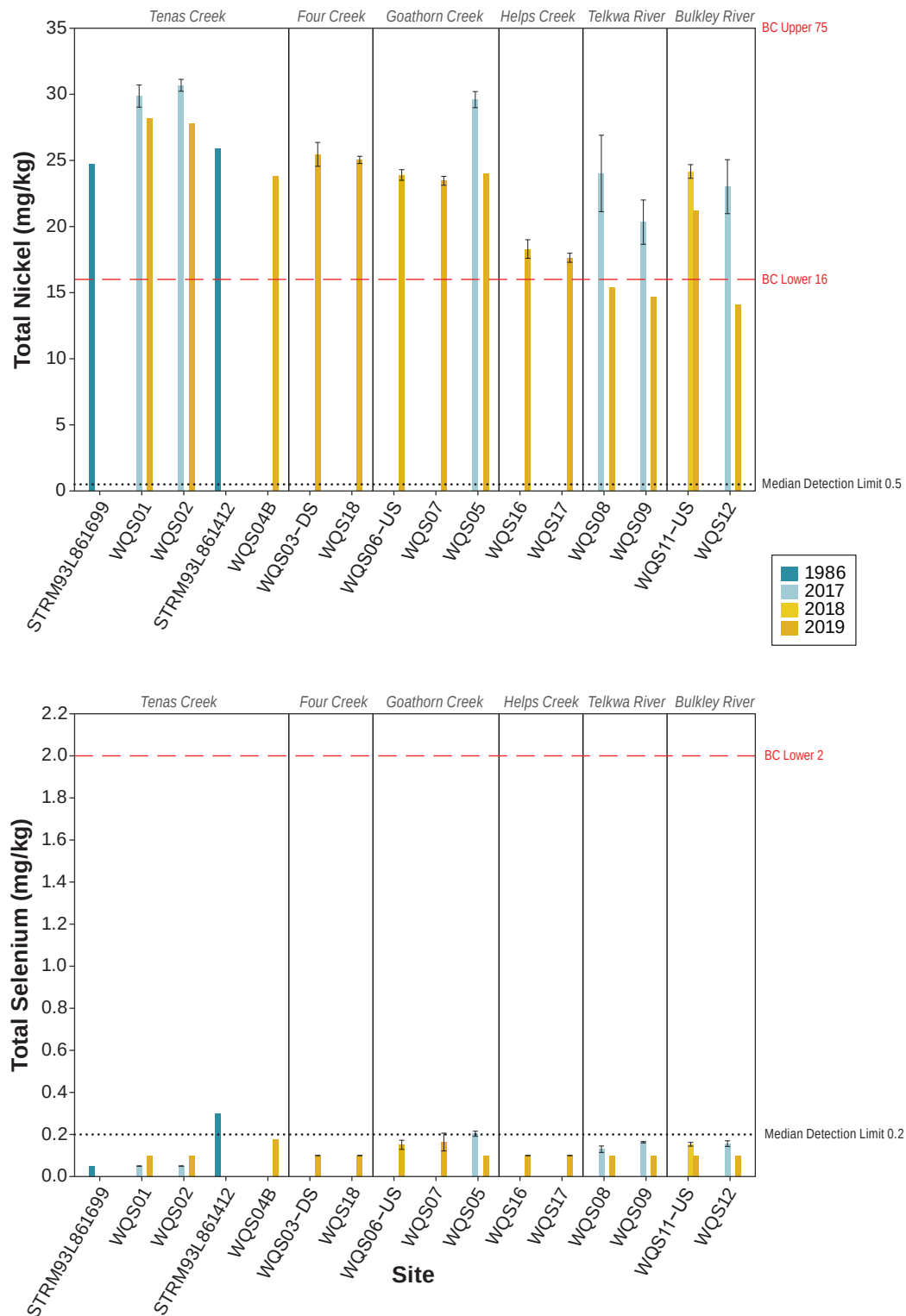


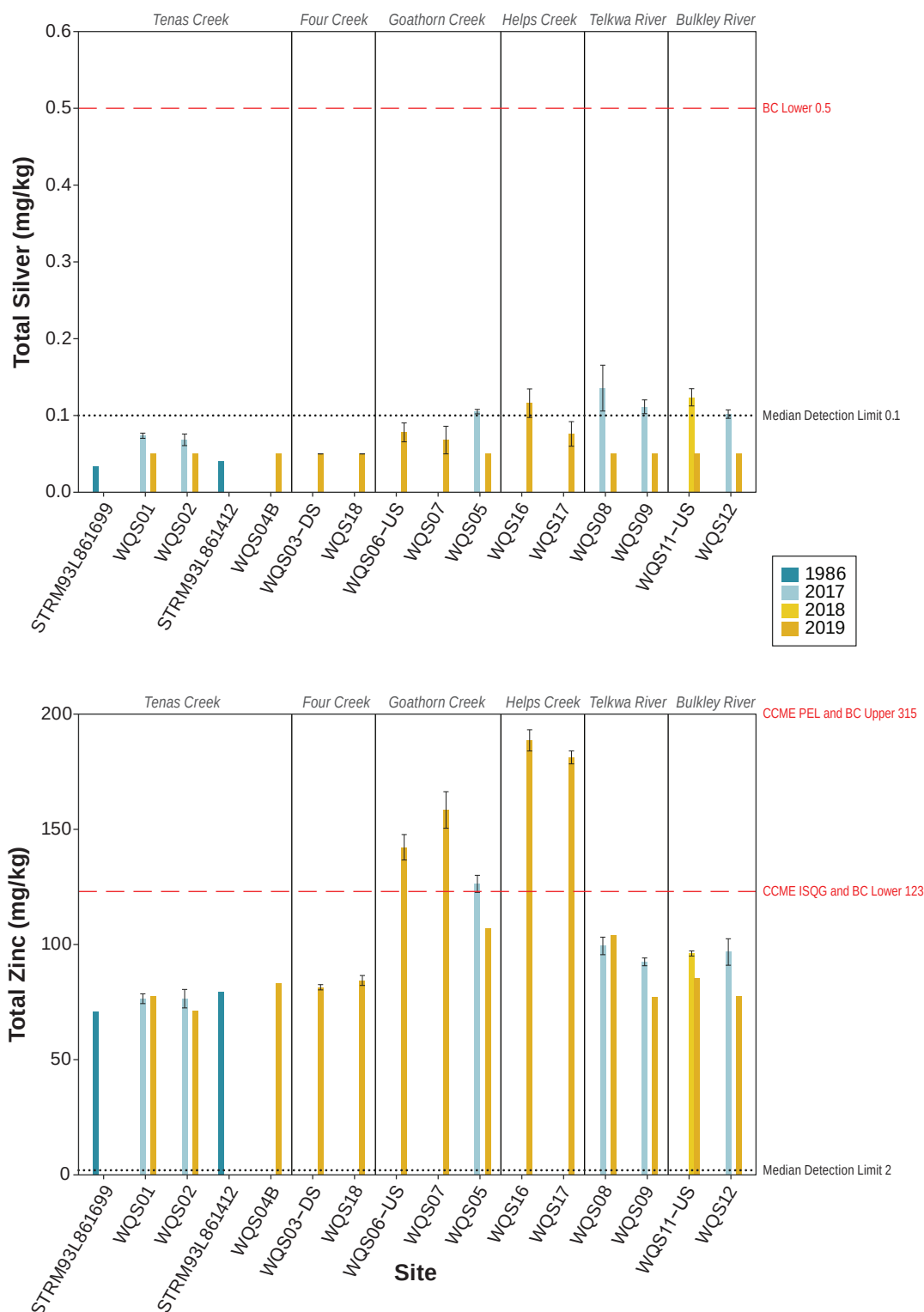
Table 9.5-1. BC and CCME Sediment Quality for the Protection of Freshwater Aquatic Life Guideline Screening, Tenas Project

Site	Arsenic BC = CCME				Cadmium BC = CCME		Chromium BC = CCME		Copper BC = CCME		Iron BC				Manganese BC				Nickel BC		Zinc BC = CCME	
	ISQG 5.9		PEL 17		ISQG 0.6		ISQG 37.3		ISQG 35.7		Lower 21,200		Upper 43,766		Lower 460		Upper 1,100		Lower 16		ISQG 123	
	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Tenas Creek																						
STRM93L861699	1.12	100%		0%		0%		0%		0%	2.13	100%	1.03	100%	2.27	100%		0%	1.54	100%		0%
WQS01	2.19	100%		0%		0%	1.16	75%	1.18	100%	2.33	100%	1.13	100%	2.82	100%	1.18	100%	1.84	100%		0%
WQS02	1.99	100%		0%		0%	1.13	75%	1.18	75%	2.34	100%	1.13	100%	2.93	100%	1.31	75%	1.87	100%		0%
STRM93L861412	1.53	100%		0%		0%		0%		0%	2.44	100%	1.18	100%	2.06	100%		0%	1.62	100%		0%
WQS04B	1.88	100%		0%		0%		0%	1.04	100%	1.91	100%		0%	1.82	100%		0%	1.49	100%		0%
Four Creek																						
WQS03-DS	1.79	100%		0%		0%		0%		0%	1.77	100%		0%	2.09	100%	1.05	20%	1.59	100%		0%
WQS18	1.82	100%		0%		0%		0%		0%	1.87	100%	1.01	20%	2.02	100%		0%	1.56	100%		0%
Goathorn Creek																						
WQS06-US	2.21	100%		0%	1.32	80%		0%	1.95	100%	2.17	100%	1.07	80%	2.28	100%	1.04	20%	1.49	100%	1.20	80%
WQS07	2.06	100%		0%	1.51	100%		0%	1.96	100%	1.98	100%	1.00	20%	2.37	100%	1.11	20%	1.47	100%	1.29	100%
WQS05	2.46	100%		0%	1.01	25%		0%	1.59	100%	2.28	100%	1.10	100%	2.51	100%	1.1	75%	1.76	100%	1.06	50%
Helps Creek																						
WQS16	3.33	100%	1.16	100%	1.4	100%		0%		0%	1.84	100%		0%	2.65	100%	1.15	80%	1.14	100%	1.53	100%
WQS17	3.20	100%	1.14	80%	1.14	80%		0%		0%	1.85	100%		0%	2.54	100%	1.09	80%	1.10	100%	1.47	100%
Telkwa River																						
WQS08	1.24	100%		0%		0%		0%	1.10	75%	2.22	100%	1.11	75%	2.79	100%	1.27	75%	1.50	75%		0%
WQS09	1.47	100%		0%		0%		0%	1.24	75%	1.92	100%	1.05	25%	2.24	100%	1.23	25%	1.27	75%		0%
Bulkley River																						
WQS11-US	1.41	100%		0%		0%	1.13	25%		0%	1.88	100%	1.02	25%	2.54	100%	1.16	50%	1.46	100%		0%
WQS12	1.57	75%		0%		0%		0%		0%	1.92	100%	1.04	25%	2.30	100%	1.23	25%	1.44	75%		0%

Notes:
All units in mg/kg; only parameters above guidelines are shown.
British Columbia working sediment quality guidelines for the protection of freshwater aquatic life (accessed September 2020).
Canadian Council of Ministers of Environment sediment quality guidelines for the protection of aquatic life (accessed September 2020).
Half the detection limit was substituted for values below the detection limit.
Split samples were averaged before calculations.
Factor represents the factor by which average sample concentrations were greater than guideline concentrations.
Percent represents the percentage of replicates collected at each site that were greater than guidelines.

Figure 9.5-7

Silver and Zinc in Tenas Project Stream Sediments, 1986, 2017 to 2019



Notes: Error bars represent the standard error of the mean.
 Values below the detection limit were plotted as half the detection limit.
 CCME sediment quality guideline: PEL = probable effect level; ISQG = interim sediment quality guideline.

9.5.1.1 *Field*

Nine sediment quality replicates were split in the field and analyzed separately (Appendix 9-B). The RPD was calculated for each set of duplicate parameters if at least one parameter concentration was greater than five times the detection limit, which amounted to 70% (235/335) of the duplicate split measurements. Of these, the calculated RPD was between 20% and 50% for 51 (22%) of the duplicate concentrations, and above 50% for 16 (7%) duplicate concentrations. The majority of these elevated RPDs were associated with metals from WQS02 in 2017 (16) and WQS04B in 2019 (22). WQS04B in particular had high RPD values, with 11 calculated RPDs above 50%. The two split samples from WQS04B had very different proportions of fines, which may explain the high variability in metals. This highlights the importance of analyzing the <63 μm size fraction for metals. Overall, field split sample results indicate some heterogeneity remained in the sample following homogenization.

9.5.1.2 *Laboratory*

The results of the 2017 to 2019 laboratory QA/QC program indicated that the data are of good quality. Laboratory duplicates and reference materials were within ALS's data quality objectives and there were no analyte detections in the methods blanks, except a single laboratory duplicate measurement of mercury that had an elevated RPD (49%). All samples were analyzed within recommended holding times.

10. AQUATIC RESOURCES

This chapter presents the methods and results of the aquatic resources baseline monitoring program. The purpose of the 2017 to 2019 aquatic resources program was to collect Project-specific baseline aquatic data. An understanding of site-specific aquatic characteristics will contribute to engineering analysis and the design of water management features; support future development of water quality and water balance models, effects assessments, management plans, and closure planning; support environmental assessment application and permitting; support aquatics monitoring programs; and monitor changes in the local environment.

The objectives of the 2017 to 2019 aquatic resource baseline program were to:

- characterize the spatial variability of aquatic resources in creeks and rivers near the Project area; and
- establish aquatic resources sites upstream and downstream of proposed Project infrastructure to support environmental assessment application, permitting, and future monitoring programs.

10.1 STUDY AREA

The study area for aquatic resources was the same as for surface water quality, as described in Section 8.1. Aquatic resources were sampled from 14 sites in the Project area, which overlapped with water quality and sediment quality sampling (Tables 10.1-1 and 10.1-2; Figure 8.1-1). Sampling was conducted in September 2017, September 2018, and August and October 2019, concurrently with sediment quality sampling. Historical aquatic resources information was also available within the Project area (Section 10.3). Historical aquatic resources data included benthic invertebrate data from Tenas Creek, Goathorn Creek, and the Bulkley River, and periphyton biomass data from the Bulkley River.

Table 10.1-1. Aquatic Resources Sampling Sites, Tenas Project

Waterbody	Site	Easting (m)	Northing (m)	Component	Description
Tenas Creek	WQS01	615171	6050438	All	Upstream reference for proposed Project infrastructure
	WQS02	616914	6053490	All	Near-field downstream of deposits and proposed associated Project infrastructure
	WQS04B*	620676	6057950	All	Mid-field downstream of deposits and proposed associated Project infrastructure; CABIN site name BUL15
Four Creek	WQS03-DS	620034	6054076	All	Immediately upstream of proposed Project infrastructure; potentially influenced by historical workings
	WQS18	620071	6054130	All	Downstream of mine hydrology and water quality influences (immediately downstream of proposed haul road)

(continued)

Table 10.1-1. Aquatic Resources Sampling Sites, Tenas Project(completed)

Waterbody	Site	Easting (m)	Northing (m)	Component	Description
Goathorn Creek	WQS06-US	620587	6053711	All	Upstream of WQS06 and of confluence with Four Creek; potentially influenced by historical workings
	WQS07	620489	6053814	All	Downstream of mine hydrology and water quality influences (upstream of proposed haul road)
	BUL16*	620784	6058012	CABIN	Upstream reference; above confluence with Tenas Creek and the bridge
	WQS05	620615	6058133	All	Mid-field downstream of confluence with Tenas Creek
Helps Creek	WQS16	625906	6055851	All	Upstream of proposed Tenas bypass road
	WQS17	625801	6055979	All	Downstream of proposed Tenas bypass road
Telkwa River	WQS08	617702	6057686	All	Upstream reference; above confluence with Goathorn Creek; ~300 m upstream of water quality site
	WQS09	621394	6058998	All	Mid-field downstream of confluence with Goathorn Creek
Bulkley River	WQS11-US	630472	6056723	All	Upstream reference for proposed rail infrastructure
	WQS12	625021	6063831	All	Mid-field downstream of proposed rail infrastructure and confluence with the Telkwa River
	BUL01*	618742	6072980	CABIN	Far-field downstream of Project; adjacent to Riverside Park in Smithers
	400434*	618410	6074024	Periphyton biomass	Far-field downstream of Project; downstream of Smithers and upstream of sewage discharge
	400435*	617870	6074979	Periphyton biomass	Far-field downstream of Project; downstream of Smithers and downstream of sewage discharge
	BUL73*	617361	6075053	CABIN	Far-field downstream of Project; downstream of Smithers and downstream of sewage discharge (~500 m downstream of 400435)

* Publicly available data.

CABIN = Canadian Aquatic Biomonitoring Network

10.2 REGULATORY AND POLICY FRAMEWORK

The provincial and federal policies and regulations discussed in Section 8.2 for surface water quality are also applicable to aquatic resources. Additionally, there is a provincial guideline for periphyton biomass for the protection of aquatic life (BC ENV 2019).

Table 10.1-2. Aquatic Resources Sample Replicates, Tenas Project

Group		Periphyton											Benthic Invertebrates										
Analysis		Biomass							Taxonomy			Tissues	Taxonomy										Tissues
Waterbody	Site	1987	1988	1989	1990	2017	2018	2019	2017	2018	2019	2019	2000	2004	2006	2007	2016	2017	2018	2019	2019		
Tenas Creek	WQS01	-	-	-	-	3	-	3	3	-	3	3	-	-	-	-	-	1	-	3	3		
	WQS02	-	-	-	-	3	-	3	3	-	3	3	-	-	-	-	-	1	-	3	3		
	WQS04B	-	-	-	-	-	-	3	-	-	3	3	3	-	1	-	-	-	-	3	3		
Four Creek	WQS03-DS	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	3	3		
	WQS18	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	3	3		
Goathorn Creek	WQS06-US	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	3	3		
	WQS07	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	3	3		
	BUL16	-	-	-	-	-	-	-	-	-	-	-	3	1	1	-	-	-	-	-	-		
	WQS05	-	-	-	-	3	-	3	3	-	3	3	-	-	-	-	-	1	-	3	3		
Helps Creek	WQS16	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	3	3		
	WQS17	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	3	3		
Telkwa River	WQS08	-	-	-	-	3	-	3	3	-	3	3	-	-	-	-	-	1	-	3	3		
	WQS09	-	-	-	-	3	-	3	3	-	3	3	-	-	-	-	-	1	-	3	3		
Bulkley River	WQS11-US	-	-	-	-	-	3	3	-	3	3	3	-	-	-	-	-	-	1	3	3		
	WQS12	-	-	-	-	3	-	3	3	-	3	3	-	-	-	-	-	1	-	3	3		
	BUL01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-		
	400434	3	6	6	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	400435	3	6	6	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	BUL73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-		

Values represent the number of replicates; values exclude field duplicates and splits.

10.3 EXISTING INFORMATION

A review of existing information was undertaken for the Tenas Project, which included examining public sources of aquatic resources data and historical reports (Table 10.3-1). Data were reviewed for quality, relevance (i.e., geographic), and compliance with requirements for Environmental Assessment and for Joint MA/EMA permit applications. Guidance was followed from the Joint AIR for MA/EMA Permits (BC MEM and MOE 2016), which recommends following the guidance outlined in the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) and the *BC Field Sampling Manual* (Clark 2002, 2013 edition). The *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016) provides detailed direction regarding the collection of baseline data for projects that trigger the Environmental Assessment process.

Table 10.3-1. Aquatic Resources Data Information Table

Documents Reviewed	Publicly available data • Bio Logic. 2003. <i>A Benthic Invertebrate Index of Biological Integrity for Streams in the Bulkley TSA: Field Season 2002</i>. • Bio Logic. 2005. <i>A Multimetric Approach to Skeena Region Stream Assessments</i>. • Bustard. 1983. <i>Assessment of Benthic Invertebrate and Juvenile Fish Populations in Goathorn and Tenas Creeks and the Lower Telkwa River, September 1983</i>. • <i>Canadian Aquatic Biomonitoring Network (CABIN) database</i>. https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network.html • <i>British Columbia Environmental Monitoring System (EMS)</i>. https://a100.gov.bc.ca/pub/ems/listDataFiles.do?userAction=mainmenu&selectionIndex=0&x=55&y=12 Client-supplied consultant reports • Bustard. 1985. <i>Telkwa Coal Project: Aquatic Resource Assessment</i>.
General Remarks	The CABIN database and BC EMS include data within the Project area; these were incorporated in the data summary below. CABIN is a standardized protocol developed by Environment and Climate Change Canada (ECCC) and field personnel require formal training. It is the recommended approach in the 'Joint AIR for MA/EMA Permits' (BC MEM and MOE 2016). The data collected by Bustard (1983 and 1985) and Bio Logic (2003 and 2005) are of limited use. Methodologies were either not those recommended by BC ENV, or were unclear. Raw data were also unavailable for the Bio Logic reports. These reports do have some broad value for understanding benthic invertebrate communities in the Project area, but due to methodological differences or lack of raw data, were not directly comparable to the data collected in 2017 to 2019.
Sampling Required for EA and by Joint AIR for Mines Act and Environmental Management Act Permits (Joint AIR for MA/EMA Permits)	• A minimum of one year of data; two years of data are preferred for the baseline study. • Replicate sampling required for periphyton and benthic invertebrates (unless CABIN protocols are implemented).

(continued)

Table 10.3-1. Aquatic Resources Data Information Table (completed)

Existing Data	The data sources listed below were deemed useful and included in the data summary: • EMS - Periphyton biomass ▪ Bulkley River U/S from Smithers Sewage (400434); 1987 to 1992, 2012 ▪ Bulkley River IDZ at Smithers (400435); 1987 to 1992, 2012 • CABIN - Benthic Invertebrates ▪ Tenas Creek (BUL15, same location as WQS04B); 2000 and 2006 ▪ Goathorn Creek (BUL 16) approximately 80 m upstream of Tenas Creek confluence; 2000, 2004, and 2006 ▪ Bulkley River at Smithers (BUL01); 2016 ▪ Bulkley River downstream of Smithers (BUL73); 2007 The data sources listed below were not deemed useful and not included in the data summary: • Bustard ▪ Goathorn Creek periphyton biomass (chlorophyll a) accumulation, taxonomy, and tissue nitrogen:phosphorus (N:P) ratios in 1984 ▪ Goathorn Creek, Tenas Creek, and Telkwa River benthic invertebrate taxonomy in 1983 and 1984 ▪ Goathorn Creek benthic invertebrate drift in 1984 • Bio Logic ▪ Benthic invertebrates from Goathorn Creek
Existing Data Issues	Bustard (1983 and 1985) The survey completed by Bustard (1985) did not conform to methodologies currently recommended by the BC Field Sampling Manual (Clark 2002, 2013 edition). Periphyton sampling was completed with an artificial substrate sampler, and therefore doesn't necessarily represent the natural community (as particle size and texture can affect periphyton biomass and/or composition; Biggs 2000). Benthic invertebrate sampling was conducted with a Waters-Knapp sampler (similar to a Hess), with six replicates collected. This approach is acceptable; however, the MOE does recommend CABIN sampling for Environmental Assessment applications and Joint Mines Act/Environmental Management Act (BC MOE 2016; BC MEM and BC MOE 2016), which was not developed at the time of historical sampling. Benthic invertebrates were also collected with a drift net. No taxonomy QA/QC was completed. Bio Logic (2003 and 2005) Limited use as raw data not provided, and unclear sampling methodologies (i.e., use of Surber and kick net samplers).
Missing Data	None.
2017 to 2018 Baseline Program	The 2017 to 2019 baseline program collected periphyton (biomass, taxonomy, and tissues) and benthic invertebrates (taxonomy, CABIN, and tissues) from Tenas Creek, Four Creek, Goathorn Creek, Helps Creek, the Telkwa River, and the Bulkley River.
Key Issues	• An upstream reference site on the Bulkley River was identified as an important station for the <i>Joint Mines Act/Environmental Management Act</i> application, and for future monitoring programs; this site was added in 2018. • Baseline water toxicity and tissue residue sampling will be required once the discharge location is finalized. Tissue residues were collected in 2019; however, replication (3 replicates collected) differed from the BC ENV selenium guideline (8 composite replicates; BC MOE 2014).
Other Comments	None.

10.4 METHODOLOGY

10.4.1 Periphyton

10.4.1.1 Sampling

Periphyton biomass (as chlorophyll *a*) was sampled from six stream sites in 2017 and one stream site in 2018. Three replicates were collected from randomly selected rocks at each site. Each replicate was a composite of three pooled subsamples scrubbed from an individual rock using a template of known surface area (19.6 cm²), a modified toothbrush, syringe, and wash bottle.

Periphyton biomass samples were prepared by gently filtering samples through a 0.45 µm glass microfibre filter using a hand pump and filter apparatus. Filters were folded in half, placed in an opaque tube, and kept frozen until they were analyzed for chlorophyll *a* by ALS Labs (ALS). Three periphyton taxonomy replicates were also collected at six stream sites in 2017 and one site in 2018. Field sampling protocols followed the same protocols as for biomass, with each replicate consisting of a composite of three pooled subsamples. Each replicate was placed in a 500 mL plastic jar and preserved with Lugol's iodine solution. Taxonomy samples were sent to Biologica Environmental Services Ltd. (Biologica) in Victoria, BC for identification and enumeration.

In 2019, periphyton biomass was also collected from eight sites and periphyton taxonomy from 14 sites. Three replicates were collected from each site. While the 2017 and 2018 samples pooled three sub-samples to create one replicate (= 58.8 cm² per replicate), in 2019 only one sub-sample was collected per replicate (= 19.6 cm² per replicate). Biomass samples were not filtered each night, but rather shipped to ALS for filtering prior to sample analysis.

10.4.1.2 Analysis

Chlorophyll *a* (chl *a*) concentration was used as an estimate of periphyton biomass (as µg chl *a*/cm²).

Periphyton density was calculated by dividing the total number of cells counted by the area sampled, and corrected for subsampling. Taxa not identified to family were included in density estimations, but removed from community composition, richness, and Simpson's diversity calculations.

Periphyton were grouped by genera for richness and Simpson's diversity calculations. Richness and diversity were calculated according to the *Metal Mining Technical Guidance for Environmental Effects Monitoring* (EC 2012c). Simpson's diversity index (*D*) was calculated as:

$$D = 1 - \sum_{i=1}^S (p_i)^2 \quad \text{[Equation 2]}$$

where:

S = the number of taxa in the replicate

p_i = the proportion of the *i*th taxon in the replicate

Simpson's diversity can range from 0 (lowest diversity) to 1 (maximum diversity). The use of Simpson's diversity index accounts for both the number of taxa present and the relative density of organisms from each taxa (evenness).

10.4.1.3 *Quality Assurance/Quality Control*

The periphyton field quality assurance/quality control (QA/QC) program in 2017 to 2019 involved the collection of three replicates for biomass and three replicates for periphyton taxonomy. Chain of custody (COC) forms were used for all samples. In addition, in 2019 field duplicate samples were collected from two stations (WQS04B and WQS06-US).

The laboratory chlorophyll *a* QA/QC measures included the use of method blanks and reference material (see Section 9.4.3.2).

Biologica followed their own internal QA/QC procedures for periphyton taxonomy that included the analysis of a minimum of 10% of samples by two separate taxonomists to ensure taxonomic accuracy and the reproducibility of sample processing methods.

10.4.2 **Benthic Invertebrates**

10.4.2.1 *Sampling*

Kick net sampling was conducted by Canadian Aquatic Biomonitoring Network (CABIN) certified field personnel at each site according to the CABIN protocol (EC 2012a). Six sites were visited in 2017, one in 2018, and 14 in 2019. In 2017 and 2018, one replicate was collected per site, while in 2019 three replicates were collected per site. A standard CABIN kick net (400 µm mesh) was used for sampling. Samples were collected by placing the kick net downstream of the collector with the flat bottom of the net resting on the substrate. The sampler then moved upstream, dragging the net along the bottom of the stream, disturbing the substrate to a depth of 5 to 10 cm using a kicking motion. The sampler zigzagged continuously over the stream bottom for three minutes. The contents of the kick net sample were transferred to a sieve, and sample debris was washed from the net using a wash bottle. Large rocks were scrubbed, rinsed, and removed from the sample. The contents were transferred into clean 1 L, pre-labelled plastic jars and preserved to a final concentration of 10% buffered formalin. Samples were sent to Biologica for enumeration and identification.

In addition, in 2017 and 2018 a habitat characterization was completed following CABIN protocols (EC 2012a). This included characterizing the reach (canopy cover, streamside vegetation, periphyton coverage, etc.), channel data (slope, wetted width, velocity, etc.), substrate data (100-pebble count, embeddedness, etc.), and in situ water chemistry. All data were uploaded to the CABIN database (<https://cabin-rcba.ec.gc.ca/cabin>). The CABIN habitat characterization was not completed in 2019.

10.4.2.2 *Analysis*

Invertebrates were sorted and identified to the lowest possible taxonomic level (usually genus). Ostracoda, Cladocera, Nematoda, Copepoda, Porifera, Platyhelminthes, and terrestrial organisms were excluded from all analysis following Environment Canada CABIN protocols (EC 2012b).

Summary Metrics

Immature or damaged specimens, as well as specimens not identified to the family level were included in abundance estimations but were excluded from all other calculations. Benthic invertebrate abundance, richness, and Simpson's diversity (D) indices were calculated for each sample at the family level. Simpson's diversity was calculated using Equation 2 (Section 10.4.1.2).

CABIN Assessment

A Reference Condition Approach (RCA) was used to assess the composition of the benthic invertebrate communities in the Project Area. The RCA uses a multivariate statistical model to compare the benthic invertebrate community at a test site with a group of invertebrate communities from CABIN reference sites with similar environmental conditions. The CABIN reference sites used for comparison were from the existing CABIN database of un-impacted or minimally impacted sites. Tenas Project sites were compared to the BC central/north coast CABIN reference model (Reynoldson and Bailey 2015).

Using the CABIN database, Tenas Project test sites were assigned to a reference group with similar environmental conditions. The BC central/north coast CABIN reference model (Reynoldson and Bailey 2015) uses seven geographic information system (GIS) derived habitat parameters to classify test sites: stream density (m/km^2), low shrubs (%), water (%), precipitation (January, February and March; mm), and minimum temperature in January ($^{\circ}C$). GIS data sources and analyses followed protocols described in the model summary (BC MEMPR 2005; McKenney et al. 2011; Natural Resources Canada 2015; Reynoldson and Bailey 2015).

Benthic invertebrate communities were compared between Tenas Project test sites and their respective reference group. The CABIN reference sites from the assigned reference group were used to create an ordination plot of benthic invertebrate communities and confidence ellipses were calculated (90, 99, and 99.9%). Three ordination plots were created to accurately visualize the ordination space. Tenas Project test sites were then plotted on the ordination, and assigned to the farthest confidence ellipse in which it resided (Rosenberg, Reynoldson, and Resh 1999). The comparison was performed at the family level.

10.4.2.3 Quality Assurance/Quality Control

COC forms were used for all benthic invertebrate samples. In 2019, triplicate samples were collected at each site, and field duplicate samples were collected from two stations (WQS04B and WQS06-US). Benthic invertebrate QA/QC followed CABIN protocols (ECCC 2012b), which included determining the sorting efficiency of the subsampled benthic invertebrates, and the percent similarity of samples identified by two separate taxonomists to ensure taxonomic accuracy and the reproducibility of sample processing results.

10.4.3 Tissue Residues

10.4.3.1 Sampling

Tissue residues were collected from periphyton and benthic invertebrate communities in 2019 at 14 stream sites. Tissue samples were collected concurrently with sediment quality and taxonomy

samples from the same site (as recommended by BC MOE 2016). Samples were analyzed by TrichAnalytics Inc.

10.4.3.2 Analysis

Analysis of metals was performed to the lowest possible detection limit using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Tissue moisture was also measured. Tissue residues were compared to current BC ENV and CCME guidelines for the protection of wildlife consumers of aquatic biota (BC ENV 2019; CCME 2020).

10.4.3.3 Quality Assurance/Quality Control

Field

The tissue quality assurance/quality control (QA/QC) program in 2019 included three sediment replicate samples collected at each stream site. Chain of custody (COC) forms were used for all samples. To determine the effectiveness of sample homogenization, a proportion of samples in 2019 were split in the field and submitted to TrichAnalytics as a blind sample and analyzed separately. The relative percent difference (RPD) between each set of tissue splits was calculated if at least one of the parameter concentrations was greater than five times the analytical detection limit (Equation 1 in Section 8.4.3.1; Clark 2002, 2013 edition).

Laboratory

The TrichAnalytics QA/QC program included laboratory replicates, and reference material. Laboratory replicates were used to assess analytical precision by taking subsamples of field samples that were subsequently analyzed separately using the same analytical methods. Finally, reference materials, which are standards with known concentrations, were analyzed using the same methods as regular samples to assess the methodological accuracy.

10.5 DATA SUMMARY

Periphyton biomass (as chlorophyll *a*) and taxonomy data are presented in Appendices 10-A and 10-B. Periphyton QA/QC results are available in Appendix 10-C. Benthic invertebrate data are presented in Appendix 10-D, the QA/QC results in Appendix 10-E, and the CABIN analytical results in Appendix 10-F. Tissue residue data are available in Appendix 10-G, with QA/QC results in Appendix 10-H.

10.5.1 Periphyton

Periphyton biomass (as chlorophyll *a*) was higher in the larger rivers than the smaller tributary creeks (Figure 10.5-1). The Telkwa River at WQS09 had the highest mean biomass (3.08 µg chl *a*/cm²) and density (97,000 cells/cm²), and the periphyton assemblage at this site was dominated by diatoms (Figure 10.5-2), primarily *Achnanthes* (Table 10.5-1). Conversely, biomass and density were much lower in Tenas, Four, Goathorn, and Helps creeks, where mean biomass was less than 0.75 µg chl *a*/cm², and density was less than 10,000 cells/cm² (except WQS01 density in 2017 with 42,500 cells/cm²; Figure 10.5-1). Periphyton biomass and density displayed considerable interannual variability.

Periphyton biomass levels remained below the BC guideline of 10 µg chl *a*/cm² and the Bulkley River provisional objective of 5 µg chl *a*/cm² (Figure 10.5-1).

Periphyton communities at all sites were dominated by either Bacillariophyceae (diatoms) or Cyanophyceae (blue-green algae; Figure 10.5-2). Tenas Creek sites were dominated by Cyanophyceae (39% to 99% of the community), which were also abundant in Goathorn Creek (56% to 85%). Bacillariophyceae were a large proportion of the remainder of the periphyton community in both creeks, and were more abundant in 2019. Within Tenas and Goathorn creeks, the Cyanophyceae *Heteroleibinia*, *Leptolyngbya*, *Phormidium*, and *Pseudanabaena* were among the dominant genera at each site (Table 10.5-1). In 2019, the higher proportion of diatoms was largely attributable to *Achnanthyidium*. While Tenas and Goathorn creeks were generally dominated by Cyanophyceae, the other creeks and rivers were dominated by Bacillariophyceae. Bacillariophyceae were largely represented by *Achnanthyidium* and *Fragilaria*.

Richness and diversity levels were moderate to high, with mean richness ranging from 8 to 23 genera/sample and Simpson's diversity from 0.19 to 0.85 (Figure 10.5-3). Samples with low diversity (Simpson's *D* < 0.5) reflect the dominance of certain taxa at these sites (i.e., one genus comprised >50% of the sample). The Bulkley River had the highest richness (mean range: 16 to 23 genera/sample) and diversity (mean range: 0.81 to 0.85) of all the sampled streams. It should be noted that the area sampled in 2017 and 2018 differed from that in 2019 (see Section 10.4.1), which can affect comparisons of richness and diversity. As such, inter-year comparisons should be limited and interpreted with caution.

The invasive *Didymosphenia*, also known as rock snot, was identified in Tenas Creek (WQS02), the Telkwa River (WQS08 and WQS09), and the Bulkley River (WQS11-US and WQS12). Therefore, extra precautions were taken to clean equipment and clothing when sampling these waterbodies to ensure it is not spread to other areas.

10.5.2 Benthic Invertebrates

10.5.2.1 Summary Metrics

Benthic invertebrate abundance displayed high temporal and spatial variability, ranging from a mean of 103 to 5,637 organisms/sample (Figure 10.5-4). Benthic invertebrate abundances were generally highest in the Bulkley River, and lowest in Four Creek.

Benthic invertebrate communities were dominated by the intolerant to moderately pollution-tolerant taxa, Ephemeroptera (mayflies; 15% to 64% of the community) and Plecoptera (stoneflies; 1% to 48% of the community; Figure 10.5-4). Ephemeroptera were largely represented by *Baetis*, *Rithrogena* and *Drunella*, and Plecoptera by *Zapada* and *Taenionema* (Table 10.5-2). A third intolerant to moderately pollution-tolerant taxon, Trichoptera (caddisflies), was abundant in the lower Bulkley River. Ephemeroptera, Plecoptera, and Trichoptera, collectively termed EPTs, generally made up the majority of the community at most sites (> 50%), except lower Tenas Creek at WQS04B in 2000, Helps Creek at WQS17, 2019 samples from the Bulkley River, and the Telkwa River, where there was an abundance of Diptera (true flies), particularly the family Chironomidae (non-biting midges). EPT presence is considered an indicator of good ecosystem health because most taxa are intolerant to moderately tolerant of pollution and poor water quality. Conversely, dipteran species are generally more pollution tolerant.

Figure 10.5-1

**Periphyton Biomass and Density in Tenas Project Streams,
1987 to 1990, and 2017 to 2019**

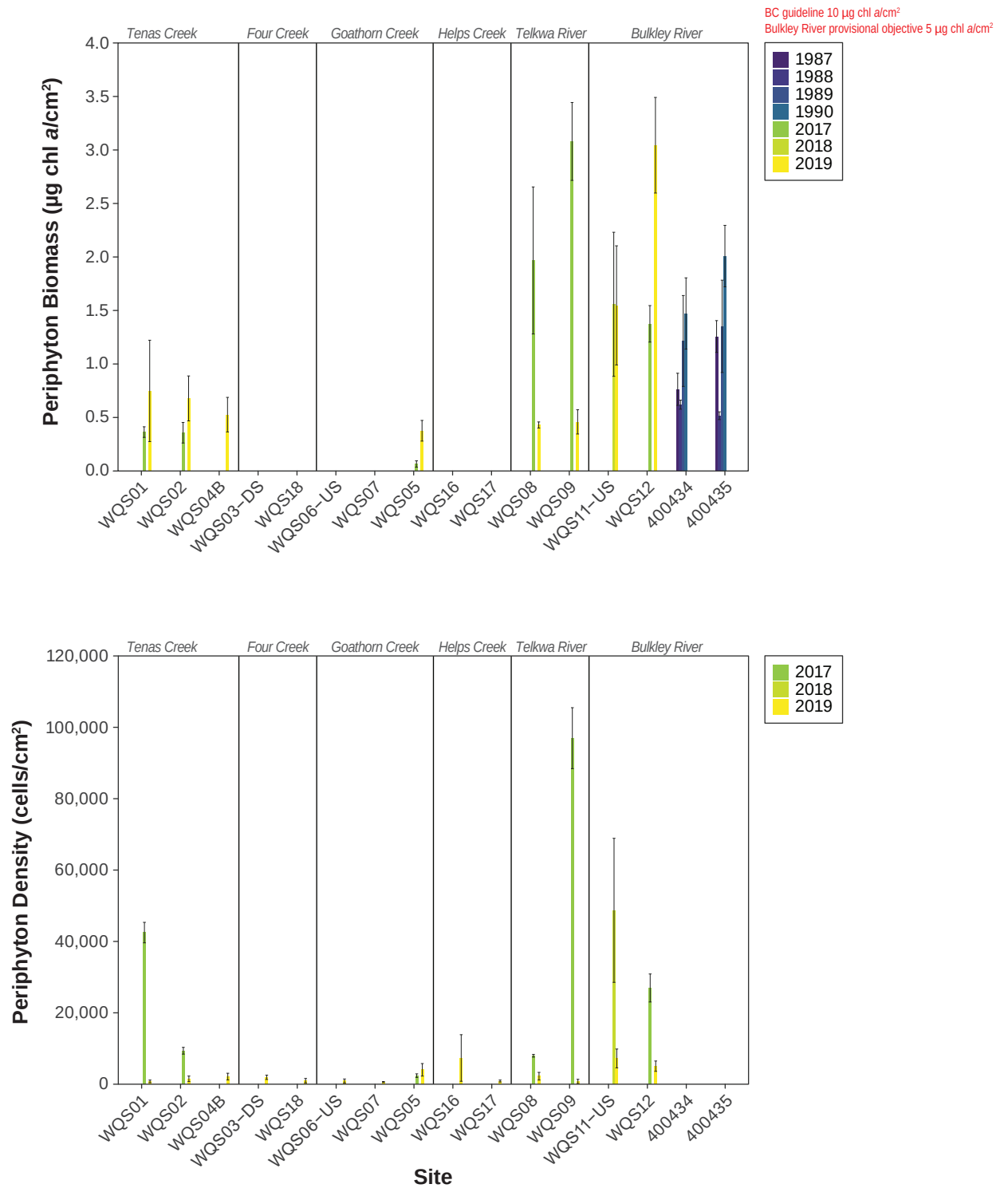
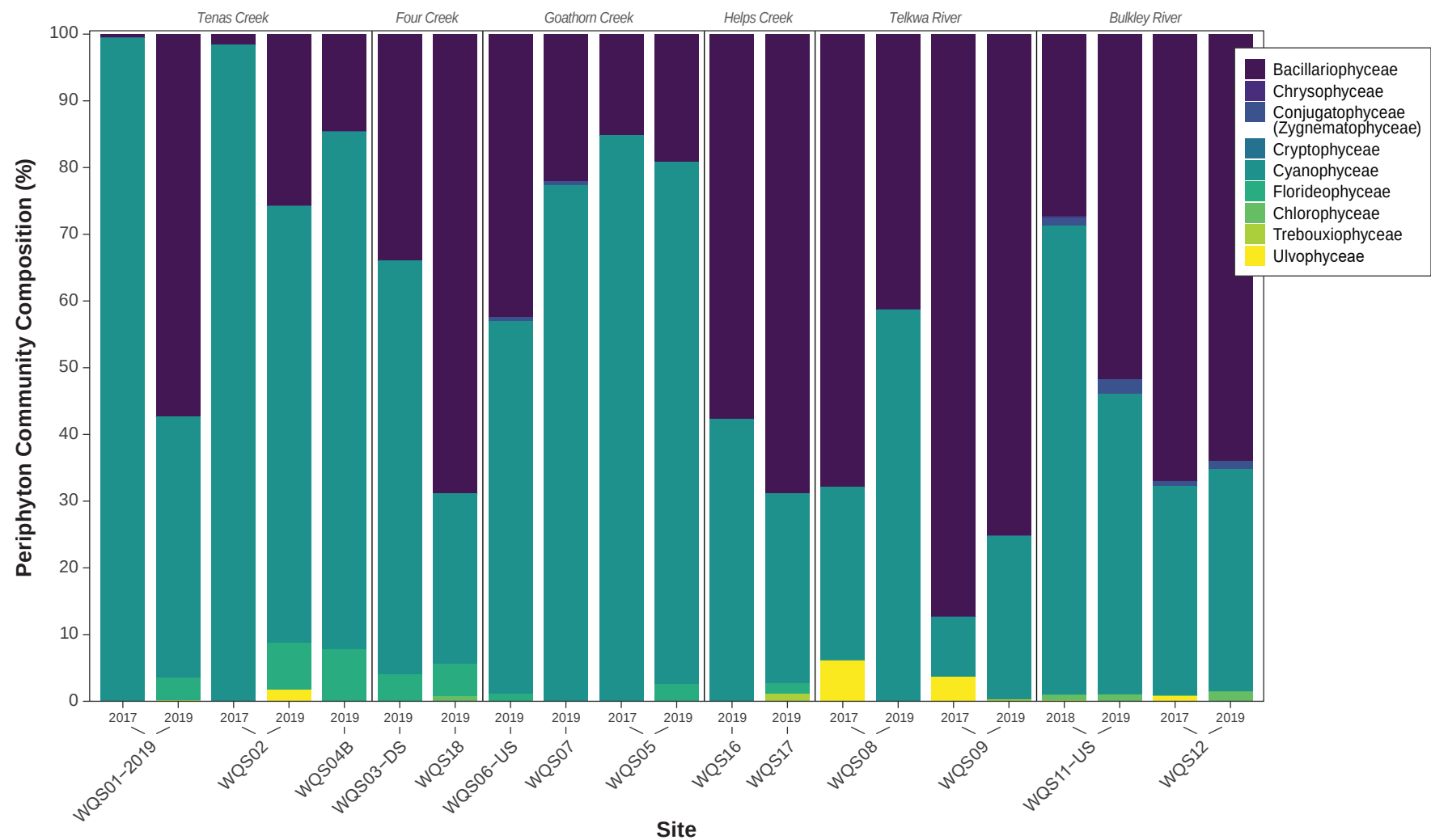


Figure 10.5-2

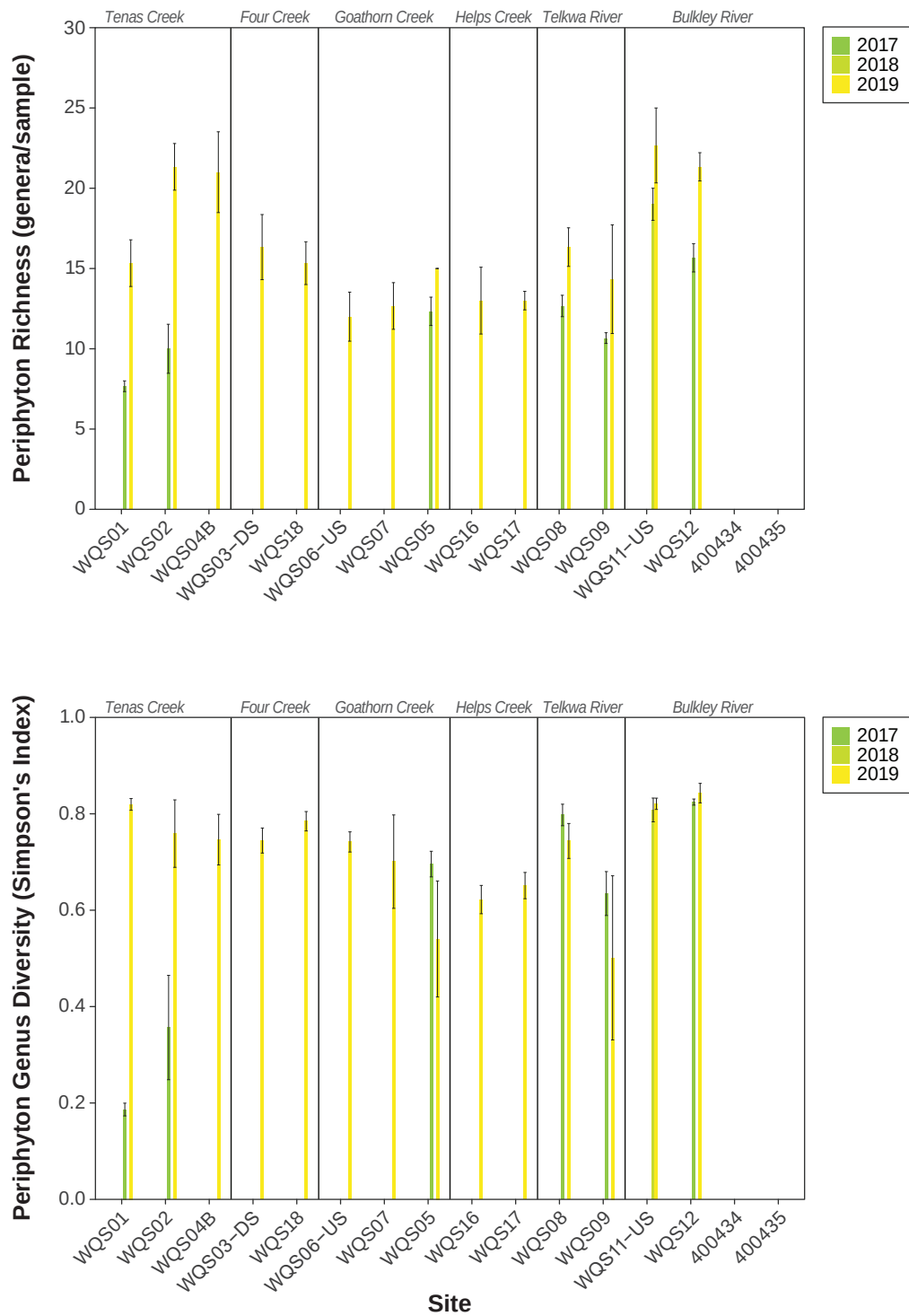
Periphyton Community Composition in Tenas Project Streams,
2017 to 2019



Notes: Community composition values represent the mean of replicates.
Immature, damaged and unidentified individuals were excluded from all analyses except density calculations.

Figure 10.5-3

Periphyton Richness and Diversity in Tenas Project Streams,
2017 to 2019



Notes: Error bars represent the standard error of the mean.

Immature, damaged and unidentified individuals were excluded from all analyses except density calculations.

Table 10.5-1. Dominant Periphyton Taxa, Tenas Project, 2017 to 2019

Waterbody	Site	Year	Class	Genus	Percent
Tenas Creek	WQS01	2017	Cyanophyceae	<i>Heteroleibeinia</i>	90%
			Cyanophyceae	<i>Leptolyngbya</i>	6%
			Cyanophyceae	<i>Pseudanabaena</i>	3%
		2019	Cyanophyceae	<i>Pseudanabaena</i>	25%
			Bacillariophyceae	<i>Encyonema</i>	21%
			Bacillariophyceae	<i>Achnanthes</i>	14%
	WQS02	2017	Cyanophyceae	<i>Heteroleibeinia</i>	77%
			Cyanophyceae	<i>Phormidium</i>	9%
			Cyanophyceae	<i>Leptolyngbya</i>	6%
		2019	Cyanophyceae	<i>Pseudanabaena</i>	43%
			Cyanophyceae	<i>Leptolyngbya</i>	10%
			Bacillariophyceae	<i>Achnanthes</i>	7%
	WQS04B	2019	Cyanophyceae	<i>Leptolyngbya</i>	37%
			Cyanophyceae	<i>Heteroleibeinia</i>	22%
			Cyanophyceae	<i>Pseudanabaena</i>	9%
Four Creek	WQS03-DS	2019	Bacillariophyceae	<i>Achnanthes</i>	24%
			Cyanophyceae	<i>Leptolyngbya</i>	19%
			Cyanophyceae	<i>Heteroleibeinia</i>	15%
	WQS18	2019	Bacillariophyceae	<i>Achnanthes</i>	39%
			Bacillariophyceae	<i>Cocconeis</i>	12%
			Cyanophyceae	<i>Chamaesiphon</i>	10%
Goathorn Creek	WQS06-US	2019	Bacillariophyceae	<i>Achnanthes</i>	39%
			Cyanophyceae	<i>Heteroleibeinia</i>	21%
			Cyanophyceae	<i>Leptolyngbya</i>	13%
	WQS07	2019	Cyanophyceae	<i>Phormidium</i>	32%
			Bacillariophyceae	<i>Achnanthes</i>	18%
			Cyanophyceae	<i>Heteroleibeinia</i>	16%
	WQS05	2017	Cyanophyceae	<i>Heteroleibeinia</i>	41%
			Cyanophyceae	<i>Leptolyngbya</i>	24%
			Cyanophyceae	<i>Tapinothrix</i>	9%
		2019	Cyanophyceae	<i>Phormidium</i>	62%
Helps Creek	WQS16	2019	Bacillariophyceae	<i>Achnanthes</i>	49%
			Cyanophyceae	<i>Heteroleibeinia</i>	30%
			Cyanophyceae	<i>Leptolyngbya</i>	5%
	WQS17	2019	Bacillariophyceae	<i>Achnanthes</i>	51%
			Cyanophyceae	<i>Heteroleibeinia</i>	20%
			Bacillariophyceae	<i>Cocconeis</i>	8%

(continued)

Table 10.5-1. Dominant Periphyton Taxa, Tenas Project, 2017 to 2019 (completed)

Waterbody	Site	Year	Class	Genus	Percent
Telkwa River	WQS08	2017	Bacillariophyceae	<i>Achnanthydium</i>	29%
			Bacillariophyceae	<i>Fragilaria</i>	23%
			Cyanophyceae	<i>Leptolyngbya</i>	14%
		2019	Cyanophyceae	<i>Phormidium</i>	25%
			Bacillariophyceae	<i>Achnanthydium</i>	23%
			Cyanophyceae	<i>Leptolyngbya</i>	22%
	WQS09	2017	Bacillariophyceae	<i>Achnanthydium</i>	43%
			Bacillariophyceae	<i>Fragilaria</i>	36%
			Cyanophyceae	<i>Pseudanabaena</i>	8%
		2019	Bacillariophyceae	<i>Achnanthydium</i>	60%
			Cyanophyceae	<i>Leptolyngbya</i>	11%
			Bacillariophyceae	<i>Diatoma</i>	7%
Bulkley River	WQS11-US	2018	Cyanophyceae	<i>Chamaesiphon</i>	22%
			Bacillariophyceae	<i>Achnanthydium</i>	19%
			Cyanophyceae	<i>Heteroleibeinia</i>	19%
		2019	Bacillariophyceae	<i>Achnanthydium</i>	25%
			Cyanophyceae	<i>Pseudanabaena</i>	22%
			Cyanophyceae	<i>Leptolyngbya</i>	15%
	WQS12	2017	Bacillariophyceae	<i>Fragilaria</i>	25%
			Cyanophyceae	<i>Phormidium</i>	21%
			Bacillariophyceae	<i>Achnanthydium</i>	14%
		2019	Bacillariophyceae	<i>Achnanthydium</i>	25%
			Cyanophyceae	<i>Pseudanabaena</i>	17%
			Cyanophyceae	<i>Leptolyngbya</i>	13%

Benthic invertebrate mean richness ranged from 11 to 25 families/sample (Figure 10.5-5). Family richness was generally higher in the larger Telkwa and Bulkley rivers compared to the smaller tributary streams, although Tenas Creek at WQS04B (historically called BUL15) and Goathorn Creek (at BUL16) had particularly high family richness. Benthic invertebrate family diversity was high (> 0.6 Simpson's diversity; Figure 10.5-5), and comparable across sites.

10.5.2.2 CABIN Assessment

Project area benthic invertebrate communities were compared to the CABIN BC central/north coast reference model using the CABIN database. The CABIN ordination results are summarized in Table 10.5-3, and ordinations are available in Appendix 10-F.

Figure 10.5-4

Benthic Invertebrate Abundance and Community Composition in Tenas Project Streams, 2000 to 2019

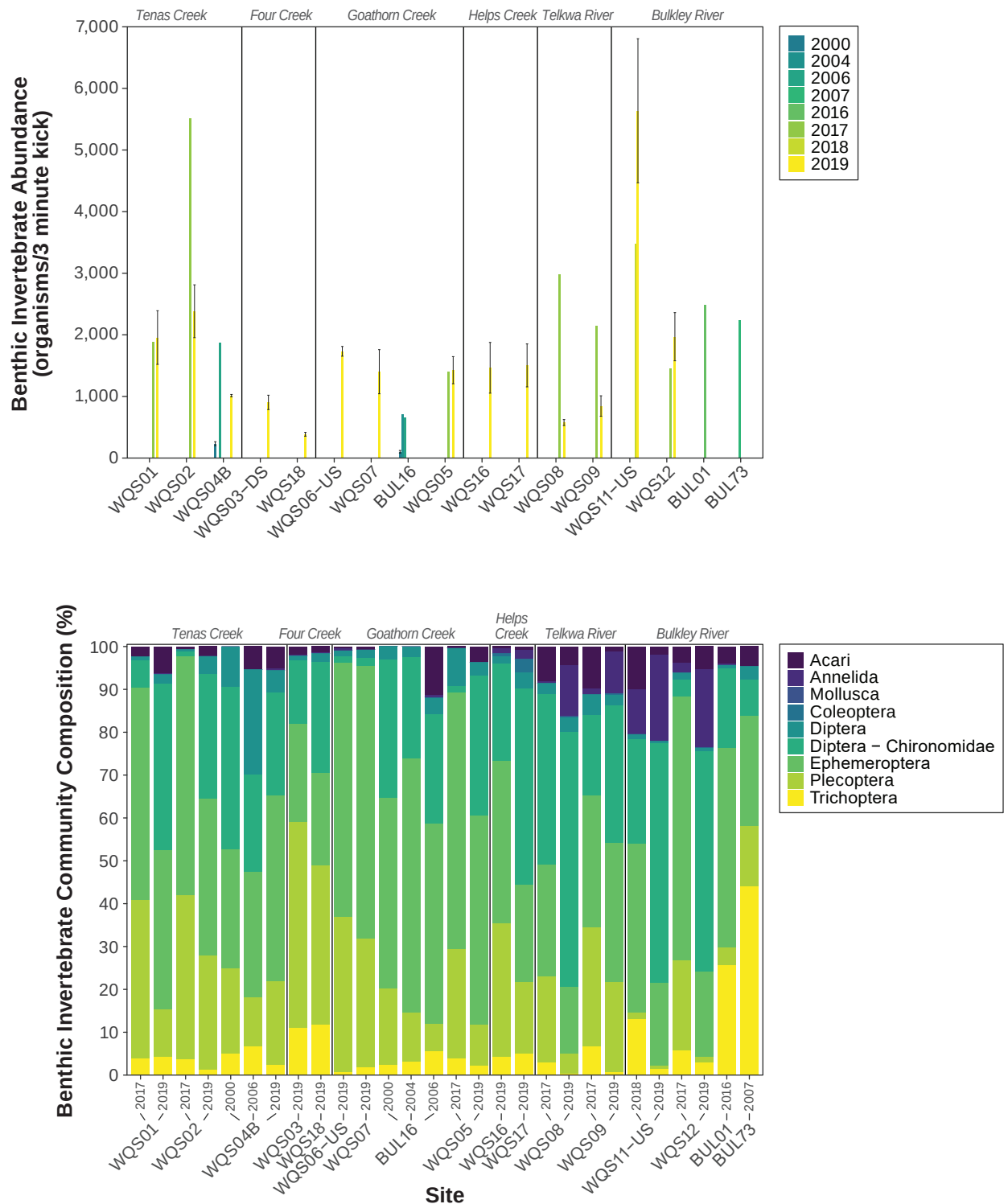
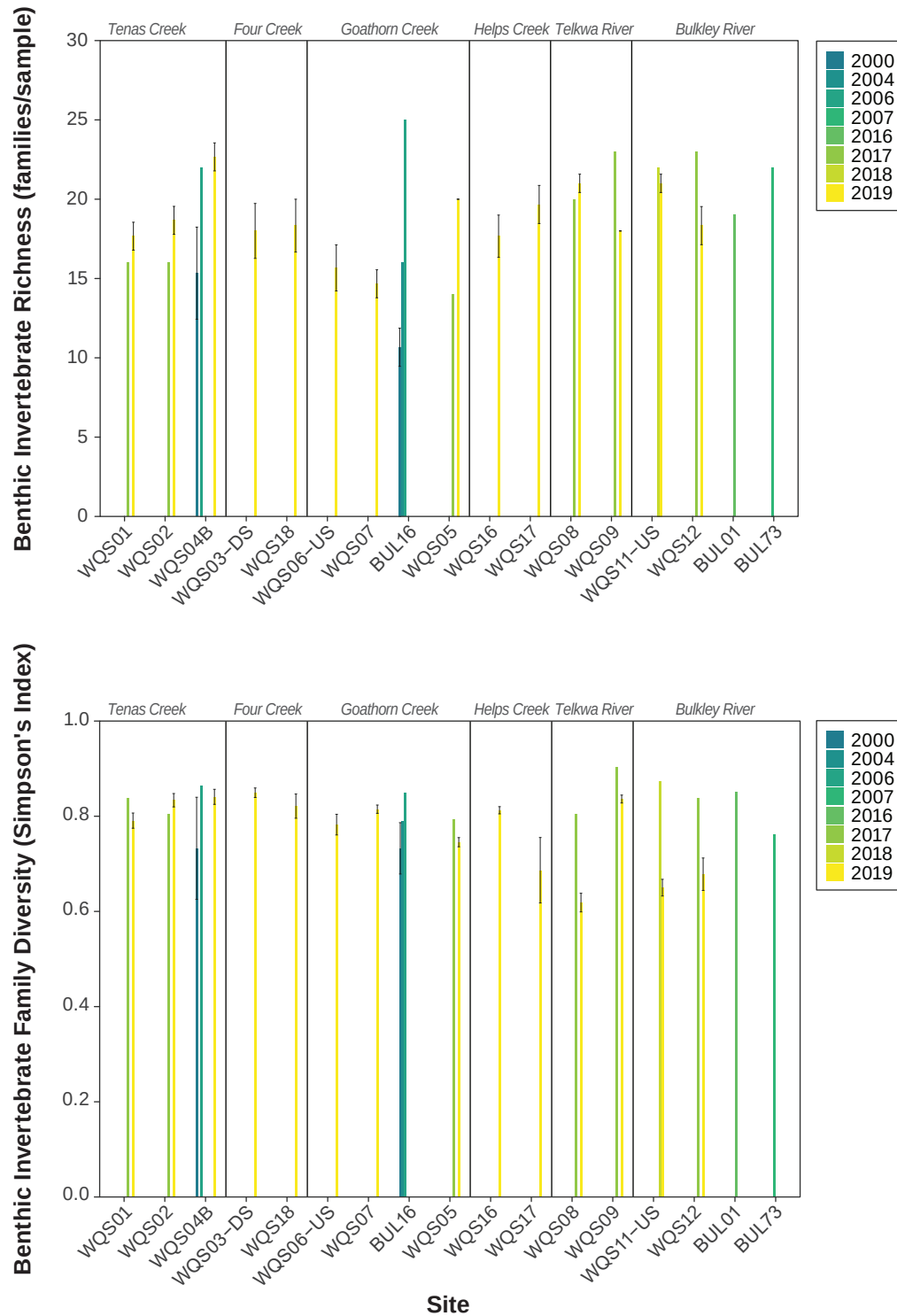


Figure 10.5-5

Benthic Invertebrate Richness and Diversity in Tenas Project Streams, 2000 to 2019



Notes: Error bars represent the standard error of the mean.

Immature, damaged and unidentified individuals were excluded from all analyses except density calculations.

Table 10.5-2. Dominant Benthic Invertebrates, Tenas Project, 2000 to 2019

Waterbody	Site	Year	Major Group	Genus	Percent
Tenas Creek	WQS01	2017	Plecoptera	<i>Zapada</i>	27%
			Ephemeroptera	<i>Baetis</i>	17%
			Ephemeroptera	<i>Rhithrogena</i>	9%
		2019	Ephemeroptera	<i>Baetis</i>	10%
			Diptera - Chironomidae	<i>Cricotopus/Orthocladius</i>	9%
			Diptera - Chironomidae	<i>Tvetenia</i>	6%
	WQS02	2017	Plecoptera	<i>Zapada</i>	20%
			Plecoptera	<i>Taenionema</i>	14%
			Ephemeroptera	<i>Drunella</i>	9%
		2019	Ephemeroptera	<i>Baetis</i>	18%
			Plecoptera	<i>Zapada</i>	15%
			Diptera - Chironomidae	<i>Cricotopus/Orthocladius</i>	6%
	WQS04B (BUL15)	2000	Plecoptera	<i>Taenionema</i>	13%
			Diptera - Other	<i>Pericoma</i>	8%
			Ephemeroptera	<i>Baetis</i>	8%
		2006	Diptera - Other	<i>Pericoma</i>	21%
			Ephemeroptera	<i>Baetis</i>	13%
			Plecoptera	<i>Zapada</i>	7%
		2019	Ephemeroptera	<i>Baetis</i>	25%
			Plecoptera	<i>Zapada</i>	9%
			Ephemeroptera	<i>Ameletus</i>	8%
Four Creek	WQS03-DS	2019	Plecoptera	<i>Taenionema</i>	13%
			Plecoptera	<i>Zapada</i>	8%
			Ephemeroptera	<i>Baetis</i>	4%
	WQS18	2019	Diptera - Chironomidae	<i>Pseudodiamesa</i>	9%
			Ephemeroptera	<i>Cinygmula</i>	5%
Goathorn Creek	WQS06-US	2019	Ephemeroptera	<i>Baetis</i>	29%
			Plecoptera	<i>Taenionema</i>	29%
			Ephemeroptera	<i>Rhithrogena</i>	11%
	WQS07	2019	Ephemeroptera	<i>Baetis</i>	31%
			Plecoptera	<i>Taenionema</i>	14%
			Ephemeroptera	<i>Rhithrogena</i>	7%
	BUL16	2000	Ephemeroptera	<i>Baetis</i>	18%
			Ephemeroptera	<i>Rhithrogena</i>	4%
			Ephemeroptera	<i>Drunella</i>	4%
		2004	Ephemeroptera	<i>Baetis</i>	33%
			Ephemeroptera	<i>Rhithrogena</i>	5%
			Ephemeroptera	<i>Epeorus</i>	3%
		2006	Ephemeroptera	<i>Baetis</i>	15%
			Ephemeroptera	<i>Cinygmula</i>	8%
			Acari	<i>Lebertia</i>	5%

(continued)

Table 10.5-2. Dominant Benthic Invertebrates, Tenas Project, 2000 to 2019 (completed)

Waterbody	Site	Year	Major Group	Genus	Percent
Goathorn Creek (cont'd)	WQS05	2017	Ephemeroptera	<i>Baetis</i>	40%
			Plecoptera	<i>Taenionema</i>	9%
			Diptera - Other	<i>Simulium</i>	8%
		2019	Ephemeroptera	<i>Baetis</i>	31%
			Diptera - Chironomidae	<i>Cricotopus/Orthocladius</i>	18%
Helps Creek	WQS16	2019	Ephemeroptera	<i>Ameletus</i>	3%
			Plecoptera	<i>Sweltsa</i>	10%
			Diptera - Chironomidae	<i>Tanytarsus</i>	8%
	WQS17	2019	Ephemeroptera	<i>Cinygmula</i>	7%
			Diptera - Chironomidae	<i>Tanytarsus</i>	7%
			Plecoptera	<i>Sweltsa</i>	6%
Telkwa River	WQS08	2017	Diptera - Chironomidae	<i>Brillia</i>	4%
			Diptera - Chironomidae	<i>Tvetenia</i>	22%
			Ephemeroptera	<i>Baetis</i>	10%
		2019	Ephemeroptera	<i>Drunella</i>	8%
			Diptera - Chironomidae	<i>Cricotopus/Orthocladius</i>	33%
	WQS09	2017	Ephemeroptera	<i>Ameletus</i>	11%
			Lumbriculida	<i>Stylodrilus</i>	7%
			Diptera - Chironomidae	<i>Cricotopus/Orthocladius</i>	8%
		2019	Ephemeroptera	<i>Baetis</i>	7%
			Acari	<i>Lebertia</i>	6%
Bulkley River	WQS11-US	2018	Diptera - Chironomidae	<i>Polypedilum</i>	9%
			Oligochaeta	<i>Stylodrilus</i>	8%
			Ephemeroptera	<i>Ameletus</i>	7%
		2019	Diptera - Chironomidae	<i>Cricotopus/Orthocladius</i>	13%
			Tubificida	<i>Nais</i>	13%
			Ephemeroptera	<i>Ameletus</i>	10%
	WQS12	2017	Plecoptera	<i>Taenionema</i>	14%
			Ephemeroptera	<i>Rhithrogena</i>	13%
			Ephemeroptera	<i>Baetis</i>	6%
		2019	Tubificida	<i>Nais</i>	17%
			Diptera - Chironomidae	<i>Microtendipes</i>	5%
	BUL01	2016	Ephemeroptera	<i>Ameletus</i>	5%
			Trichoptera	<i>Baetis</i>	19%
			Trichoptera	<i>Arctopsyche</i>	12%
	BUL73	2007	Trichoptera	<i>Hydropsyche</i>	5%
			Trichoptera	<i>Arctopsyche</i>	8%
			Plecoptera	<i>Hydropsyche</i>	8%
				<i>Taenionema</i>	7%

Note: WQS04B entered as BUL15 in CABIN database.

Table 10.5-3. Benthic Invertebrate Community Status Based on Reference Condition Approach, 2017 to 2019

Site	Year	Replicate	Stress	Vector 1 vs 2	Vector 1 vs 3	Vector 2 vs 3	Overall
Tenas Creek							
WQS01	2017	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
WQS02	2017	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
WQS04B	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
Four Creek							
WQS03-DS	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Mildly Divergent	Similar to Reference	Similar to Reference	Mildly Divergent
		3	0.20	Similar to Reference	Similar to Reference	Mildly Divergent	Mildly Divergent
WQS18	2019	1	0.20	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent
		2	0.20	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent
		3	0.20	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent
Goathorn Creek							
WQS06-US	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
WQS07	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference

(continued)

Table 10.5-3. Benthic Invertebrate Community Status Based on Reference Condition Approach, 2017 to 2019 (continued)

Site	Year	Replicate	Stress	Vector 1 vs 2	Vector 1 vs 3	Vector 2 vs 3	Overall
Goathorn Creek (cont'd)							
BUL16	2000	1	0.20	Similar to Reference	Highly Divergent	Divergent	Highly Divergent
		2	0.19	Divergent	Divergent	Similar to Reference	Divergent
		3	0.20	Mildly Divergent	Highly Divergent	Highly Divergent	Highly Divergent
	2004	1	0.19	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
	2006	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
WQS05	2017	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
Helps Creek							
WQS16	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
WQS17	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
Telkwa River							
WQS08	2017	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
	2019	1	0.20	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent
		2	0.20	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent
		3	0.20	Similar to Reference	Mildly Divergent	Mildly Divergent	Mildly Divergent
WQS09	2017	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
	2019	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		2	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
		3	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference

(continued)

Table 10.5-3. Benthic Invertebrate Community Status Based on Reference Condition Approach, 2017 to 2019 (completed)

Site	Year	Replicate	Stress	Vector 1 vs 2	Vector 1 vs 3	Vector 2 vs 3	Overall
Bulkley River							
WQS11-US	2018	1	0.13	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent
	2019	1	0.20	Similar to Reference	n/a	n/a	Similar to Reference
		2	0.20	Mildly Divergent	n/a	n/a	Mildly Divergent
		3	0.12	Mildly Divergent	Similar to Reference	Similar to Reference	Mildly Divergent
WQS12	2017	1	0.12	Similar to Reference	Divergent	Divergent	Divergent
	2019	1	0.13	Mildly Divergent	Mildly Divergent	Similar to Reference	Mildly Divergent
		2	0.12	Mildly Divergent	Similar to Reference	Similar to Reference	Mildly Divergent
		3	0.12	Similar to Reference	Mildly Divergent	Mildly Divergent	Mildly Divergent
BUL01	2016	1	0.20	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
BUL73	2007	1	0.20	Mildly Divergent	Mildly Divergent	Similar to Reference	Mildly Divergent

All sites were compared to the CABIN BC central/north coast.

Sites were assigned to the farthest band in which they resided in the three ordination plots (Rosenberg, Reynoldson, and Resh 1999).

Darker shading represents a greater divergence from the reference community.

Project area sites belonged to reference group 2 with the following probabilities: WQS01 (81%), WQS02 (79%), WQS04B (80%), WQS03-DS (73%), WQS18 (73%), WQS06-US (76%), WQS07 (75%), BUL16 (86%), WQS05 (77%), WQS16 (82%), WQS17 (82%), WQS08 (77%), WQS09 (77%), BUL01 (57%), and BUL73 (56%).

Bulkley River sites near the Telkwa River belonged to reference group 3 with the following probabilities: WQS11-US (96%), and WQS12 (90%).

n/a = number of sites in the ordination was comparatively small so only two dimensions were required to be plotted to obtain a low ordination stress value.

Sites were first assigned to a reference group based on GIS-derived habitat characteristics. Project area sites were determined to belong to reference group 2, with high probability (56% to 86%). The only exceptions were sites on the Bulkley River in proximity to the Telkwa River (WQS11-US and WQS12), which had a high probability of belonging to reference group 1 (90% to 96%). Project area benthic invertebrate communities were then compared to benthic invertebrate communities from their respective reference groups.

Benthic invertebrate communities in the majority of streams and samples were similar to the reference communities (within 90% confidence ellipse), including Tenas Creek, Goathorn Creek (except BUL16 in 2000, discussed below), Helps Creek, and the Telkwa River (WQS09, and WQS08 in 2017; Table 10.5-3). Given these creeks have similar benthic invertebrate communities to the reference communities, this suggests that these benthic invertebrate communities are healthy.

Benthic invertebrate communities in Four Creek, as well as 2019 samples from the upstream site WQS08 in the Telkwa River were mildly divergent from the reference communities (between the 90% to 99% confidence ellipses). Within Four Creek, this was observed both upstream and downstream of the road crossing. Benthic invertebrate communities in Four Creek had comparatively low abundance, high proportions of Plectoptera and/or Trichoptera, and fewer Ephemeroptera compared to the mean of the reference communities. Compared to the reference communities mean and other samples from the Telkwa River, WQS08 in 2019 had lower abundance and diversity, a higher proportion of the pollution-tolerant taxa Chironomidae, and fewer pollution-intolerant taxa such as Ephemeroptera and Plecoptera.

Goathorn Creek at BUL16 benthic invertebrate communities in 2000 were divergent (between the 99% to 99.9% confidence ellipse) or highly divergent (outside the 99.9% confidence ellipse) from the reference communities. This likely reflected the low abundance, and highly variable proportions of Chironomidae, Ephemeroptera, and Plecoptera in these samples. By contrast, benthic invertebrate communities in 2004 and 2006 were similar to reference communities.

Bulkley River benthic invertebrate communities ranged from being similar to the reference communities, to divergent from the reference communities. WQS12 in 2017 was divergent from the reference communities. While WQS12 in 2017 had lower abundance than the reference communities mean, there was a higher proportion of the pollution-intolerant Ephemeroptera, and a lower proportion of pollution-tolerant Chironomidae. By contrast, WQS11-US and WQS12 samples that were mildly divergent from the reference communities tended to have higher proportions of Chironomidae, and fewer pollution-intolerant taxa such as Plecoptera, Ephemeroptera, and Trichoptera. BUL73 was mildly divergent from the reference communities mean, and distinct from other Bulkley River samples by having a proportionally high number of the Trichopteran Hydropsychidae, which tend to be more tolerant than other taxa of this order.

10.5.3 Tissue Residues

Generally, periphyton tissue metal concentrations were much higher than benthic invertebrate tissues, with the exception of cadmium, copper, mercury, molybdenum, selenium, and zinc (Figures 10.5-6 to 10.5-13). There was large variability between replicate samples (as indicated by the error bars), and the field QA/QC indicated reduced precision (see Section 10.5.4.3).

Figure 10.5-6

Periphyton and Benthic Invertebrate Tissue Arsenic and Cadmium
in Tenas Project Streams, 2019

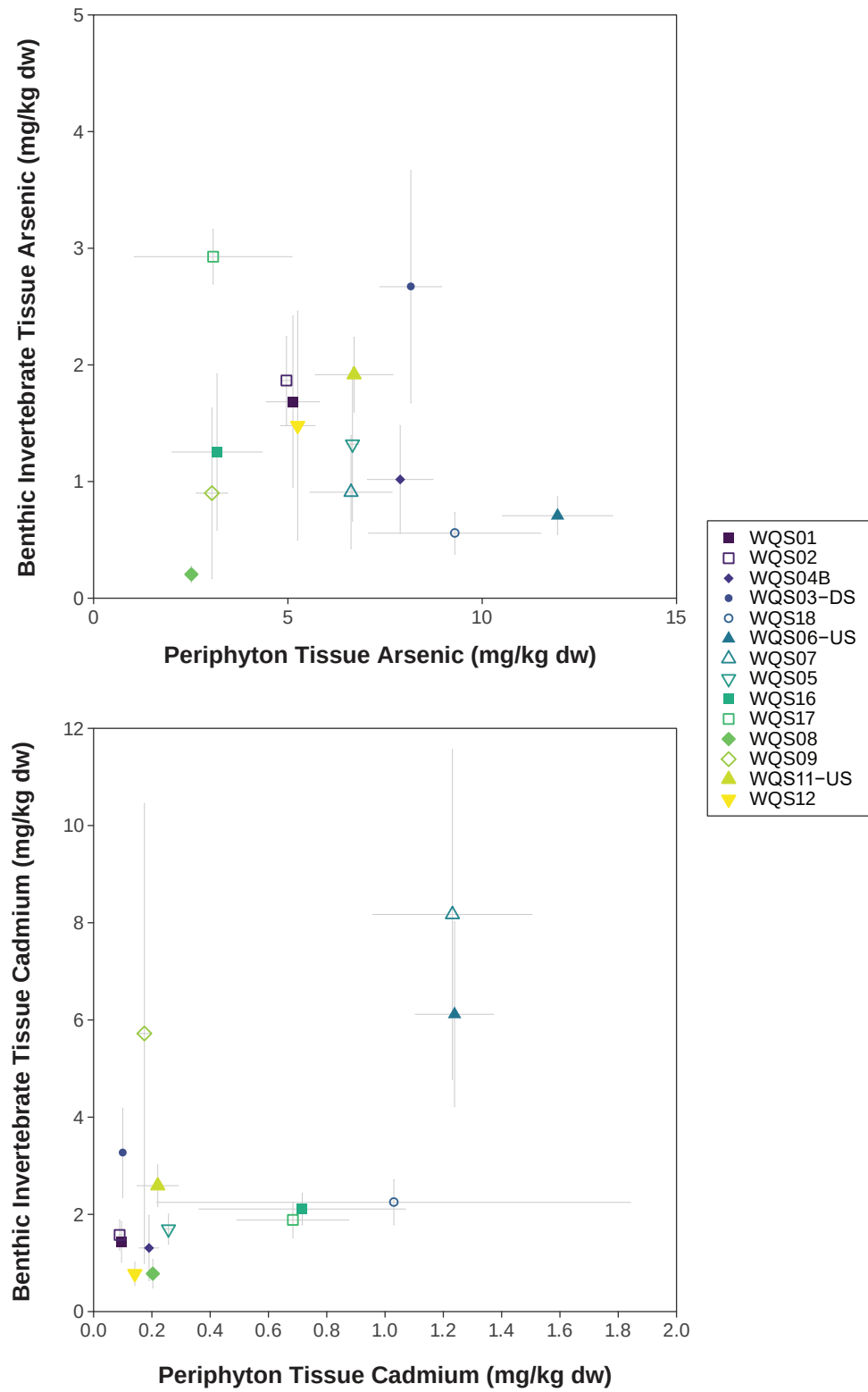
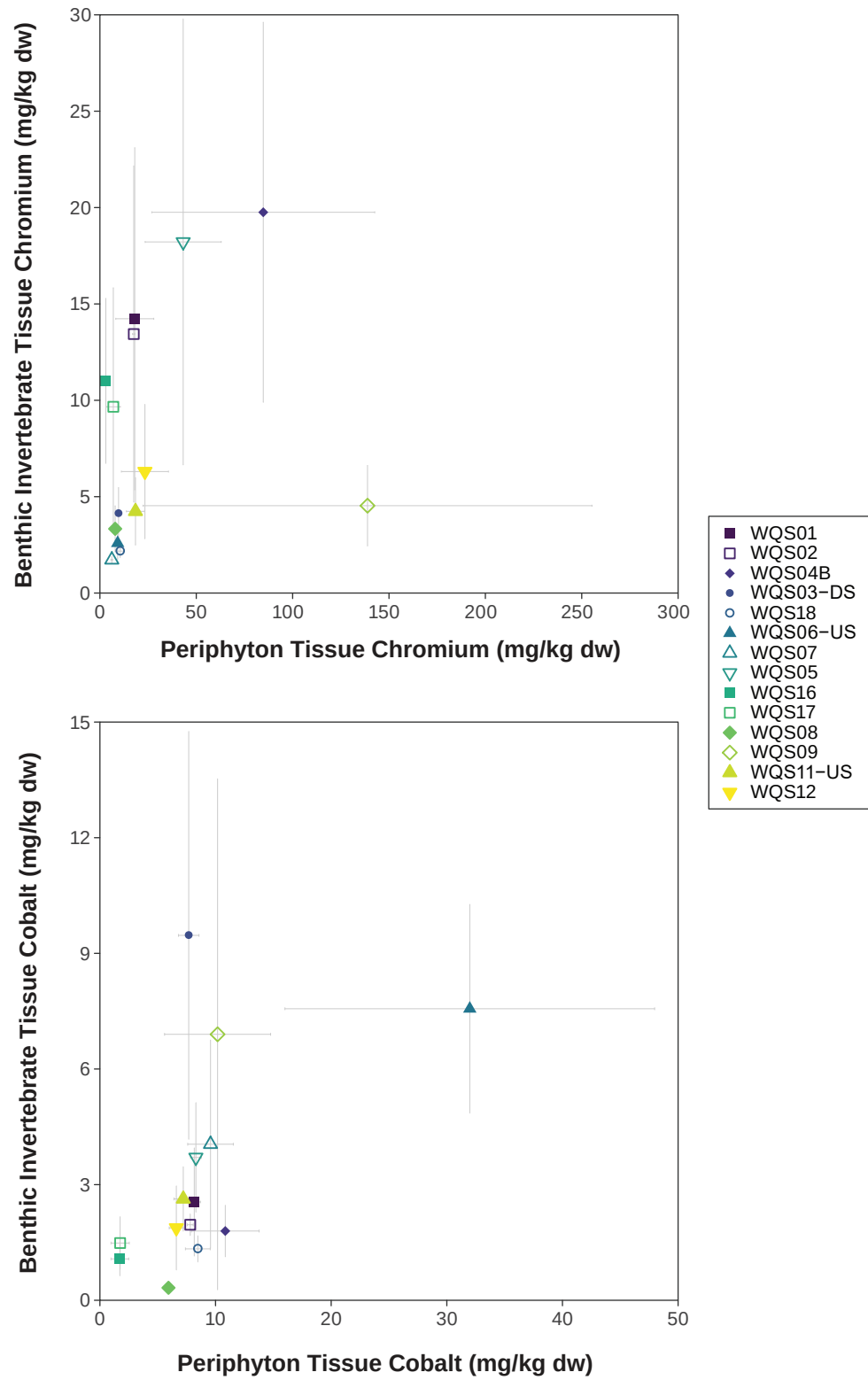


Figure 10.5-7

Periphyton and Benthic Invertebrate Tissue Chromium and Cobalt
in Tenas Project Streams, 2019



Note: Error bars represent the standard error of the mean.

Figure 10.5-8

Periphyton and Benthic Invertebrate Tissue Copper and Iron
in Tenas Project Streams, 2019

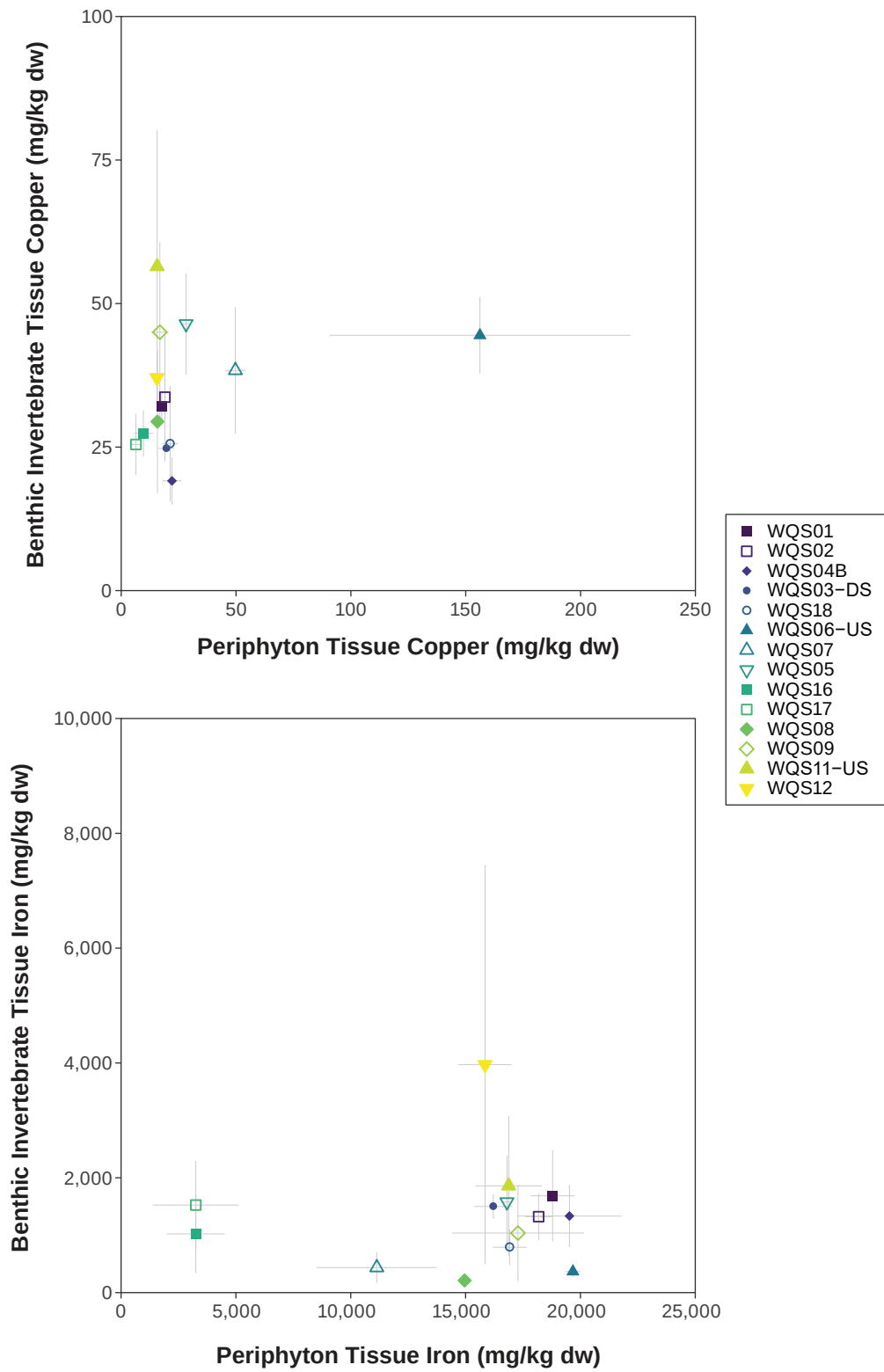
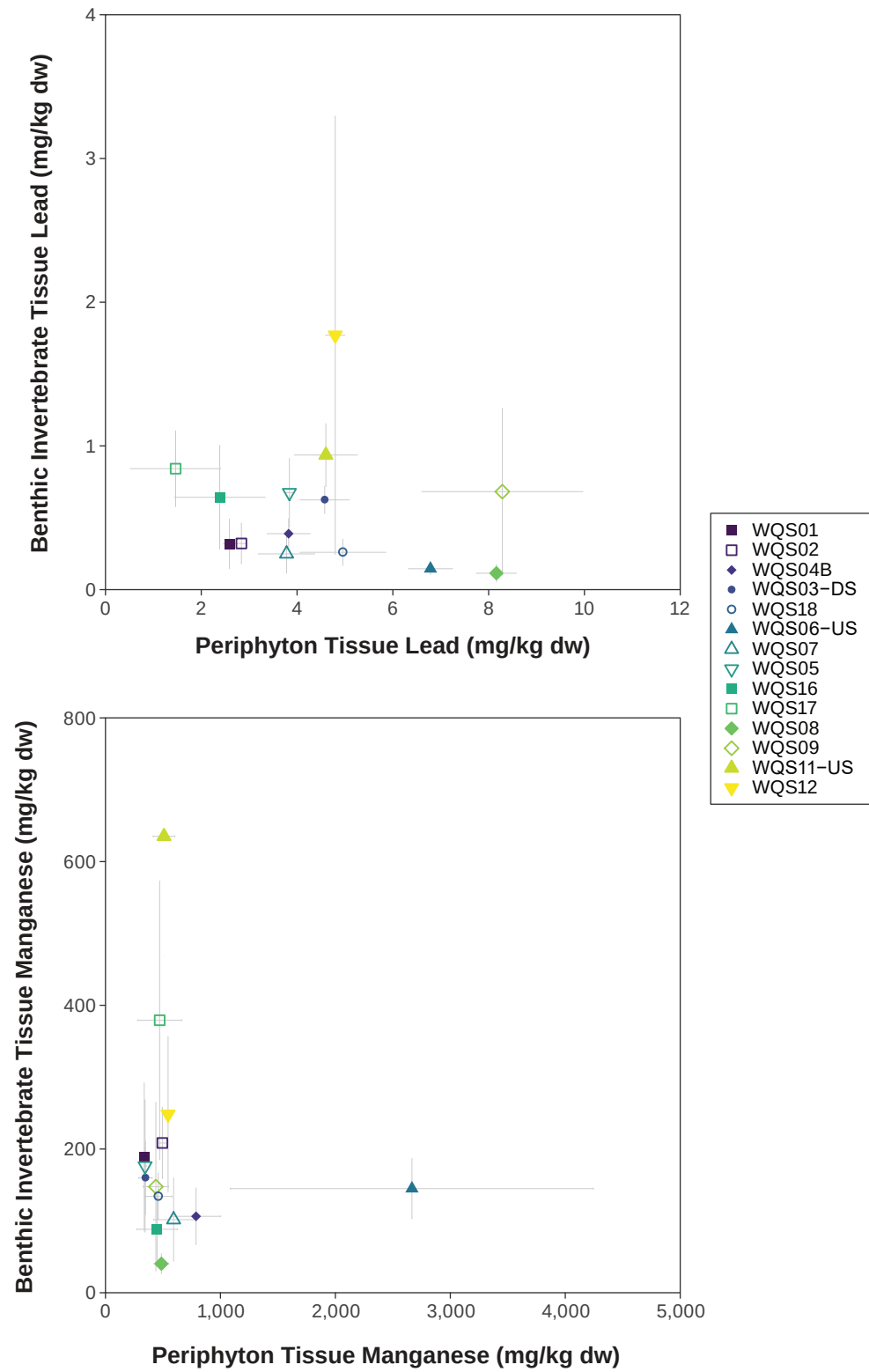


Figure 10.5-9

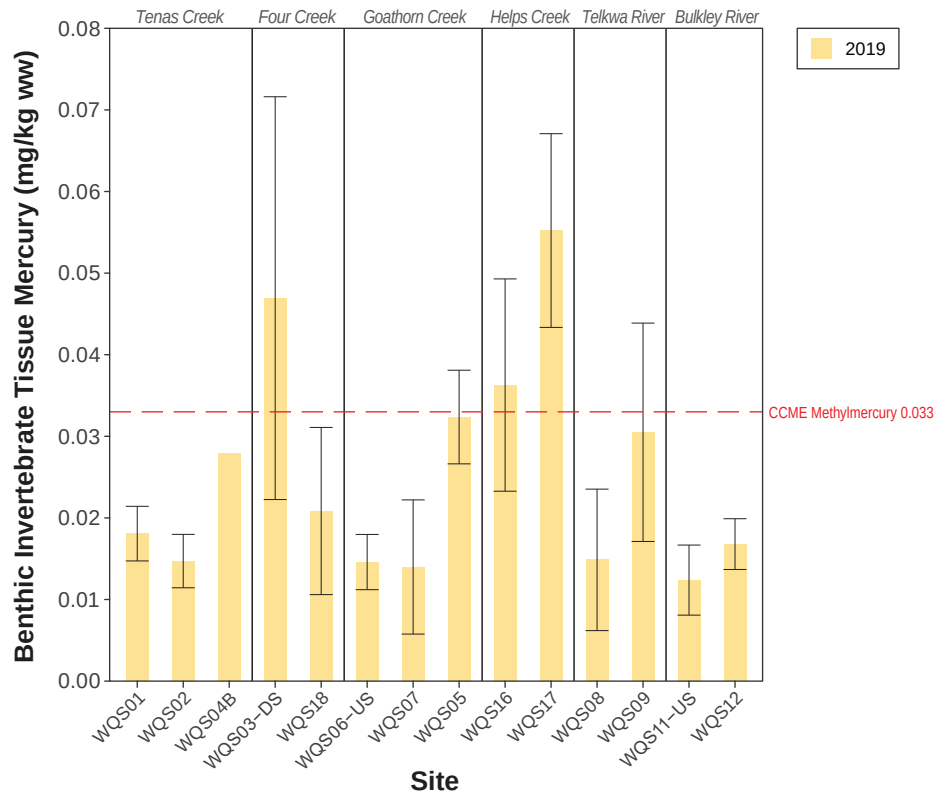
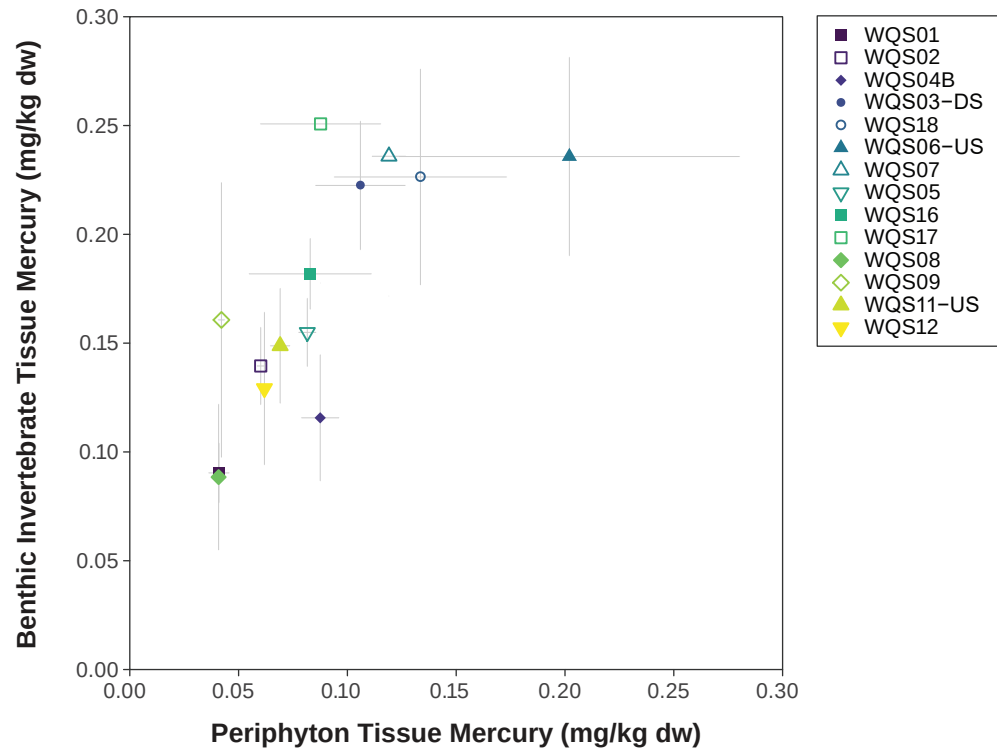
Periphyton and Benthic Invertebrate Tissue Lead and Manganese
in Tenas Project Streams, 2019



Note: Error bars represent the standard error of the mean.

Figure 10.5-10

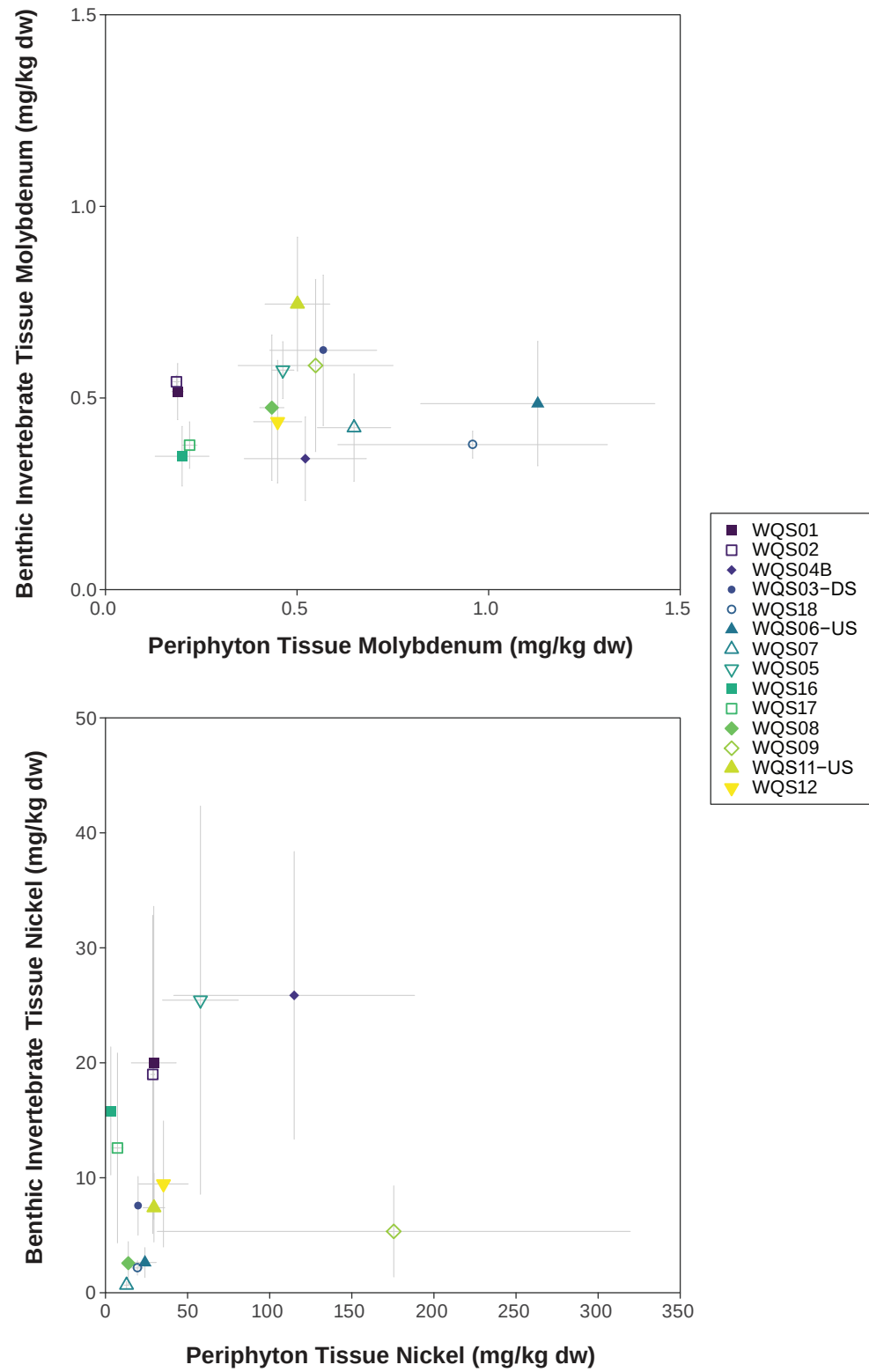
Periphyton and Benthic Invertebrate Tissue Mercury
in Tenas Project Streams, 2019



Note: Error bars represent the standard error of the mean.

Figure 10.5-11

**Periphyton and Benthic Invertebrate Tissue Molybdenum and Nickel
in Tenas Project Streams, 2019**



Note: Error bars represent the standard error of the mean.

Figure 10.5-12

Periphyton and Benthic Invertebrate Tissue Selenium and Uranium
in Tenas Project Streams, 2019

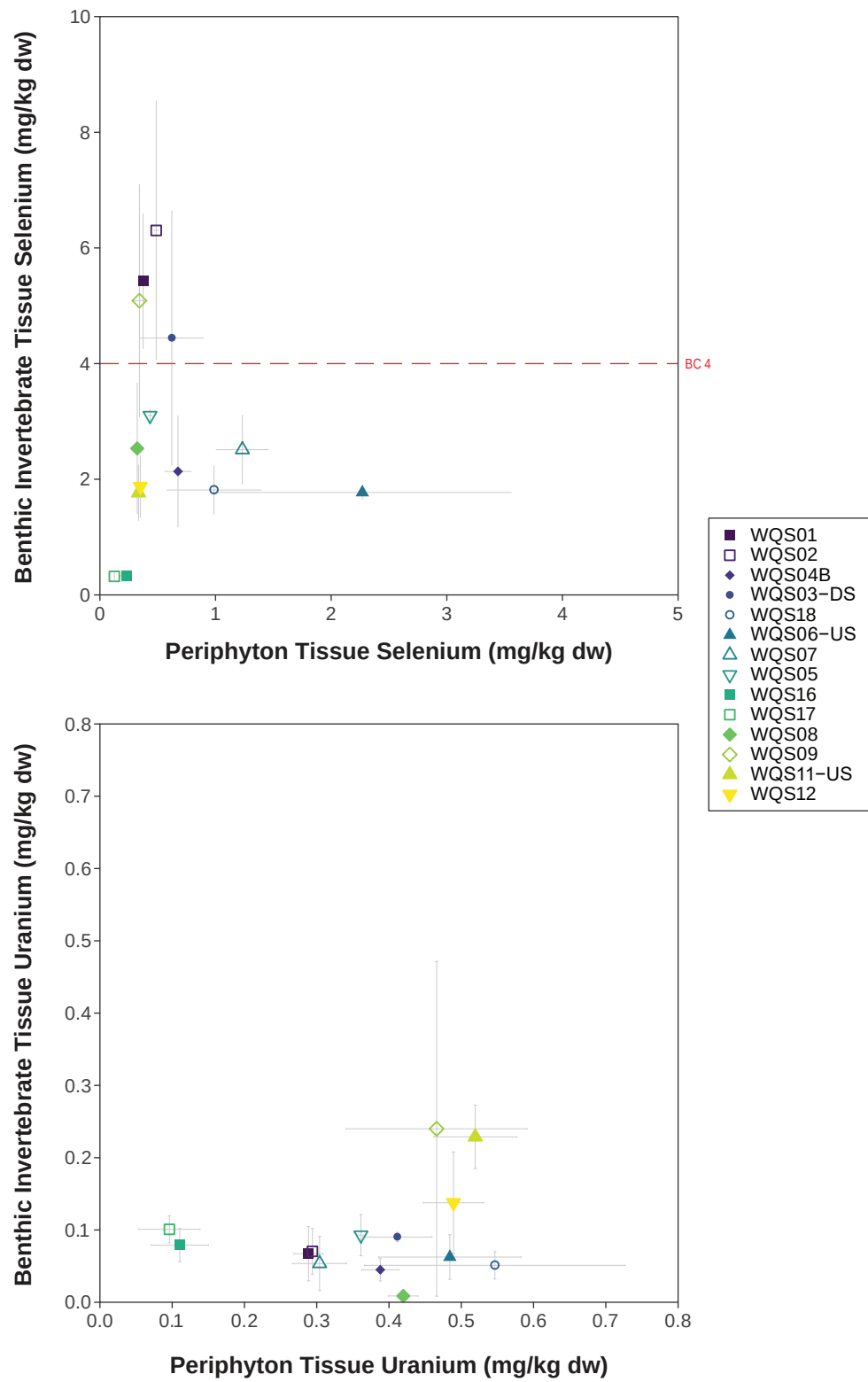
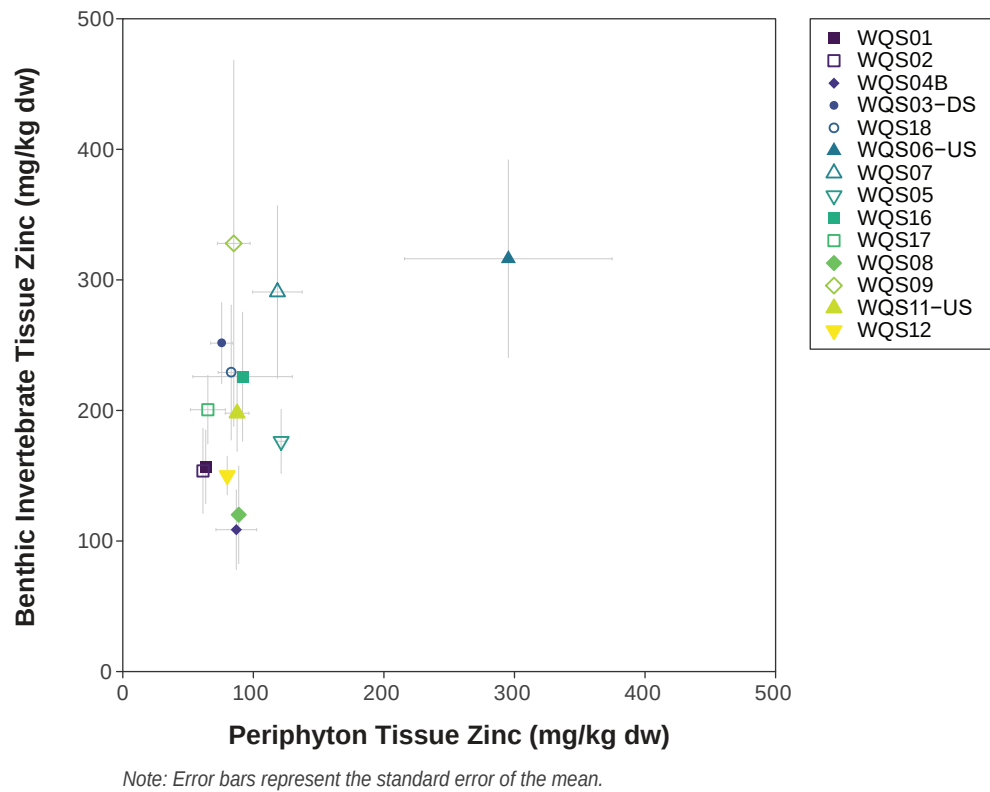


Figure 10.5-13

Periphyton and Benthic Invertebrate Tissue Zinc
in Tenas Project Streams, 2019



Tissue metal concentrations were typically highest in Goathorn Creek at WQS06-US. Periphyton tissues at this site had elevated arsenic, cadmium, cobalt, copper, manganese, mercury, molybdenum, selenium, and zinc (Figures 10.5-6 to 10.5-13). Several of these metals were also elevated in the benthic invertebrate tissues (cadmium, cobalt, mercury, and zinc). Cadmium, mercury, and zinc were also elevated downstream at WQS07 (Figures 10.5-6, 10.5-10, and 10.5-13). Nearby in Four Creek, tissue arsenic, cobalt, and mercury were also comparatively high (Figures 10.5-6, 10.5-7, and 10.5-10). Within Tenas Creek, tissue chromium and nickel concentrations were elevated, particularly at the downstream site, WQS04B (Figures 10.5-7 and 10.5-11). Sediment chromium and nickel concentrations were also elevated in Tenas Creek. The two upstream sites on Tenas Creek, WQS01 and WQS02, had the highest benthic invertebrate tissue selenium concentrations in the area (mean 5.42 and 6.30 mg/kg dw, respectively; Figure 10.5-12). Benthic invertebrate tissue mercury was highest in Helps Creek at WQS17, with elevated concentrations also found in Four Creek and Goathorn Creek (Figure 10.5-10). Tissue metal concentrations in the Telkwa River were typically higher downstream at WQS09 compared to the upstream site, WQS08. Benthic invertebrate tissues from the Bulkley River had comparatively high concentrations of copper, iron, lead, manganese, molybdenum, and uranium (Figures 10.5-8, 10.5-9, 10.5-11, and 10.5-12).

Benthic invertebrate tissue mercury concentrations were above the CCME methylmercury guideline (0.033 mg/kg ww) in Four Creek (WQS03-DS), Goathorn Creek (WQS05), Helps Creek (WQS16 and WQS17), and the Telkwa River (WQS09; Figure 10.5-10). Guideline exceedances were most common and by the highest factor in Helps Creek.

Tenas Creek (WQS01 and WQS02), Four Creek (WQS03-DS), Goathorn Creek (WQS05), and the Telkwa River (WQS08 and WQS09) all had benthic invertebrate tissues above the BC selenium guideline (4 mg/kg dw), with the highest concentrations found in Tenas Creek (Figure 10.5-12).

10.5.4 Quality Assurance/Quality Control

10.5.4.1 Periphyton

Laboratory QA/QC for chlorophyll *a* samples included reference materials and method blanks. The concentrations of all reference materials were within their target data quality objective ranges and all method blanks were below detection limits. Chlorophyll *a* samples from 2017 were not analyzed within the recommended holding time (28 days). This may have resulted in under-estimations of chlorophyll *a*, as it degrades over time. Samples from 2018 and 2019 were analyzed within the recommended holding time.

To determine periphyton taxonomic precision, specimens from eight samples were sent to an independent taxonomist for quality control sorting (Appendices 10-B and 10-C). The percent similarity between the original and QC taxonomist was high (81% to 98%). The QC results indicated that the data were reproducible and of good quality.

10.5.4.2 Benthic Invertebrates

The debris estimated recovery ranged from 95 to 100% in 2017 to 2019 (Appendix 10-E), indicating that benthic invertebrate specimen recovery from sample debris was very high. To determine taxonomic precision, specimens from seven samples were sent to an independent taxonomist (Appendix 10-E).

Between taxonomists, there were no disagreements or misidentifications in 2017, and in 2018 and 2019 disagreements between taxonomists were small (≤ 3 per sample). The taxonomic resolution differed for ≤ 6 specimens per sample, and specimen difference in enumeration was ≤ 7 per sample. Overall, the percent taxonomic agreement ranged from 99 to 100%, indicating that the data were of good quality.

10.5.4.3 *Tissue Residues*

Field

Five periphyton tissue samples and six benthic invertebrate tissue samples were split and analyzed separately (Appendix 10-H). RPDs were calculated for those parameters that had concentrations at least five times greater than their detection limit, which was 95% (146/154) of the duplicate measurements (Clark 2002, 2013 edition). Of these, calculated the RPD value was between 20% and 50% for 45 (31%) of the duplicate concentrations and greater than 50% for 65 (45%) of the duplicate concentrations. This indicates substantially reduced precision, and may reflect incomplete homogenization or increased sample variability. Results should be interpreted with caution.

Laboratory

Laboratory QA/QC included laboratory replicates, and reference materials (Appendix 10-H). RPD values were calculated for laboratory replicates greater than 20 times the detection limit and all laboratory duplicates fell within their designated RPD data quality objective ($\leq 40\%$). The concentrations of all certified reference materials were within their target data quality objective range (70 to 130%). The laboratory QA/QC results indicate that the tissue residue data is of good quality.

11. FISH AND FISH HABITAT

This chapter describes the fish and fish habitat baseline study conducted for the Project in 2017 - 2018. The purpose of the 2017- 2018 fish and fish habitat baseline study was to characterize fish habitat and fish community structure in the project area. This information will inform mine design and the assessment of potential project effects on fish and fish habitat, will support future permitting, and will support future monitoring programs and management plans.

The specific objectives of the 2017-2018 fish and fish habitat baseline program were to:

- summarize existing fish and fish habitat data for waterbodies within the study area;
- confirm fish distribution and community composition in study area streams;
- assess existing fish habitat conditions, including the presence of barriers;
- sample fish in order to characterize biological data for fish species captured, including tissue metal concentrations; and
- identify potential critical habitat for Pacific salmon in the Goathorn and Tenas Creek watersheds.

11.1 STUDY AREA

The Tenas Project lies between Tenas Creek and Goathorn Creek, both of which form part of the Telkwa River watershed. The Telkwa River is a tributary to the Bulkley River, which ultimately feeds into the Skeena River.

The 2017 and 2018 fish and fish habitat baseline program study area focused primarily on the main streams and rivers surrounding the proposed Tenas project area, and included Goathorn Creek, Tenas Creek, the Telkwa River, and the Bulkley River. Sampling sites were set up to reflect proposed project infrastructure and included upstream reference and downstream receiving environment sites. Figure 11.1-1 shows the locations of sampling sites in relation to proposed project infrastructure; the sampling locations overlap with the water quality sites (see Figure 8.1-1) where possible.

Sampling was undertaken for several purposes in 2018. Reference and receiving environment sites sampled in 2017 were resampled in 2018 to collect additional data on fish populations, fish health and tissue quality. Site WQS08 (upper Telkwa River) was sampled in 2017, but could not be sampled in 2018 due to high water levels and poor access at the time of sampling. All of the data presented for this site reflect conditions in October 2017.

11.2 REGULATORY AND POLICY FRAMEWORK

Project specific fish and fish habitat data collection for the Tenas Project is collected as part of EA requirements and is a component of the Joint AIR for MA/EMA AIR Permits (BC MEM and BC MOE 2016). It will allow for the determination of potential project-related effects to fish and fish habitat. Collection of baseline data is also recommended in the *Metal Mining Environmental Effects*

Monitoring (EEM) Technical Guidance Document (Environment Canada 2011) in order to implement a Before-After-Control-Impact (BACI) study that will allow the influences of the mine to be separated from the influence of natural environmental factors.

Fish and fish habitat baseline data collection will also inform permit applications that may be required for the Project.

Fisheries Act

The *Fisheries Act* prohibits causing *serious harm to fish* that are part of, or support, a commercial, recreational or Aboriginal (CRA) fishery (section 35 of the *Fisheries Act*). If proponents are unable to completely avoid or mitigate *serious harm to fish*, their projects will normally require authorization under subsection 35(2) of the *Fisheries Act* in order for the project to proceed without contravening the Act. Fisheries and Oceans Canada (DFO) interprets *serious harm to fish* as:

- The death of fish.
- A permanent alteration to fish habitat on a spatial scale, duration, or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds, nursery, rearing, food supply areas, migration corridors, or any other area in order to carry out one or more of their life processes. The destruction of fish habitat of a spatial scale, duration, or intensity that results in fish no longer being able to rely on such habitats for use as spawning grounds, nursery, rearing, food supply areas, migration corridor, or any other area in order to carry out one or more of their life processes.

After efforts have been made to avoid and mitigate impacts, any residual *serious harm to fish* is required to be offset. An offset measure is one that counterbalances unavoidable *serious harm to fish* resulting from a project with the goal of maintaining or improving the productivity of the CRA fishery. Where possible, offset measures should support available fisheries' management objectives and local restoration priorities.

Determination of *serious harm*, submission of a Request for Project Review and/or application for Authorization, and identification of offsetting measures all require a thorough understanding of baseline conditions, as do the permit applications outlined in the sections below.

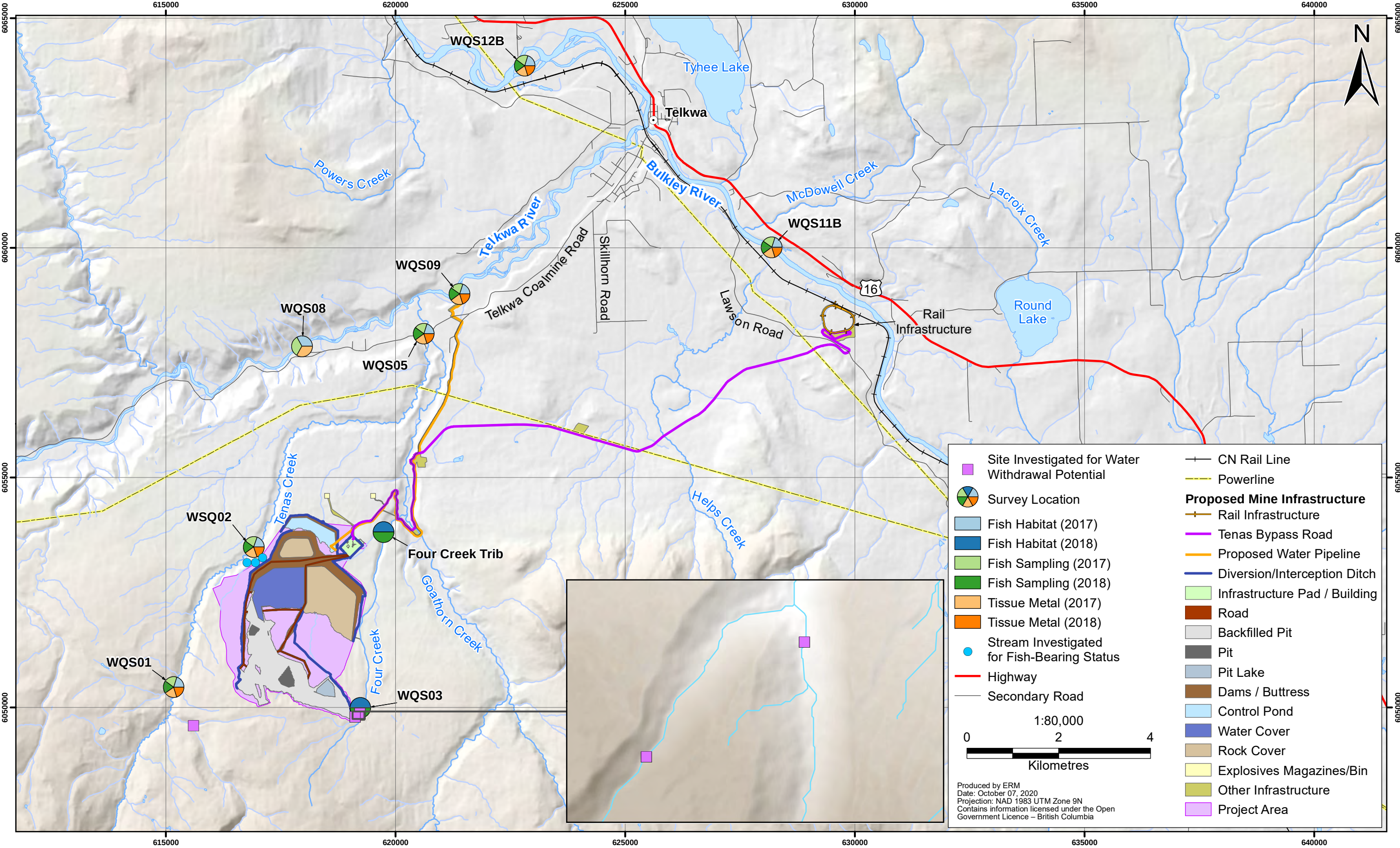
Navigation Protection Act

The *Navigation Protection Act* protects the public right of navigation. An Approval is required for works or construction within a scheduled water course. None of the study area watercourses are currently included on the List of Scheduled Waters.

Species at Risk Act

The *Species at Risk Act* (SARA) protects Schedule 1 listed species from being killed, harmed, harassed, captured, or taken, and their designated critical habitat from being destroyed. No Schedule 1 listed aquatic species, nor any designated critical habitat, have been identified in the study area.

Figure 11.1-1
Fish and Fish Habitat Survey Locations, Tenas Project, 2017-2018



Water Sustainability Act

The provincial *Water Sustainability Act* (WSA) protects streams in British Columbia. “Stream” as defined by the WSA includes lakes, ponds, rivers, creeks, ravines, gulches, wetlands, and glaciers, whether or not usually containing water (or ice).

Project works in or around water will require application for a Change Approval or submission of Notification of Instream Works, depending on the scope and complexity of proposed activities.

The WSA also provides special protection for 15 designated *sensitive streams* within British Columbia. None of the study area watercourses are currently included on this list.

11.3 EXISTING INFORMATION

Baseline studies began with a review of existing information on the freshwater environment in the study area, as described in Table 11.3-1. Most information on fish distribution and habitat in the Project area was collected from Habitat Wizard (BC MOE 2018), which compiles information collected from various public reports, including consultant reports, government report, and permit summary reports. Some reports were available in full text, including aquatic resource assessments conducted by previous Project proponents.

Table 11.3-1. Fish and Fish Habitat Data Information Table

Documents Reviewed	• Bustard, D. 1983. 1982 <i>Investigations of Adult Coho Salmon in the Telkwa River</i>. Smithers, BC: Produced by Dave Bustard and Associates for Crowsnest Resources Ltd. • Bustard, D. 1983. 1982 <i>Investigations of adult pink salmon in the Telkwa River</i>. For READ Environmental & Planning Associates Ltd. • Bustard, D. 1984. <i>Assessment of Benthic Invertebrate and Juvenile Fish Populations in Goathorn and Tenas Creeks and the Lower Telkwa River, 1983</i>. • Bustard, D. 1985. <i>Telkwa Coal Project Aquatic Resource Assessment</i>. Prepared by D. Bustard and Associates for the Telkwa Coal Project: Smithers, BC. • Bustard, D. 1998. <i>Telkwa Coal Project Aquatic Resources Inventory</i>. Prepared for Telkwa Coal Ltd. by Dave Bustard & Associates: Smithers, BC. • Crows Nest Resource Ltd. and READ Environmental & Planning Associates Ltd. 1983. <i>Telkwa Project: Stage I Application</i>. For Energy, Mines and Petroleum Resources, Government of British Columbia, Victoria, BC. • Triton. 1997. 1996 Reconnaissance Level Fish and Fish Habitat Inventory in Working Unit 13 (Telkwa River Watershed). Prepared by Triton Environmental Consultants Ltd. for Pacific Inland Resources Ltd. and BC Ministry of Environment, Lands and Parks: Terrace, BC. • BC MOE. 2018. HabitatWizard. British Columbia Ministry of Environment and Climate Change Strategy Habitat Wizard website. <http://www.env.gov.bc.ca/habwiz/>. Accessed Mar 2018.
General Remarks	• Considerable data on fish habitat and community composition is available for the main Project streams via Habitat Wizard (Four, Goathorn, Tenas, Telkwa, Bulkley; BC MOE 2018). • Little to no data available for smaller tributaries on the proposed mine site. • General data on fish community is out of date (early 80's) and should be updated to identify changes. • Little to no information on salmon spawning locations in Goathorn Creek.

(continued)

Table 11.3-1. Fish and Fish Habitat Data Information Table (completed)

Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (Joint AIR, based on BC MEM and MOE. 2016)	- Describe fish populations and presence of provincially listed species or ecological communities, federally listed species, and genetically distinct populations. - Describe current and potential use of fish resources by First Nations, sport, or commercial fisheries. - Assess and describe fish habitat relative to access roads and utility corridors, waste rock piles, and effluent discharge or seepage locations. - Identify which data reflect un-impacted baseline vs. conditions affected by previous development. - Provide brief description and rationale for a conceptual fish habitat compensation plan, if applicable. - Identify spatial and/or temporal gaps in the database. - Develop a tissue residue database for metals and, if appropriate, organic contaminants.
Existing Data	- Telkwa River, Goathorn Creek, Tenas Creek: Pre 1985. - Bulkley River: 1999. - Telkwa River: 1986-2000. - Goathorn Creek: 1998, 2009. - Tenas Creek: 1998. - Four Creek: 1997, 1998.
Existing Data Issues	Much of the existing information on fish resources in Goathorn and Tenas creeks is decades old and requires updating to reflect changes in the environment (e.g., due to land use, climate change), changes in regulatory guidelines, and changes to laboratory standards and detection limits.
Missing Data	MDMER guidelines (Environment Canada 2011) suggest that fish sampling include: - Fecundity estimates. - Sampling in two seasons. - Sampling of two species.
2017–March 2018 Baseline Program	Tissue sampling is focused on collecting data (including metrics such as fecundity, energy storage, and energy usage) from Rainbow Trout, which are the most widespread species in the Project area. Sampling has occurred in October 2017. A second species is not available due to the low species diversity in Goathorn and Tenas creeks.
June 2018 – March 2019 Baseline Program	Tissue sampling is focused on collecting data (including metrics such as fecundity, energy storage, and energy usage) from Rainbow Trout, which are the most widespread species in the Project area. Sampling has occurred in June 2018. A second species is not available due to the low species diversity in Goathorn and Tenas creeks.
Key Issues	- Spawning surveys are important to identify critical habitat in lower Goathorn and Tenas Creeks. Some species (i.e., pink) leave freshwater as soon as they hatch; thus, the only way to identify their habitat is to see the adults spawning. - MDMER sampling – Sampling in October was conducted with a fall spawning sentinel species in mind (i.e., Dolly Varden); however, rainbow trout were the most widespread species available. Spring sampling should be conducted to maximize the probability of capturing mature, fecund rainbow trout for a complete dataset. A second season of sampling is also useful to track seasonal differences in tissue quality, fish health, and habitat usage (through catch-per-unit-effort), and to provide an estimate of variance, upon which monitoring studies will rely.
Other Comments	No further comments.

Fish species presence is relatively well documented within and adjacent to the Project area, particularly in the Telkwa River and in the Bulkley River. Tenas Creek and Goathorn Creek provide fish habitat for most of their lengths. Three salmon species, as well as mountain whitefish (*Prosopium williamsoni*), have been reported in lower Goathorn Creek, while rainbow trout (*Oncorhynchus mykiss*) and Dolly Varden (*Salvelinus malma*) have been reported in both streams. Four Creek, which runs along the north side of the Project site, provides habitat for Dolly Varden throughout its length, as well as rainbow trout in the lowest reach (Bustard 1997). The Telkwa River supports an important run of coho salmon (*O. kisutch*), and also provides habitat for chinook (*O. tshawytscha*) and pink salmon (*O. gorbuscha*), rainbow trout/steelhead, Dolly Varden, mountain whitefish, and some coarse fish species. The Bulkley River supports populations of all five Pacific salmon species, as well as a world-renowned steelhead run. It also contains numerous other salmonids, as well as several coarse fish species (BC MOE 2018). Several of these species, primarily salmonids, are utilized in CRA fisheries. Table 11.3-2 describes fish species presence in study area waterbodies.

Table 11.3-2. Fish Species Present in Tenas Project Waterbodies

Stream	Fish Species	
	Common Name	Scientific Name
Goathorn Creek	chinook salmon	<i>Oncorhynchus tshawytscha</i>
	coho salmon	<i>Oncorhynchus kisutch</i>
	pink salmon	<i>Oncorhynchus gorbuscha</i>
	rainbow trout/steelhead	<i>Oncorhynchus mykiss</i>
	Dolly Varden	<i>Salvelinus malma</i>
Four Creek	Dolly Varden	<i>Salvelinus malma</i>
	unidentifiable trout	<i>Oncorhynchus</i> spp.
Tenas Creek	Dolly Varden	<i>Salvelinus malma</i>
	bull trout	<i>Salvelinus confluentus</i>
	mountain whitefish	<i>Prosopium williamsoni</i>
	rainbow trout/steelhead	<i>Oncorhynchus mykiss</i>
Telkwa River	chinook salmon	<i>Oncorhynchus tshawytscha</i>
	coho salmon	<i>Oncorhynchus kisutch</i>
	pink salmon	<i>Oncorhynchus gorbuscha</i>
	rainbow trout/steelhead	<i>Oncorhynchus mykiss</i>
	Dolly Varden	<i>Salvelinus malma</i>
	mountain whitefish	<i>Prosopium williamsoni</i>
	peamouth chub	<i>Mylocheilus caurinus</i>
Bulkley River	sucker (general)	<i>Catostomus</i> spp.
	chinook salmon	<i>Oncorhynchus tshawytscha</i>
	coho salmon	<i>Oncorhynchus kisutch</i>
	pink salmon	<i>Oncorhynchus gorbuscha</i>
	sockeye salmon	<i>Oncorhynchus nerka</i>
	chum salmon	<i>Oncorhynchus keta</i>
	rainbow trout/steelhead	<i>Oncorhynchus mykiss</i>

(continued)

Table 11.3-2. Fish Species Present in Project Area Waterbodies (completed)

Stream	Fish Species	
	Common Name	Scientific Name
Bulkley River (cont'd)	cutthroat trout	<i>Oncorhynchus clarkii</i>
	coastrange sculpin	<i>Cottus aleuticus</i>
	prickly sculpin	<i>Cottus asper</i>
	slimy sculpin	<i>Cottus cognatus</i>
	white sucker	<i>Catostomus commersonii</i>
	brassy minnow	<i>Hybognathus hankinsoni</i>
	lake chub	<i>Couesius plumbeus</i>
	burbot	<i>Lota lota</i>
	Dolly Varden	<i>Salvelinus malma</i>
	bull trout	<i>Salvelinus confluentus</i>
	longnose sucker	<i>Catostomus catostomus</i>
	largescale sucker	<i>Catostomus macrocheilus</i>
	sucker (general)	<i>Catostomus spp.</i>
	longnose dace	<i>Rhinichthys cataractae</i>
	reidside shiner	<i>Richardsonius balteatus</i>
	lamprey (general)	<i>Lampetra spp.</i>
	threespine stickleback	<i>Gasterosteus aculeatus</i>
	lake trout	<i>Salvelinus namaycush</i>
	lake whitefish	<i>Coregonus clupeaformis</i>
	Minnow (general)	<i>Cyprinidae spp.</i>
	Northern pikeminnow	<i>Ptychocheilus oregonensis</i>

Notes:

Data summarized from Habitat Wizard (BC MOE 2018)

Bold text indicates species captured during 2017 or 2018 field studies.

Fish habitat and community assessments were conducted in 1983 and 1984 as part of an aquatic resources assessment for a previous owner of the Telkwa Coal Project (Bustard 1985), with 20 sites being revisited in 1997 (Bustard 1998). Reconnaissance level fish and fish habitat inventory was also completed for the Telkwa watershed in 1996 as part of resource planning in the area (Triton 1997). Habitat assessments indicated that the lower reaches of Goathorn and Tenas creeks were suitable for steelhead spawning and rearing, and fish community assessments generally captured steelhead and rainbow trout juveniles in abundance in both creeks. Potential falls barriers are present on the upper reaches of Tenas Creek (Triton 1997), and a confirmed falls barrier is present on Goathorn Creek, 15 km upstream of its confluence with Telkwa River (Bustard 1998). Habitat in the upper reaches of the watershed was more suitable for Dolly Varden, and abundance of this species was higher in the upper reaches than in the lower reaches. It is considered likely that the population in Four Creek is a resident population (Bustard 1998).

Steelhead spawning population sizes were estimated for Goathorn Creek, Tenas Creek and the lower Telkwa River during the 1984 aquatic resources assessment (Bustard 1985). These estimates rely heavily on assumptions of survival from fry through adulthood, and were not supplemented by spawning surveys. The assessment estimated that Goathorn Creek supported approximately

52 spawning steelhead, Tenas Creek supported approximately 107 spawning steelhead, and the lower Telkwa River supported approximately 347 spawning steelhead.

Coho salmon spawning surveys showed that, as predicted, the upper Telkwa River is an important spawning area for this species, and juvenile coho salmon are found throughout the Telkwa and Bulkley Rivers and their tributaries (Bustard 1985). The low water levels and presence of anchor and frazil ice in Goathorn and Tenas Creek limit their use by late-fall spawning fish such as coho; however, the lower reaches are used by juveniles for rearing.

Pink salmon spawning surveys in Goathorn Creek showed that there is variation in abundance of pink salmon throughout the years. 58 pinks were observed in 1983, while none were observed in both 1984 and 1997 (Bustard 1998). Pink salmon seem to only use the lower reaches of Goathorn Creek.

Tissue metal concentrations measured in 1984 in Goathorn and Tenas Creeks were similar among species, and similar to those of fish from other Bulkley River tributaries (Bustard 1985).

11.4 METHODOLOGY

The 2017 and 2018 fish and fish habitat field program was designed to supplement historical data, as well as to provide robust fish and fish habitat data at the receiving environment (i.e., downstream of mine influence) and at reference sites (i.e., outside of the mine influence) in near-field, mid-field, and far-field locations. The study design was based on methods recommended in the *EEM Technical Guidance Document* (Environment Canada 2011), in order that baseline data collected will be suitable for use in a BACI monitoring program after development.

The 2017 field program occurred between October 11 and 14, at seven individual sites (Table 11.4-1; Figure 11.1-1). Habitat assessment and fish sampling, including collection of tissue metals samples, occurred at all seven sites. Sites were chosen to reflect near-field, mid-field, and far-field receiving environment sites, as well as upstream reference sites.

The 2018 field program occurred between June 12 and 19, at eight individual sites, as well as investigation into three additional small streams draining the mine site. Fish sampling, including collection of tissue metals samples, occurred at six of the sites. One site had no fish caught while another could not be sampled due to high water. Fish habitat assessment occurred at three of the sites, while the three additional small streams could not be located. Spawning surveys were also conducted in August, October, and November.

11.4.1 Fish Habitat

Stream habitat assessments were conducted at all sites in either 2017 or 2018. At each site, the watercourse was assessed using methods based on the Reconnaissance 1:20,000 Fish and Fish Habitat Inventory Protocol (RISC 2001) and the Reconnaissance 1:20,000 Fish and Fish Habitat Inventory: Site Card Field Guide (RIC 1999a). This protocol involves characterizing fish habitat over a 100 metre (m)-long section of watercourse by measuring physical attributes (e.g., channel width, gradient, temperature, and water quality), characterizing cover types and substrate (dominant and sub-dominant cover and substrate type, cover abundance, and location), and describing stream morphology (Table 11.4-2). Data and field observations are recorded on the Reconnaissance 1:20,000 Fish and Fish Habitat Inventory Site Card (RIC 1999a).

Table 11.4-1. 2017 and 2018 Fish and Fish Habitat Baseline Sample Locations

Watercourse	Site ID	Easting (m)	Northing (m)	Type	Years Sampled	Habitat Assessment	Fish Sampling	Tissue Metals
Tenas Creek	WQS01	615171	6050438	Reference	2017, 2018	X	X	X
	WQS02	616914	6053490	Near-field receiving environment	2017, 2018	X	X	X
Four Creek	WQS03	619235	6049989	Near-field upstream receiving environment	2018	X	X	-
Goathorn Creek	WQS05	620615	6058133	Near-field receiving environment	2017, 2018	X	X	X
Telkwa River	WQS08	617964	6057860	Reference	2017	X	X	X
	WQS09	621394	6058998	Mid-field receiving environment	2017, 2018	X	X	X
Bulkley River	WQS11B	628189	6060013	Reference	2017, 2018	X	X	X
	WQS12B	622812	6063967	Far-field receiving environment	2017, 2018	X	X	X
Four Creek Tributary	N/A	619740	6053815	Confirm fish presence/absence	2018	X	X	-

Note: UTM Coordinates are in NAD 83 Zone 9V.

Table 11.4-2. Physical and Biological Habitat Attributes Assessed at Each Study Site

Substrate Types	Physical Measurements	Habitat	Cover
% Sand	Length (m)	Habitat Type	% Deep Pool
% Gravel	Mean Depth (m)	Pool Type	% Boulder
% Cobble	Bankfull Depth (m)	Pool Residual Depth	% Instream Vegetation
% Boulder	Wetted Width (m)	Bank Stability	% Undercut
% Bedrock	Bankfull Width (m)	Confinement	% Large Woody Debris
Bank Texture	Gradient (%)	Hill-slope Coupling	% Small Woody Debris
	Bank Height (m)	Stream Pattern	% Canopy Closure
		Islands/Bars	% Riparian Cover
		Fish Passage Barriers	% Overhanging Vegetation

Data collected for each habitat variable were used to evaluate the overall quality of fish habitat. Professional knowledge and expertise was used to rank habitat suitability for each fish life history stage (i.e., spawning, rearing, and over-wintering), and overall habitat quality (categorized as none, marginal, important, or critical; Table 11.4-3). Stream size classification criteria based on size and fish presence is shown in Table 11.4-4.

Table 11.4-3. Life History Habitat Suitability and Overall Habitat Quality Criteria Assessed at Stream Sites

Rank	Criteria
Life Stage Suitability	
None	No habitat present for any life history stage.
Poor	Most of the necessary physical/biological components of the habitat for this life history stage are missing or severely deficient.
Fair	Some of the necessary physical/biological components of the habitat for this life history stage are present, but a key component is missing.
Good	All of the necessary physical/biological components of the habitat for this life history stage are present
Overall Habitat Quality	
None	No habitat present.
Marginal	Low productive capacity.
Important	Common habitat which supplies basic needs of fish (typically includes rearing habitat with some spawning habitat potential).
Critical	Rare or exceptionally productive or unusual habitat with very high habitat values, which are uncommon and/or highly valuable.

Table 11.4-4. Forest Practices Code Stream Classification Criteria

Stream Classification	Mean Channel Width (m)	Fish Present?
S1	> 20.0	Yes
S2	5.0 to 20.0	Yes
S3	1.5 to 5.0	Yes
S4	< 1.5	Yes
S5	> 3	No
S6	≤ 3.0	No

11.4.2 Fish Community

Fish sampling at the Tenas Project was conducted during October 2017 and June 2018 to determine fish presence, species composition, and to collect fish for tissue metal analysis. Fish sampling occurred at WQS01, WQS08, and WQS11B reference and WQS02, WQS03, WQS05, WQS09, and WQS12B receiving environment sites (See Table 11.4-1 and Figure 11-1.1).

The study design for fish community sampling followed Resource Inventory Standards Committee (RISC) Fish Collection Methods and Standards (RIC 1997), Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures (RISC 2001), and the Reconnaissance (1:20,000) Fish and

Fish Habitat Inventory: Fish Collection Field Guide (RIC 1999b). For the determination of fish presence and species composition, electrofishing was conducted over a minimum 100 m stream section using one pass with no stop nets. A systematic sweep was conducted across the entire wetted width from the downstream to the upstream site boundary. Electrofisher voltage (V), duty cycle (%) and frequency (Hz) settings remained consistent where possible. To collect fish for tissue metal analysis, extra effort was expended to collect the required number of fish. Electrofishing in spawning areas during fish spawning activity was avoided to reduce the chance of harming fish and impacting spawning activities.

Salmon spawning surveys were conducted during the 2018 field season. Aerial surveys were performed, followed by ground surveys (Figure 11.4-1).

Chinook spawning surveys were conducted in August 2018. A one day aerial survey was completed and followed by point surveys on the ground where the river was easily accessible. These occurred on the Telkwa River as well as the Lower Goathorn Creek.

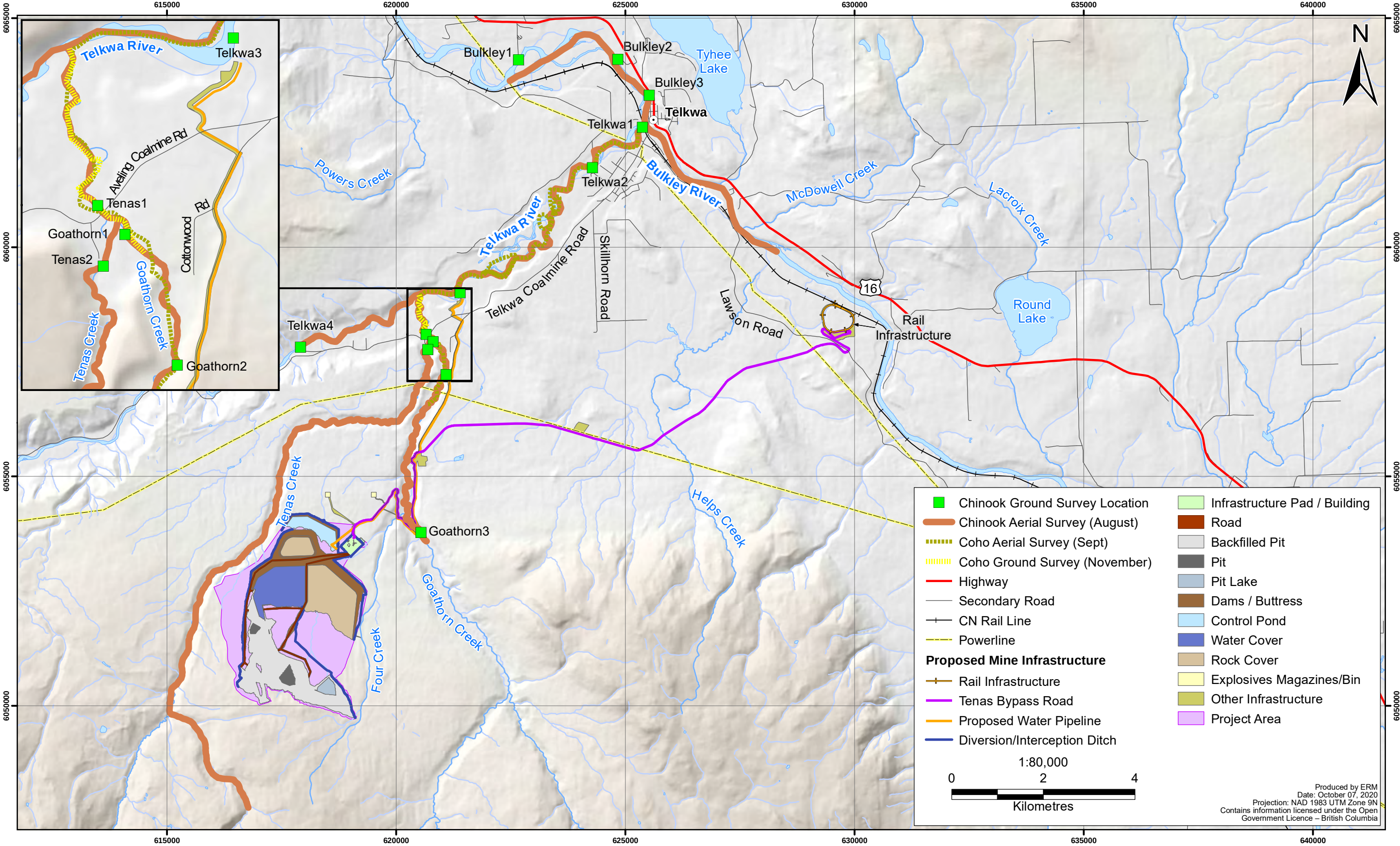
Aerial coho spawning surveys took place in October but no signs of fish were observed. The ground surveys were completed in November instead in an attempt to compensate for low water levels and were focused on the Lower Goathorn Creek from the Coal Mine Road Bridge to the confluence with the Telkwa River.

11.4.3 Fish Biology

Fish captured during the 2017 and 2018 baseline programs were sampled for biological data including fork length, weight, condition, and age. Following capture, fish were identified to species and given a unique sample number. Length was measured to the nearest 1 millimetre (mm) with a measuring board. Species with a forked tail (e.g., rainbow trout) were measured from the nose to the tail notch for fork length (FL). Species without a forked tail (e.g., suckers) were measured from the nose to the end of the tail for total length (TL). Wet weight was collected (to the nearest 0.01 gram (g)) with an Ohaus 200 g or 300 g scale. Observations were recorded on the general condition of fish, noting the presence of deformities, erosions, lesions, and tumours (DELTs), and age (through the collection of scale and fin ray samples from a subsample of fish).

To determine fish age, scales were collected with tweezers below the posterior margin of the dorsal fin on the left side of the sampled fish. For fish that were sacrificed for tissue metal sampling, otoliths were collected as ageing structures. Aging structures from each fish were placed on wax paper and kept in an envelope labeled with the site, date, species, and unique sample number and sent to North/South Consultants Inc. (Winnipeg, Manitoba) for analysis. Age was estimated by counting the number of annuli (yearly rings) on each structure. Scales were attached to plastic fiches and annuli were counted with a microfiche reader. Otoliths were polished and mounted to plastic fiches and annuli were counted under a microscope.

Figure 11.4-1
Salmon Spawning Survey Locations, Tensas Project, 2018



11.4.4 Fish Tissue Metals

Fish health and tissue metal sampling was conducted at receiving and reference environment sites (Table 11.4-5). Sampling was conducted in October 2017 and June 2018, with the objective being to target sexually mature fish for analyses of fecundity. Rainbow trout of similar fork length (generally between 90 and 180 mm) were targeted for tissue metals analysis at each site. Fish were sacrificed in the field and kept on ice, then dissected in the office at the end of each field day. Each fish was sampled for fork length, body weight, sex, maturity, gonad weight (where possible), liver weight, and age. Once livers and gonads were weighed, they were replaced inside the body cavities and the whole fish were placed in labelled plastic bags, frozen and shipped to ALS Environmental of Vancouver, BC for metals analysis.

Table 11.4-5. Metal Analyses and Detection Limits for Fish Tissue Metals

Parameter	Lowest Detection Limit	Units	Parameter	Lowest Detection Limit	Units
Physical Tests (Tissue)			Metals (Tissue) (cont'd)		
Moisture	0.50	%	Manganese (Mn)-Total	0.010	mg/kg ww
Metals (Tissue)			Mercury (Hg)-Total	0.0010	mg/kg ww
Aluminum (Al)-Total	0.40	mg/kg ww	Molybdenum (Mo)-Total	0.0040	mg/kg ww
Antimony (Sb)-Total	0.0020	mg/kg ww	Nickel (Ni)-Total	0.040	mg/kg ww
Arsenic (As)-Total	0.0040	mg/kg ww	Phosphorus (P)-Total	2.0	mg/kg ww
Barium (Ba)-Total	0.010	mg/kg ww	Potassium (K)-Total	4.0	mg/kg ww
Beryllium (Be)-Total	0.0020	mg/kg ww	Rubidium (Rb)-Total	0.010	mg/kg ww
Bismuth (Bi)-Total	0.0020	mg/kg ww	Selenium (Se)-Total	0.010	mg/kg ww
Boron (B)-Total	0.20	mg/kg ww	Silver (Ag)-Total	0.0010	mg/kg ww
Cadmium (Cd)-Total	0.0010	mg/kg ww	Sodium (Na)-Total	4.0	mg/kg ww
Calcium (Ca)-Total	4.0	mg/kg ww	Strontium (Sr)-Total	0.010	mg/kg ww
Cesium (Cs)-Total	0.0010	mg/kg ww	Tellurium (Te)-Total	0.0040	mg/kg ww
Chromium (Cr)-Total	0.010	mg/kg ww	Thallium (Tl)-Total	0.00040	mg/kg ww
Cobalt (Co)-Total	0.0040	mg/kg ww	Tin (Sn)-Total	0.020	mg/kg ww
Copper (Cu)-Total	0.020	mg/kg ww	Uranium (U)-Total	0.00040	mg/kg ww
Iron (Fe)-Total	0.60	mg/kg ww	Vanadium (V)-Total	0.020	mg/kg ww
Lead (Pb)-Total	0.0040	mg/kg ww	Zinc (Zn)-Total	0.10	mg/kg ww
Lithium (Li)-Total	0.10	mg/kg ww	Zirconium (Zr)-Total	0.040	mg/kg ww
Magnesium (Mg)-Total	0.40	mg/kg ww			

Note: ww = wet weight

Once in the laboratory, samples were placed in aluminum weigh boats and weighed to the nearest 0.001 g to provide a total sample weight. Tissue samples were analyzed for metals concentrations according to procedures adapted from the United States Environmental Protection Agency (EPA; US EPA 1995). The tissue samples were then placed in a Precision mechanical convection oven at a temperature of 100.3°C for a period of 24 to 36 hrs. Once the tissue samples were dried, they were weighed in the weigh boat to determine the dry weight of the tissue. Tissue samples were

homogenized and sub-sampled prior to hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis was by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS). Mercury concentrations were analyzed by atomic fluorescence spectrophotometry. The 35 metals analyzed and their detection limits are presented in Table 11.4-5. Silver was analyzed in 2017, but not 2018.

11.4.5 Quality Assurance/Quality Control

To ensure consistency and accuracy of collected data, a quality assurance/quality control (QA/QC) program was established at the outset of the field program. For all fish habitat and community surveys, data sheets were reviewed at the end of each field day to ensure data were complete and collected properly. Field notes were transcribed onto electronic spreadsheets once in the office and all transcriptions were checked visually against the field forms and any errors corrected.

The data were plotted (e.g., weight-length plots) to identify outliers that may have resulted from transcription errors. If transcription errors could not be amended, then those data were excluded from further analysis. Several weights were excluded from analyses because it was determined that the error in measurement was too great. These were generally from very small (less than 40 mm) fish, where excess water and wind caused fluctuations in the scale measurement that could not be corrected.

To assess the accuracy of the fish tissue metal analyses, ALS conducted two measures of quality control: method blanks (MB) and comparison with reference material (CRM). A method blank is a test where no tissue was added. To further assess the accuracy of the metal analyses, CRM was employed, where samples of a reference material, VA-NRC-TORT2 or lobster hepatopancreas, certified by the National Research Council of Canada, were subjected to the same analytical procedures as the tissue samples. The measured concentrations of each metal were then compared to the known metal concentrations in the certified material to determine if they fell within the 95% confidence limits expected for each metal.

11.4.6 Data Analysis

The variables used to assess fish community and biological data included: relative species abundance, length, weight, condition, and catch-per-unit-effort (CPUE). Data analysis and interpretation for these variables followed Guy and Brown (2007). Several of these variables required calculation. A description of the calculations is presented below.

The CPUE statistic is used as an estimate of relative abundance of fish. A key factor that allows comparison of CPUE data is the standardization (type of trap, mesh size, etc.) of sampling devices. Fishing gear and methods (e.g., electrofisher duty cycle, type and size of minnow traps, and a consistent amount of bait) were applied consistently at all sites to facilitate comparison of CPUE data.

For electrofishing, CPUE was calculated as the number of fish caught per 100 seconds (s) of electrofishing:

$$CPUE = \text{number of fish caught} / 100 \text{ s}$$

Where sample sizes were less than 10, we performed bootstrap resampling of our data (10,000 resamples) in order to generate a mean, standard deviation (SD) of the mean, and 95% confidence interval (CI) of the mean. Bootstrapping involves resampling a dataset with replacement. For example, if a dataset contained four values (A, B, C, D), bootstrapping could hypothetically return the following resamples (A, A, C, D; A, B, B, B; A, B, D, D; A, B, C, D; and so on). In such cases, the bootstrap 95% CI are likely narrower than true 95% CI whereas the regular 95% CI are likely larger than the true 95% CI. Thus, bootstrapping provides a less conservative estimate of error variance than conventional estimates for comparing the mean from small sample sizes.

Condition and weight-length regressions are indicators of the relative health of fish within a lake. Condition factor was based on the following formula from Ricker (1975):

$$\text{Condition (K)} = \text{weight (g)} \times 10^5 / \text{length}^3 \text{ (mm)}$$

Weight was multiplied by 10^5 to avoid fractional values, and a length-weight exponent of exactly 3 was assumed to apply to all species of fish.

Measurements of liver size relative to body size are indicative of energy storage in fish. Livers were extracted from rainbow trout sacrificed for tissue metal analysis, and were weighed to the nearest 0.01 g. Liver weight was regressed on total body weight for fish collected from each waterbody, and the slopes of the regression lines were compared using a generalized linear model (GLM). If the slopes of the regressions were equal, then y-intercepts were compared to determine if there were differences in energy storage among fish from different streams. If the slopes of the regression lines were significantly different, then the calculated hepatosomatic index (HSI) was used as a proxy to compare energy storage. HSI is calculated using the following equation:

$$\text{HSI} = 100 (\text{liver weight/body weight})$$

All tissue metals data were reported in units of milligrams/ kilogram (mg/kg) wet weight (wwt). Tissue metals concentration data were summarized in descriptive statistics tables for each fish species, and sampling site. Mean metals concentrations (mg/kg wwt), standard error (SE), and minimum and maximum values were calculated.

Selenium data for rainbow trout were converted from mg/kg wwt to mg/kg dry weight (dwt) for direct comparison with selenium guidelines for British Columbia (BC MOE 2014), using the following formula:

$$[\text{Selenium}] \text{ mg/kg dw} = [\text{Selenium}] \text{ mg/kg ww} / ((100 - \% \text{ moisture})/100)$$

All data were managed using Microsoft Excel 2010. All statistics were conducted according to Zar (1999). R software (R Core Team 2016) was used for statistical analyses.

11.5 DATA SUMMARY

11.5.1 Fish Habitat

11.5.1.1 Overview

Complete Reconnaissance 1:20,000 (RISC 2001) data for each sampling site are presented in Appendix 11-A. This information is summarized below. Sampling site locations are shown in Figure 11.1-1.

11.5.1.2 Tenas Creek

Fish habitat within Tenas Creek was surveyed upstream of the proposed mine project at WQS01 (Photo 11.5-1) and adjacent to the proposed mine at WQS02 (Photo 11.5-2).

Channel width ranged from 3.4 m to 4.5 m with a mean of 4.1 m, making Tenas Creek S3⁸-sized at WQS01. Cobbles and gravels represented the dominant and subdominant substrate types. Boulder and trace amounts of large woody debris (LWD) provided the majority of cover for fish at upstream sites.



Photo 11.5-1. Tenas Creek fish habitat site WQS01 located upstream of proposed mine site (upstream view). October 12, 2017.

⁸ Refer to Table 11.4-4 for stream size rating criteria



Photo 11.5-2. Tenas Creek fish habitat adjacent to the proposed mine site at WQS02 (downstream view). October 14, 2017.

WQS01 was ranked as *important*⁹ for resident Dolly Varden and Rainbow Trout. Spawning and rearing habitat were *good*, based on the presence of appropriate-sized gravel and abundant rearing habitat. Overwintering and migratory habitat were fair: a few slack water pools were observed, and no barriers prevented passage to similar habitat upstream.

WQS02 had channel widths ranging from 8 m to 15 m, with a mean of 10.6 m width, making Tenas Creek S2-sized at this location. Cobbles and boulders represented the dominant and subdominant substrate types. Boulder and trace amounts of LWD provided the majority of cover for fish.

Overall, WQS02 was rated an *important* site. Spawning and rearing habitat were *good*. Many patches of appropriate spawning gravels for Dolly Varden and rainbow trout were present at the site, as was abundant cobble providing cover and potential for invertebrate production. Migratory habitat was also *good*, as no barriers to fish passage were evident and additional good rearing and spawning habitat was noted upstream. Dolly Varden were observed both at the site and further upstream. Overwintering habitat was *fair*, as pools and slack water areas were limited.

11.5.1.3 Goathorn Creek

Fish habitat within Goathorn Creek was surveyed downstream of the proposed mine project at WQS05 (Photo 11.5-3), located just below the confluence of Tenas, Four, and Goathorn creeks.

⁹ Refer to Table 11.4-3 for habitat rating criteria.



Photo 11.5-3. Goathorn Creek fish habitat site WQS05 located downstream of the confluence of Tenas Creek, Four Creek, and Goathorn Creek (downstream view). October 11, 2017.

Goathorn Creek at WQS05 is an S2-sized stream, with channel widths ranging from 14 m to 20 m (mean 16.8 m). Gravel and cobbles represented the dominant and subdominant substrate types. Habitat cover was dominated by LWD with boulders and undercut banks noted as sub-dominant.

Spawning habitat is *good* for salmon and resident fish, with patches of gravels and sufficient stream flow. Rearing and migration are also *good*. The site has abundant cover and is well connected to Dolly Varden spawning habitat upstream. As with the Tenas Creek sites, overwintering habitat is only *fair*, as the site is shallow and contains few pools. Overall, upstream Goathorn Creek was rated an *important* site for fisheries value.

11.5.1.4 Telkwa River

Fish habitat within Telkwa River was surveyed upstream at WQS08, and downstream at the Goathorn Creek confluence into the Telkwa River at WQS09.

Gravel and cobbles represented the dominant and subdominant substrate types at Site WQS08. LWD dominated habitat cover for small fish with both boulders and undercut banks ranking as subdominant. Channel width ranged from 35 m to 38 m with a mean of 36 m for an S1-sized watercourse. Site WQS08 provides *good* rearing habitat with abundant cobble and boulder cover for invertebrate production (Photo 11.5-4). This site has *good* migration habitat that can be used to access upstream spawning and rearing habitat. Spawning and overwintering habitat are both *fair*. Some small areas with appropriate gravels and flow are present. Few pools or slack water areas were observed. Overall, this is an *important* site for fisheries value.



Photo 11.5-4. Telkwa River fish habitat site WQS08 located upstream of the Goathorn and Telkwa rivers' confluence (upstream view). October 15, 2017.

Downstream from WQS08 and the Goathorn Creek / Telkwa River confluence is WQS09 (Photo 11.5-5). WQS09 includes high quality (i.e., *good*) spawning areas for salmon and *good* rearing habitat with abundant boulder cover for small fish. Overwintering habitat is *good*: the site has sufficient flow but few slack water areas. Migration potential is considered *good* with connectivity to major spawning habitat upstream. The Telkwa River is S1-sized at WQS09. Channel width ranged from 42 m to 45 m with a mean channel width of 44 m. Cobbles and boulders represented the dominant and subdominant substrate types. Overall, there was a moderate amount of cover, with boulders dominating. This site is listed as *critical* with a fisheries sensitive zone¹⁰ (FSZ) and a back channel providing rearing habitat for salmon fry.

11.5.1.5 Bulkley River

Fish habitat within Bulkley River was surveyed upstream at WQS11B and downstream of the Telkwa River confluence into the Bulkley River at site WQS12B. The Bulkley River is an S1-sized stream with large channel morphology at both sites: channel width was approximately 120 m at both WQS11B and WQS12B.

The main substrates at Site WQS11B were gravel (dominant) and cobbles (sub-dominant). Site WQS11B provides *good* spawning habitat with patches of suitable gravels (dead pink salmon were noted along banks at time of survey; Photo 11.5-6). This is a *good* migration site with major spawning habitat located upstream. Rearing habitat is *fair*, as very little cover is available for fry. Overwintering habitat is also *fair*, given the short supply of slack water pools at WQS11B. Overall, this site was ranked as *important*, given its spawning values.

¹⁰ Fisheries sensitive zones are side and back channels, ponds, swamps, seasonally flooded depressions, lake littoral zones, and estuaries that are seasonally occupied by overwintering fish (BC Environment 1995).



Photo 11.5-5. Telkwa River fish habitat site WQS09 located downstream of the Goathorn and Telkwa rivers' confluence (downstream view). October 13, 2017.



Photo 11.5-6. Bulkley River fish habitat site WQS11B located upstream of the Telkwa River and Bulkley River confluence (downstream view). October 12, 2017.

Downstream of WQS11B and the confluence of the Bulkley and Telkwa rivers is site WQS12B (Photo 11.5-7), which features an FSZ. Similar to WQS11B, the main substrate is gravel (dominant) and cobbles (sub-dominant). Site WQS12B was ranked as *critical*, as it has abundant available *good* pink salmon spawning habitat. Although there is limited cover for small fish, extensive back-channel sloughs do provide important rearing habitat for these fish, resulting in a ranking of *good*. Overwintering and migratory habitat were also ranked as *good*. The mainstem is deep enough to provide refugia¹¹ in the wintertime, and the site is well-connected to additional salmon spawning habitat upstream.



Photo 11.5-7. Bulkley River fish habitat site WQS12B located downstream of the Telkwa River and Bulkley River confluence (downstream view). October 14, 2017.

11.5.1.6 Four Creek

Fish habitat within Four Creek was surveyed at WQS03. Channel width ranged from 1.8 m to 4 m with a mean of 2.83 m, making Four Creek an S3-sized stream at this location (Photo 11.5-8).

The main substrates at Site WQS03 were gravel (dominant) and cobbles (sub-dominant). Site WQS03 provides *poor* spawning habitat, as there were very few suitable gravel areas. This is a *good* rearing area because it had a lot of cover including large woody debris. *Fair* overwintering habitat exists here due to a few good pools. Overall, this site was ranked as *important* for fisheries values, mainly due to the presence of good rearing habitat for resident Dolly Varden.

¹¹ Refugia are areas in which a population of organisms can survive through a period of unfavorable conditions. Latin for “in refuge”.



Photo 11.5-8. Four Creek at site WQS03, looking upstream. June 12, 2018.

11.5.1.7 Other Streams

Several other streams were assessed in 2018 in order to confirm non-fish-bearing status, and to identify potential areas for water withdrawal to support the proposed project.

Three tributary streams to Tenas Creek were visited in June 2018 to determine if they provide seasonal or permanent fish habitat. The mainstem of Tenas Creek was walked through the area where the confluences of the tributaries were mapped; however, no tributary streams were found. The field team investigated a beaver pond on the right bank of Tenas Creek near where one of the tributaries was mapped (Photo 11.5-9); however, it was fed from the mainstem of Tenas Creek and no other inflow was found.

The ground survey was followed up by an aerial survey, which located one of the mapped channels; however, it seeped into the ground approximately 200 m from the bank of Tenas Creek. Based on this information, all three tributaries were classified as *intermittent* and *non-fish-bearing*.

One tributary to Four Creek was assessed in June 2018 because the map depicted it as draining the north end of the proposed mine site. The stream had a mean bankfull width of 2.1 m, and a mean wetted width of 1.4 m. Pools had a mean residual depth of 0.2 m. The gradient averaged 15%; however, the first 30 m of the stream closest to the confluence with Four Creek had a gradient in excess of 21% (Photo 11.5-10). Cover was abundant and dominated by boulders, followed by large and small woody debris and overhanging vegetation. The bed material was dominated by cobbles and gravel. Habitat quality was considered *fair* for rearing due to the presence of small pools, *poor* for spawning due to the lack of spawning gravel, and *poor* for overwintering due to the shallow depth. A 0.8 m barrier at the confluence likely prevents fish access, and no fish were captured during electrofishing. The stream was considered *non-fish-bearing*, and was classified as S6.



Photo 11.5-9. Beaver pond adjacent to Tenas Creek. June 14, 2018.



Photo 11.5-10. Four Creek tributary looking downstream towards gradient barrier (>30%). June 18, 2018.

Two tributaries of Four Creek upstream of WQS03 were assessed in October and December 2018 as part of the search for potential water withdrawal sites (Photo 11.5-11). Both sites featured very low flow (total estimated discharge of both sites was 6.68 L/s on October 9, and 2.46 L/s on December 11). No permanent barriers to fish migration were identified, and it is assumed that both sites are fish-bearing due to their proximity to WQS03.



Photo 11.5-11. Tributary of Four Creek near WQS03, showing flow measurements on a narrow, shallow channel. October 9, 2018.

One tributary of the east fork of Tenas Creek was assessed in October 2018 as part of the search for potential water withdrawal sites. This stream features a large beaver pond at the upstream end (Photo 11.5-12); however, downstream of this point, the stream flows down a steep canyon and was mostly dewatered on October 9, 2018 (Photo 11.5-13). No fish access is possible due to gradient and obstruction barriers in the canyon.

11.5.2 Fish Community

Fish communities of Tenas Creek and Goathorn Creek were dominated by rainbow trout and Dolly Varden in both October 2017 and June 2018 (Table 11.5-1; Appendix 11-B). A small number of juvenile coho salmon were also captured in lower Goathorn Creek in 2017, but not in 2018. CPUE for rainbow trout was higher in 2017 than 2018 in both Tenas and Goathorn creeks. Dolly Varden CPUE was similar in both years in both streams.



Photo 11.5-12. Beaver pond at upstream end of East Fork Tenas Creek tributary. October 9, 2018.



Photo 11.5-13. East Fork Tenas Creek tributary, looking downstream through the steep, dewatered canyon section. October 9, 2018.

Table 11.5-1. Summary of Electrofishing CPUE in Project Area Streams, 2017 to 2018

Stream	YearSpeciesN			Standard CPUE						Bootstrapped CPUE				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Bulkley River	2017	Coho Salmon	2	1.65	1.55	1.75	0.14	0.1	1.56	1.75	1.65	0.07	1.55	1.75
		Lamprey (General)	1	0.15	0.15	0.15	-	-	0.15	0.15	-	-	-	-
		Rainbow Trout	2	2.17	1.55	2.78	0.87	0.61	1.58	2.75	2.17	0.44	1.55	2.78
		Sucker (General)	2	0.33	0.22	0.44	0.16	0.11	0.23	0.43	0.33	0.08	0.22	0.44
	2018	Chinook Salmon	2	0.29	0.04	0.53	0.35	0.25	0.05	0.52	0.29	0.17	0.04	0.53
		Coho Salmon	3	0.26	0.17	0.45	0.16	0.09	0.17	0.43	0.26	0.07	0.17	0.45
		Dolly Varden	1	0.13	0.13	0.13	-	-	0.13	0.13	-	-	-	-
		Lamprey (General)	1	0.13	0.13	0.13	-	-	0.13	0.13	-	-	-	-
		Longnose Sucker	2	0.43	0.4	0.46	0.05	0.03	0.4	0.46	0.43	0.02	0.4	0.46
		Minnow (General)	1	0.5	0.5	0.5	-	-	0.5	0.5	-	-	-	-
		Northern Pikeminnow	1	0.04	0.04	0.04	-	-	0.04	0.04	-	-	-	-
		Rainbow Trout	3	2.37	1.05	4.26	1.68	0.97	1.08	4.14	2.36	0.79	1.05	4.26
		Sucker (General)	1	0.04	0.04	0.04	-	-	0.04	0.04	-	-	-	-
		White Sucker	2	0.2	0.15	0.25	0.07	0.05	0.15	0.25	0.2	0.04	0.15	0.25
Four Creek	2018	Dolly Varden	1	0.88	0.88	0.88	-	-	0.88	0.88	-	-	-	-
Goathorn Creek	2017	Coho Salmon	1	0.19	0.19	0.19	-	-	0.19	0.19	-	-	-	-
		Dolly Varden	1	0.39	0.39	0.39	-	-	0.39	0.39	-	-	-	-
		Rainbow Trout	1	2.13	2.13	2.13	-	-	2.13	2.13	-	-	-	-
	2018	Dolly Varden	1	0.38	0.38	0.38	-	-	0.38	0.38	-	-	-	-
		Rainbow Trout	1	0.63	0.63	0.63	-	-	0.63	0.63	-	-	-	-
Telkwa River	2017	Coho Salmon	2	0.56	0.24	0.89	0.46	0.32	0.26	0.87	0.56	0.23	0.24	0.89
		Dolly Varden	2	0.2	0.16	0.24	0.06	0.04	0.16	0.24	0.2	0.03	0.16	0.24
		Mountain Whitefish	2	0.16	0.08	0.24	0.11	0.08	0.08	0.24	0.16	0.06	0.08	0.24
		Rainbow Trout	2	1.77	1.38	2.17	0.56	0.4	1.4	2.15	1.77	0.28	1.38	2.17

(continued)

Table 11.5-1. Summary of Electrofishing CPUE in Project Area Streams, 2017 to 2018 (completed)

Stream	Year	Species	N	Standard CPUE						Bootstrapped CPUE				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Telkwa River (cont'd)	2018	Coho Salmon	2	1.57	1.49	1.66	0.12	0.08	1.5	1.65	1.58	0.06	1.49	1.66
		Dolly Varden	1	0.36	0.36	0.36	-	-	0.36	0.36	-	-	-	-
		Rainbow Trout	1	1.16	1.16	1.16	-	-	1.16	1.16	-	-	-	-
Tenas Creek	2017	Dolly Varden	2	1.17	0.7	1.63	0.66	0.46	0.72	1.61	1.16	0.33	0.7	1.63
		Rainbow Trout	2	1.62	1.05	2.18	0.8	0.57	1.08	2.15	1.62	0.4	1.05	2.18
	2018	Dolly Varden	2	1.71	1.34	2.08	0.52	0.37	1.36	2.06	1.71	0.26	1.34	2.08
		Rainbow Trout	2	0.78	0.37	1.19	0.59	0.41	0.39	1.17	0.78	0.29	0.37	1.19
Unnamed Tributary	2018	No Fish Caught	1	0	0	0	-	-	0	0	-	-	-	-

Notes:

N = number of samples

Min = minimum

Max = maximum

SD = standard deviation

SE = standard error

CI = confidence interval

Steelhead (migratory rainbow trout) are known to be present in both Goathorn and Tenas creeks; however, there is no way to differentiate between migratory and non-migratory forms without seeing spawning adults. A spawning survey for adult steelhead could not be undertaken in 2018 due to high water levels and turbid conditions during the spawning season. Historical reports by Bustard (1985) assumed that all rainbow trout in the Goathorn and Tenas systems were potentially steelhead, and estimated a spawning population size of approximately 159 adults. Mapping exercises presented in the Bustard reports suggested that the majority of steelhead spawning likely took place in the lower 5 km of Tenas Creek, and the lower 2 km of Goathorn Creek.

In the Bulkley River, fish species diversity was higher in 2018 than in 2017; however, total CPUE was similar among years. Rainbow trout were the dominant species in both years. Coho salmon CPUE was higher in 2017 than in 2018, and reflects the outmigration of smolts, which likely occurred prior to the June 2018 sampling event.

In the Telkwa River, coho salmon were dominant in 2018, while rainbow trout dominated the catch in 2017. Total CPUE was higher in 2018 than 2017. Sampling in 2018 was complicated by high water levels, which made sampling at WQS08 impossible. Sampling at WQS09 was conducted in two different locations and the habitat types sampled in 2018 were different from those sampled in 2017 (e.g., sampling in June 2018 targeted small side channels and off-channel areas, whereas in October, main channel habitats, log jams, and braids were targeted).

Salmon spawning surveys were conducted in August, October, and November 2018 to identify potential critical habitat for Chinook and coho salmon in receiving environment waters. Aerial and ground surveys for Chinook in August 2018 did not identify any fish, redds, carcasses, or signs of spawning. A single fin from a large, unidentified fish was found in Goathorn Creek just downstream from the Tenas Creek confluence; however, it could not be determined which species it came from or how long it had been there.

An aerial survey in October 2018 for coho salmon was cut short after no signs of fish were observed in any Project area streams. Communication with a DFO biologist on the same day suggested that due to the low water levels in 2018, it could be too early to find spawners (B. Finnegan, pers. comm.). In addition, the biologist confirmed that coho spawn mainly in the upper Telkwa River and adults are unlikely to be present in Goathorn Creek.

A ground survey of lower Goathorn Creek was subsequently undertaken in early November to look for signs of coho spawning. No fish, redds, carcasses, or other signs of fish were seen, despite the presence of suitable coho spawning habitat. The low water levels present in the Bulkley River watershed throughout late summer and early fall may have altered the timing and distribution of spawning adults in those systems. Salmon are known to be “triggered” to move onto their spawning grounds by changes in water temperature and flow, and the anomalous flows during the 2018 spawning season may have caused them to remain in larger rivers downstream until later in the season. The ground survey took place after the peak of spawning typically occurs; however, signs of spawning (e.g., redds, carcasses) would still have been present in the stream. No significant flooding or weather events occurred between the aerial survey and the ground survey that could have flushed out salmon carcasses and made redds difficult to identify.

Although spawning surveys did not turn up any significant signs of Chinook or coho salmon in 2018, it would be premature to say that these species do not utilize Goathorn and Tenas Creeks.

11.5.3 Fish Biology

Raw data are presented in Appendix 11-C. Results of biological analyses for rainbow trout and Dolly Varden are presented below. Other species were not captured in sufficient numbers at all sites to make meaningful analyses of fish health.

Fish captured during the October 2017 and June 2018 sampling events were pooled for analyses of biological parameters at each site. Some sites were sampled in only one season, which may affect comparisons of size (fish captured in October were generally larger than those captured in June due to differences in life stage); thus, this was mentioned wherever applicable.

11.5.3.1 Rainbow Trout

Rainbow trout were the most abundant species captured in the Project area in both 2017 and 2018. There were significant differences in mean length, weight, and condition of rainbow trout among sites sampled in 2017 and 2018 (Table 11.5-2). The mean length of rainbow trout was significantly larger at Tenas Creek sites than other sites in the Project area (ANOVA; $F_{6,268} = 6.291$, $P < 0.01$). In particular, rainbow trout captured from WQS01 were significantly larger than fish from all other sites. The smallest rainbow trout were captured at WQS11 on the Bulkley River. These differences were likely due to the large number of young-of-year (YOY) rainbow trout captured on the larger rivers.

Rainbow trout are spring spawners, spawning in mid- to late-May in most northern streams, and emerging some weeks later (depending on temperature) (McPhail 2007). In Tenas and Goathorn Creeks, which are smaller, colder systems, the mean size tended to be larger because YOY had likely not emerged from the gravel at the time of the June sampling period and were therefore caught in smaller numbers. This is reflected in the length-frequency analysis, particularly for WQS01 (Tenas Creek), which shows that all of the fish captured fell into a narrow size range over 100 mm (Figure 11.5-1). At WQS02 (lower Tenas Creek), more YOY fish were captured; however, the majority of rainbow trout captured measured over 80 mm in length. In contrast, the highest modes in the length-frequency analyses for sites on the Bulkley and Telkwa Rivers (WQS11, WQS12, and WQS09) tended to fall into the 40 to 60 mm size range.

Similarly, the mean weight of rainbow trout was significantly different among sites, and was highest at WQS01 on Tenas Creek (ANOVA; $F_{6,249} = 4.489$, $P < 0.01$). The differences in mean weight among sites was less pronounced than the differences in mean length because the weight of YOY fish in the field was difficult to measure due to the extremely small size of fish and the relatively large inaccuracies introduced by added water on the scales.

In contrast, the mean condition factor (a measure of relative weight and health of fish) was significantly higher at WQS11 (Bulkley River) than WQS01 on Tenas Creek (ANOVA; $F_{6,249} = 3.027$, $P < 0.01$). This was likely also due to the higher water temperatures (and therefore, productivity) of the Bulkley River relative to the smaller streams in the Project area.

Weight-length regressions for rainbow trout were compared among sites as another measure of relative fish health (Figure 11.5-2). There was no significant effect of the interaction between length and site on weight (GLM, $P > 0.05$ for all sites), which indicates that the length-weight relationship is similar among sites. Significant differences in the intercepts of the regression lines reveal differences in weight-at-length among sites (GLM, $F_{13,242} = 1.315$, $P < 0.01$). The highest weight-at-length for rainbow trout occurred at site WQS09 (Telkwa River), while the lowest occurred at WQS11 (Bulkley River).

Table 11.5-2. Length, Weight, and Condition of Fish in Project Area Streams, 2017 and 2018

Site	Species	Year	N	Standard Data						Bootstrapped Data				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Length (mm)														
WQS01	Dolly Varden	2017	14	111	74	155	22	6	79	149	111	6	100	122
	Rainbow trout		9	114	103	132	9	3	103	130	114	3	109	120
	Dolly Varden	2018	34	100	67	129	14	2	74	125	100	2	95	104
	Rainbow trout		6	116	102	132	13	5	102	132	116	5	107	126
WQS02	Dolly Varden	2017	7	106	77	128	23	9	78	128	106	8	89	121
	Rainbow trout		22	90	42	178	36	8	42	159	90	7	76	105
	Dolly Varden	2018	18	89	54	119	20	5	54	116	89	4	80	97
	Rainbow trout		16	83	39	140	27	7	42	128	83	7	70	96
WQS03	Dolly Varden	2018	6	95	54	120	27	11	57	120	95	10	74	112
WQS05	Coho salmon	2017	2	80	62	97	25	18	63	96	80	12	62	97
	Dolly Varden		4	85	51	141	43	21	51	138	85	18	52	119
	Rainbow trout		22	74	39	116	27	6	40	115	74	5	63	84
	Dolly Varden	2018	6	88	51	120	29	12	52	120	88	11	67	109
Rainbow trout	10		96	45	138	32	10	45	136	96	10	77	114	
WQS08	Coho salmon	2017	11	69	55	90	12	4	55	89	69	3	63	75
	Dolly Varden		2	95	91	98	5	4	91	98	95	2	91	98
	Mountain whitefish		1	97	97	97	-	-	97	97	-	-	-	-
	Rainbow trout		17	82	40	161	30	7	42	139	82	7	69	95
WQS09	Coho salmon	2017	2	79	52	105	37	27	53	104	79	19	52	105
	Dolly Varden		2	166	160	171	8	6	160	171	165	3	160	171
	Mountain whitefish		2	59	55	62	5	4	55	62	58	2	55	62
	Rainbow trout		18	83	39	126	19	5	50	118	83	4	74	91
	Coho salmon	2018	55	51	30	92	15	2	30	79	51	2	47	55
	Dolly Varden		6	94	52	133	34	14	54	132	94	13	69	119
	Rainbow trout		29	64	42	131	24	4	43	114	64	4	56	72

(continued)

Table 11.5-2. Length, Weight, and Condition of Fish in Project Area Streams, 2017 and 2018 (continued)

Site	Species	Year	N	Standard Data						Bootstrapped Data				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Length (mm; <i>cont'd</i>)														
WQS11	Coho salmon	2017	12	63	47	85	13	4	48	84	63	4	57	70
	Lamprey (general)		1	80	80	80	-	-	80	80	-	-	-	-
	Rainbow trout		19	108	50	170	32	7	56	162	108	7	94	122
	Sucker (general)		3	93	53	134	41	23	55	132	93	19	53	134
	Chinook salmon	2018	3	107	93	119	13	8	94	119	107	6	93	119
	Coho salmon		10	45	39	49	3	1	39	49	45	1	43	47
	Longnose sucker		8	50	34	98	21	7	35	91	50	7	40	65
	Rainbow trout		60	58	36	153	23	3	36	110	58	3	52	64
	White sucker		3	121	114	125	6	4	115	125	121	3	114	125
WQS12	Coho salmon	2017	21	64	44	95	16	3	44	92	64	3	58	71
	Rainbow trout		21	83	40	151	29	6	41	142	83	6	71	96
	Sucker (general)		3	114	100	142	24	14	100	140	114	11	100	142
	Minnow (general)	2018	12	70	35	99	16	5	42	96	70	4	62	79
	Chinook salmon		1	45	45	45	-	-	45	45	-	-	-	-
	Coho salmon		4	46	42	50	4	2	42	50	46	2	43	49
	Dolly Varden		3	92	49	142	47	27	51	139	92	22	49	142
	Lamprey (general)		2	125	122	128	4	3	122	128	125	2	122	128
	Longnose sucker		12	53	27	76	15	4	30	74	53	4	45	61
	Northern pikeminnow		1	143	143	143	-	-	143	143	-	-	-	-
	Rainbow trout		26	69	35	133	27	5	37	123	69	5	59	79
	Sucker (general)		1	25	25	25	-	-	25	25	-	-	-	-
	White sucker		9	84	48	150	38	13	49	148	84	12	62	110

(continued)

Table 11.5-2. Length, Weight, and Condition of Fish in Project Area Streams, 2017 and 2018 (continued)

Site	Species	Year	N	Standard Data						Bootstrapped Data				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Weight (g)														
WQS01	Dolly Varden	2017	14	13.77	4.00	32.98	8.02	2.14	4.91	30.58	13.80	2.07	10.09	18.19
	Rainbow trout		9	15.64	9.59	24.18	4.08	1.36	10.21	22.82	15.64	1.30	13.27	18.35
	Dolly Varden	2018	34	9.18	3.00	17.00	3.35	0.57	3.83	16.17	9.17	0.57	8.09	10.29
	Rainbow trout		6	17.47	11.02	24.50	5.97	2.44	11.14	24.48	17.44	2.25	13.18	21.80
WQS02	Dolly Varden	2017	7	12.45	4.40	19.67	6.60	2.49	4.62	19.54	12.39	2.32	7.76	16.73
	Rainbow trout		22	12.22	0.77	62.25	13.79	2.94	0.82	45.61	12.23	2.90	7.34	18.62
	Dolly Varden	2018	18	7.51	1.61	17.18	4.33	1.02	1.65	16.20	7.51	1.00	5.61	9.52
	Rainbow trout		16	8.67	0.47	29.16	7.30	1.83	0.66	23.95	8.64	1.77	5.45	12.32
WQS03	Dolly Varden	2018	6	12.00	2.00	23.00	8.46	3.45	2.50	22.50	11.96	3.17	6.00	18.17
WQS05	Coho salmon	2017	2	6.06	2.37	9.76	5.23	3.69	2.55	9.58	6.07	2.62	2.37	9.76
	Dolly Varden		4	9.73	1.01	28.93	13.19	6.60	1.02	27.35	9.79	5.66	1.07	21.98
	Rainbow trout		22	5.97	0.68	16.69	5.29	1.13	0.71	16.25	5.96	1.12	3.86	8.21
	Dolly Varden	2018	6	8.97	1.54	16.34	6.43	2.62	1.58	16.27	8.98	2.42	4.19	13.73
	Rainbow trout		10	13.11	0.82	26.83	9.68	3.06	0.87	26.36	13.15	2.90	7.61	18.80
WQS08	Coho salmon	2017	11	3.90	1.57	7.58	2.05	0.62	1.64	7.41	3.90	0.55	2.89	5.02
	Dolly Varden		2	7.72	6.77	8.68	1.35	0.96	6.82	8.63	7.73	0.67	6.77	8.68
	Mountain whitefish		1	7.18	7.18	7.18	-	-	7.18	7.18	-	-	-	-
	Rainbow trout		17	8.43	0.64	47.43	10.83	2.63	0.72	33.61	8.53	2.40	4.72	13.62
WQS09	Coho salmon	2017	1	11.83	11.83	11.83	-	-	11.83	11.83	11.83	0.00	11.83	11.83
	Dolly Varden		2	45.11	43.33	46.88	2.51	1.78	43.42	46.79	45.09	1.03	43.33	46.88
	Mountain whitefish		2	1.58	1.34	1.82	0.34	0.24	1.35	1.81	1.58	0.12	1.34	1.82
	Rainbow trout		18	6.71	0.49	18.86	4.24	1.00	1.57	15.88	6.72	0.98	4.93	8.77
	Coho salmon	2018	47	2.00	0.20	12.47	2.18	0.32	0.21	5.87	2.10	0.01	2.09	2.10
	Dolly Varden		6	12.02	1.36	28.66	11.37	4.64	1.50	27.62	12.00	4.21	4.50	20.63
	Rainbow trout		27	4.55	0.76	24.10	5.74	1.11	0.80	18.15	4.53	1.01	2.70	6.61

(continued)

Table 11.5-2. Length, Weight, and Condition of Fish in Project Area Streams, 2017 and 2018 (continued)

Site	Species	Year	N	Standard Data						Bootstrapped Data				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Weight (g; <i>cont'd</i>)														
WQS11	Coho salmon	2017	7	3.46	0.90	6.75	2.33	0.88	1.00	6.64	3.61	0.54	2.81	4.36
	Rainbow trout		16	20.24	2.66	57.25	14.16	3.54	3.96	50.29	20.40	3.14	14.43	27.43
	Sucker (general)		2	16.77	8.64	24.91	11.50	8.13	9.05	24.50	16.67	4.82	8.64	24.91
	Chinook salmon	2018	3	13.74	8.65	17.16	4.49	2.59	8.99	17.07	13.74	2.12	8.65	17.16
	Coho salmon		10	1.03	0.31	1.47	0.35	0.11	0.41	1.45	1.03	0.10	0.82	1.22
	Longnose sucker		8	2.10	0.45	10.65	3.50	1.24	0.47	9.17	2.09	1.15	0.63	4.62
	Rainbow trout		48	3.82	0.24	34.30	5.89	0.85	0.43	13.87	3.83	0.85	3.76	2.41
	White sucker		3	19.72	16.17	22.54	3.25	1.88	16.38	22.44	19.72	1.53	16.17	22.54
WQS12	Coho salmon	2017	18	3.92	1.74	8.38	2.25	0.53	1.78	8.08	3.92	0.48	3.07	4.88
	Rainbow trout		19	9.67	1.39	36.29	9.31	2.14	2.29	31.10	9.72	2.01	6.17	14.06
	Sucker (general)		3	19.54	12.43	33.20	11.83	6.83	12.46	32.19	19.62	5.55	12.43	33.20
	Minnow (general)	2018	11	5.39	3.00	11.36	2.59	0.78	3.10	10.71	5.38	0.72	4.13	6.92
	Chinook salmon		1	1.05	1.05	1.05	-	-	1.05	1.05	-	-	-	-
	Coho salmon		4	1.04	0.77	1.39	0.30	0.15	0.77	1.37	1.04	0.13	0.79	1.28
	Dolly Varden		3	11.47	1.46	27.23	13.81	7.98	1.67	26.15	11.48	6.51	1.46	27.23
	Lamprey (general)		2	4.11	3.89	4.33	0.31	0.22	3.90	4.32	4.11	0.16	3.89	4.33
	Longnose sucker		10	1.78	0.62	5.13	1.46	0.46	0.64	4.75	1.78	0.39	1.07	2.66
	Northern pikeminnow		1	31.73	31.73	31.73	-	-	31.73	31.73	-	-	-	-
	Rainbow trout		26	5.79	0.35	26.22	6.97	1.37	0.46	22.91	5.78	1.34	3.38	8.54
	White sucker		9	10.61	1.30	33.59	13.19	4.40	1.41	33.50	10.59	4.14	3.39	19.68
Condition (g/mm³)														
WQS01	Dolly Varden	2017	14	0.93	0.83	1.06	0.07	0.02	0.84	1.05	0.93	0.02	0.90	0.96
	Rainbow trout		9	1.04	0.88	1.23	0.11	0.04	0.88	1.21	1.04	0.03	0.97	1.10
	Dolly Varden	2018	34	0.89	0.73	1.12	0.09	0.01	0.75	1.07	0.89	0.01	0.86	0.92
	Rainbow trout		6	1.08	0.98	1.14	0.06	0.02	0.99	1.14	1.08	0.02	1.04	1.12

(continued)

Table 11.5-2. Length, Weight, and Condition of Fish in Project Area Streams, 2017 and 2018 (continued)

Site	Species	Year	N	Standard Data						Bootstrapped Data				
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Condition (g/mm ³ ; cont'd)														
WQS02	Dolly Varden	2017	7	0.97	0.85	1.07	0.07	0.03	0.86	1.06	0.97	0.02	0.92	1.01
	Rainbow trout		22	1.13	0.90	1.34	0.12	0.03	0.93	1.32	1.13	0.03	1.08	1.18
	Dolly Varden	2018	18	0.96	0.63	1.18	0.14	0.03	0.66	1.15	0.96	0.03	0.89	1.02
	Rainbow trout		16	1.13	0.79	1.29	0.13	0.03	0.83	1.28	1.13	0.03	1.06	1.19
WQS03	Dolly Varden	2018	6	1.18	1.09	1.33	0.10	0.04	1.10	1.32	1.18	0.04	1.12	1.25
WQS05	Coho salmon	2017	2	1.03	0.99	1.07	0.06	0.04	0.99	1.07	1.03	0.03	0.99	1.07
	Dolly Varden		4	0.88	0.76	1.03	0.12	0.06	0.76	1.02	0.88	0.05	0.78	0.98
	Rainbow trout		22	1.10	0.90	1.48	0.15	0.03	0.92	1.45	1.10	0.03	1.04	1.16
	Dolly Varden	2018	6	1.07	0.90	1.31	0.16	0.06	0.91	1.29	1.07	0.06	0.96	1.19
Rainbow trout	10		1.10	0.90	1.36	0.15	0.05	0.90	1.34	1.10	0.05	1.02	1.19	
WQS08	Coho salmon	2017	11	1.10	0.94	1.37	0.11	0.03	0.94	1.31	1.10	0.03	1.04	1.16
	Dolly Varden		2	0.91	0.90	0.92	0.01	0.01	0.90	0.92	0.91	0.01	0.90	0.92
	Mountain whitefish		1	0.79	0.79	0.79	-	-	0.79	0.79	-	-	-	-
	Rainbow trout		17	1.08	0.97	1.35	0.10	0.02	0.98	1.30	1.08	0.02	1.04	1.13
WQS09	Coho salmon	2017	1	1.02	1.02	1.02	-	-	1.02	1.02	1.02	0.00	1.02	1.02
	Dolly Varden		2	1.00	0.94	1.06	0.08	0.06	0.94	1.06	1.00	0.03	0.94	1.06
	Mountain whitefish		2	0.78	0.76	0.81	0.04	0.03	0.76	0.81	0.78	0.01	0.76	0.81
	Rainbow trout		18	1.04	0.83	1.25	0.09	0.02	0.88	1.21	1.04	0.02	1.00	1.08
	Coho salmon	2018	47	1.07	0.29	1.60	0.22	0.03	0.70	1.46	1.05	0.04	1.00	1.10
	Dolly Varden		6	1.01	0.85	1.22	0.15	0.06	0.85	1.21	1.01	0.06	0.90	1.12
	Rainbow trout		27	1.14	0.90	2.23	0.25	0.05	0.90	1.72	1.14	0.05	1.06	1.24

(continued)

Table 11.5-2. Length, Weight, and Condition of Fish in Project Area Streams, 2017 and 2018 (completed)

Site	Species	Year	N	Standard Data							Bootstrapped Data			
				Mean	Min	Max	SD	SE	Lower CI	Upper CI	Mean	SD	Lower CI	Upper CI
Condition (g/mm ³ ; cont'd)														
WQS11	Coho salmon	2017	7	1.06	0.76	1.32	0.20	0.08	0.78	1.31	1.04	0.05	0.96	1.14
	Rainbow trout		16	1.10	0.69	1.34	0.15	0.04	0.79	1.30	1.10	0.03	1.03	1.16
	Sucker (general)		2	1.06	1.04	1.07	0.02	0.02	1.04	1.07	1.05	0.01	1.04	1.07
	Chinook salmon	2018	3	1.10	1.02	1.19	0.09	0.05	1.02	1.18	1.10	0.04	1.02	1.19
	Coho salmon		10	1.08	0.52	1.36	0.23	0.07	0.62	1.34	1.08	0.07	0.93	1.20
	Longnose sucker		8	1.02	0.91	1.14	0.10	0.03	0.91	1.14	1.02	0.03	0.95	1.08
	Rainbow trout		48	1.01	0.51	1.40	0.20	0.03	0.56	1.33	1.01	0.03	1.01	0.95
	White sucker		3	1.10	1.07	1.15	0.04	0.02	1.07	1.15	1.10	0.02	1.07	1.15
WQS12	Coho salmon	2017	18	1.18	0.98	1.56	0.14	0.03	0.98	1.47	1.18	0.03	1.13	1.23
	Rainbow trout		19	1.16	1.00	1.36	0.10	0.02	1.01	1.35	1.16	0.02	1.12	1.20
	Sucker (general)		3	1.22	1.16	1.30	0.07	0.04	1.16	1.30	1.22	0.03	1.16	1.30
	Minnow (general)	2018	11	1.28	1.17	1.42	0.07	0.02	1.18	1.41	1.28	0.02	1.24	1.32
	Chinook salmon		1	1.15	1.15	1.15	-	-	1.15	1.15	-	-	-	-
	Coho salmon		4	1.08	1.02	1.14	0.06	0.03	1.02	1.14	1.08	0.02	1.03	1.12
	Dolly Varden		3	1.04	0.93	1.24	0.17	0.10	0.93	1.23	1.04	0.08	0.93	1.24
	Lamprey (general)		2	0.22	0.19	0.24	0.04	0.02	0.19	0.24	0.22	0.02	0.19	0.24
	Longnose sucker		10	1.00	0.73	1.22	0.18	0.06	0.75	1.22	1.00	0.05	0.90	1.09
	Northern pikeminnow		1	1.09	1.09	1.09	-	-	1.09	1.09	-	-	-	-
	Rainbow trout		26	1.13	0.65	1.32	0.17	0.03	0.76	1.32	1.13	0.03	1.06	1.19
	White sucker		9	1.18	0.98	1.29	0.10	0.03	1.00	1.28	1.18	0.03	1.12	1.24

Notes:

N = number of samples*Min* = minimum; *Max* = maximum*SD* = standard deviation; *SE* = standard error*CI* = confidence interval

Figure 11.5-1

**Length-Frequency Distribution of Rainbow Trout in
Tenas Project Waterbodies, 2017 and 2018**

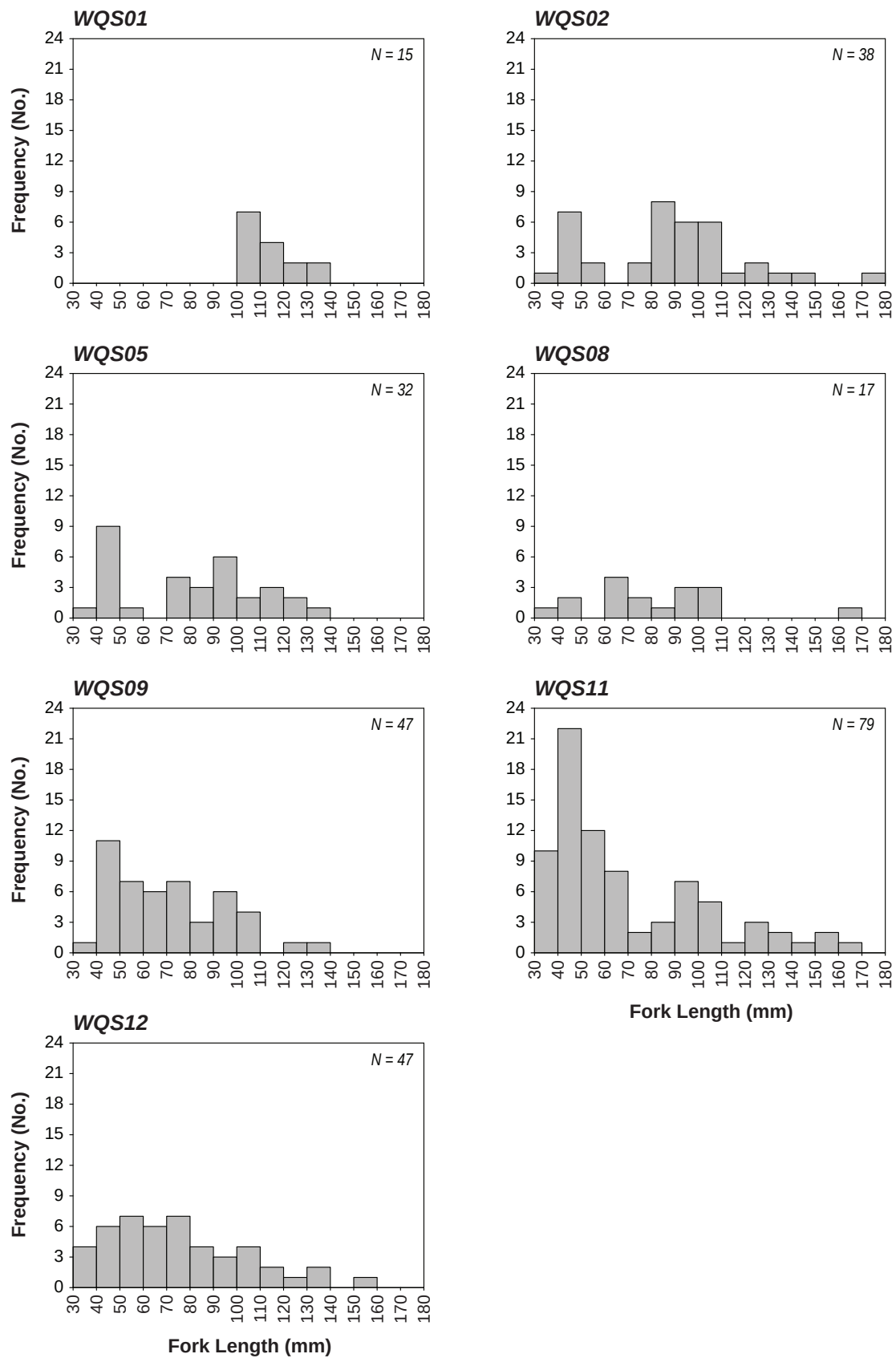
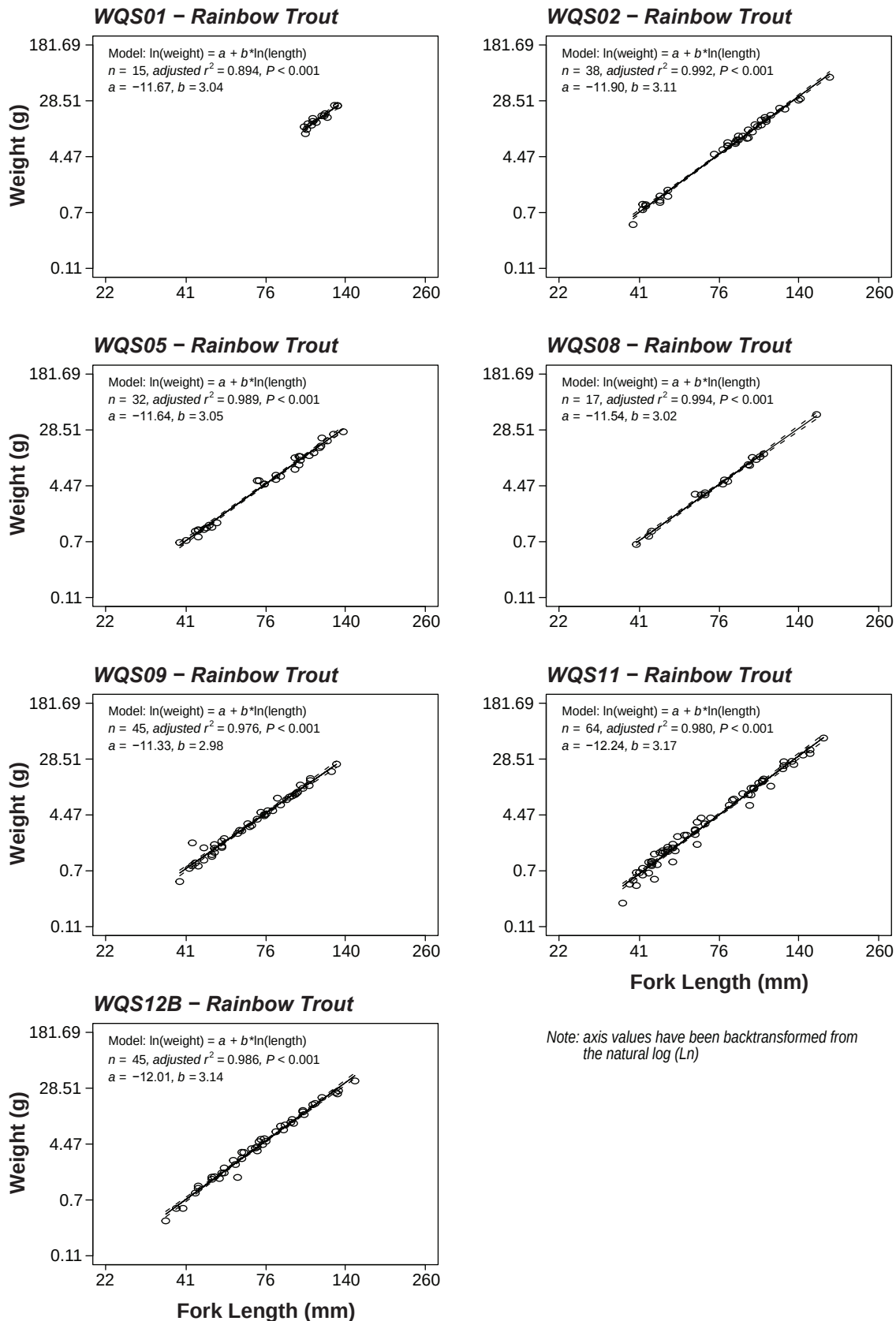


Figure 11.5-2

Weight-Length Regressions for Rainbow Trout in Tenas Project Waterbodies, 2017 and 2018



Energy storage among rainbow trout sacrificed for tissue metals analysis was also assessed using relative liver size (liver weight-total weight regression; Figure 11.5-3). There were no significant effects of the interaction between site and total weight on liver weight (GLM, $P > 0.05$ for all interactions), indicating that the relationship between liver size and total weight was similar among sites. There were significant differences in the intercepts among sites (GLM, $F_{13,86} = 20.83$, $P < 0.01$), indicating that relative liver weight differed among sites. Relative liver weights were highest at sites WQS11 (Bulkley River) and WQS09 (Telkwa River) and lowest at site WQS01 (Tenas Creek). Relative liver weights were also low at site WQS08 relative to other sites in the Project area; however, since this site was only sampled in October, this result could be influenced by season rather than a difference in fish health.

The mean age of rainbow trout differed significantly among sites (ANOVA, $F_{6,115} = 3.129$, $P < 0.01$), with fish captured from WQS05 (Goathorn Creek) being significantly younger than fish from WQS11 (Bulkley River). However, these results are not representative of all of the fish captured from these sites. Age data was collected mainly from those fish sacrificed for metals analysis, and were not generally collected from the many YOY fish sampled.

Length-at-age of all rainbow trout captured was estimated using three models: a von Bertalanffy model, a modified von Bertalanffy model (which fixes the theoretical size at age-0 at 0), and a linear model (Figure 11.5-4).

The linear model best described the relationship between fork length and age for the rainbow trout analyzed from the Tenas Project area (Akaike weight = 0.63, $R^2 = 0.25$; Figure 11.5-4). The poor fit of the von Bertalanffy and modified von Bertalanffy models is likely due to the small size and age range of fish sampled. All of the fish sampled for aging structures fell between one and three years of age, which makes estimating asymptotic size statistically difficult.

In general, the results of rainbow trout comparisons among sites reflect the differences in habitat conditions (i.e., smaller, colder headwater streams versus larger, warmer rivers). While differences in fish size and condition exist among sites, these can mostly be attributed to differences in habitat conditions and the timing of sampling.

11.5.3.2 Dolly Varden

Dolly Varden were captured at all sites in the Project area; however, they were only captured in numbers sufficient for statistical analysis at 5 sites (WQS01, WQS02, WQS03, WQS05, WQS09). In contrast to rainbow trout, there were no significant differences among sites in the mean length (ANOVA, $F_{6,95} = 1.504$, $P = 0.19$) or mean weight (ANOVA, $F_{6,95} = 1.173$, $P = 0.327$) of Dolly Varden in the Tenas Project area (Table 11.5-1).

Relatively few Dolly Varden were captured in the Project area, compared to rainbow trout. Length-frequency distributions for fish captured in Tenas Creek (WQS01 and WQS02) showed that the majority fell into the 80 to 100 mm size range (Figure 11.5-5). Few Dolly Varden under 60 mm were captured, and the largest fish fell into the 150 to 160 mm size range. In Goathorn Creek (WQS05), the majority of Dolly Varden captured fell into the 50 to 60 mm size range. A single large (approximately 400 mm) adult Dolly Varden was observed in lower Goathorn Creek during the June 2018 sampling event; however, it was not captured or measured. Only six Dolly Varden were captured in upper Four Creek (WQS03) in June 2018; thus, it is not possible to use the size distribution to make inferences about the population; however, the majority of fish captured fell into the 110 to 120 mm size range.

Figure 11.5-3

Liver Weight-Body Weight Regressions for Rainbow Trout in Tenas Project Waterbodies, 2017 and 2018

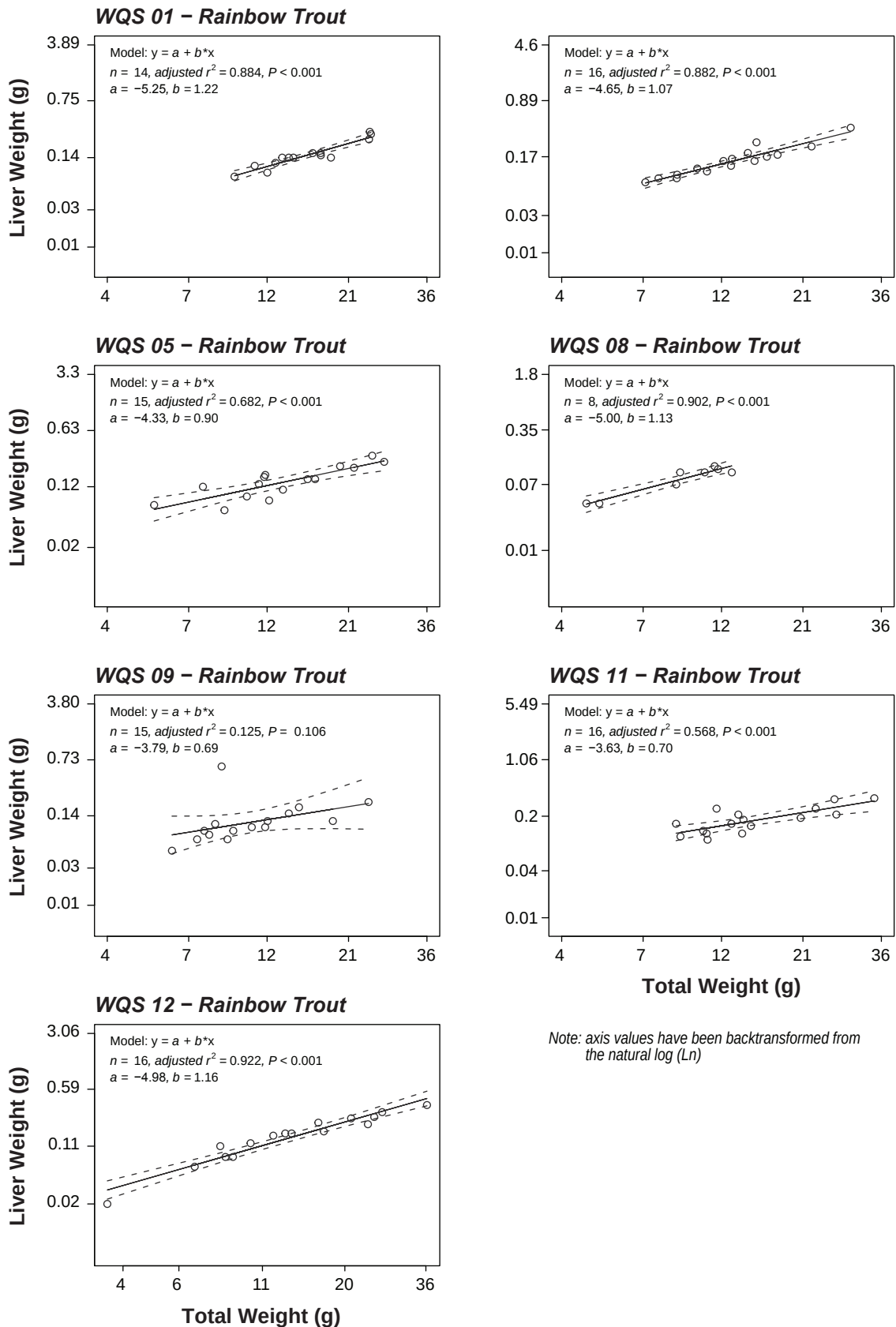


Figure 11.5-4

Length-at-Age Analysis for Rainbow Trout in
Tenas Project Waterbodies, 2017 and 2018

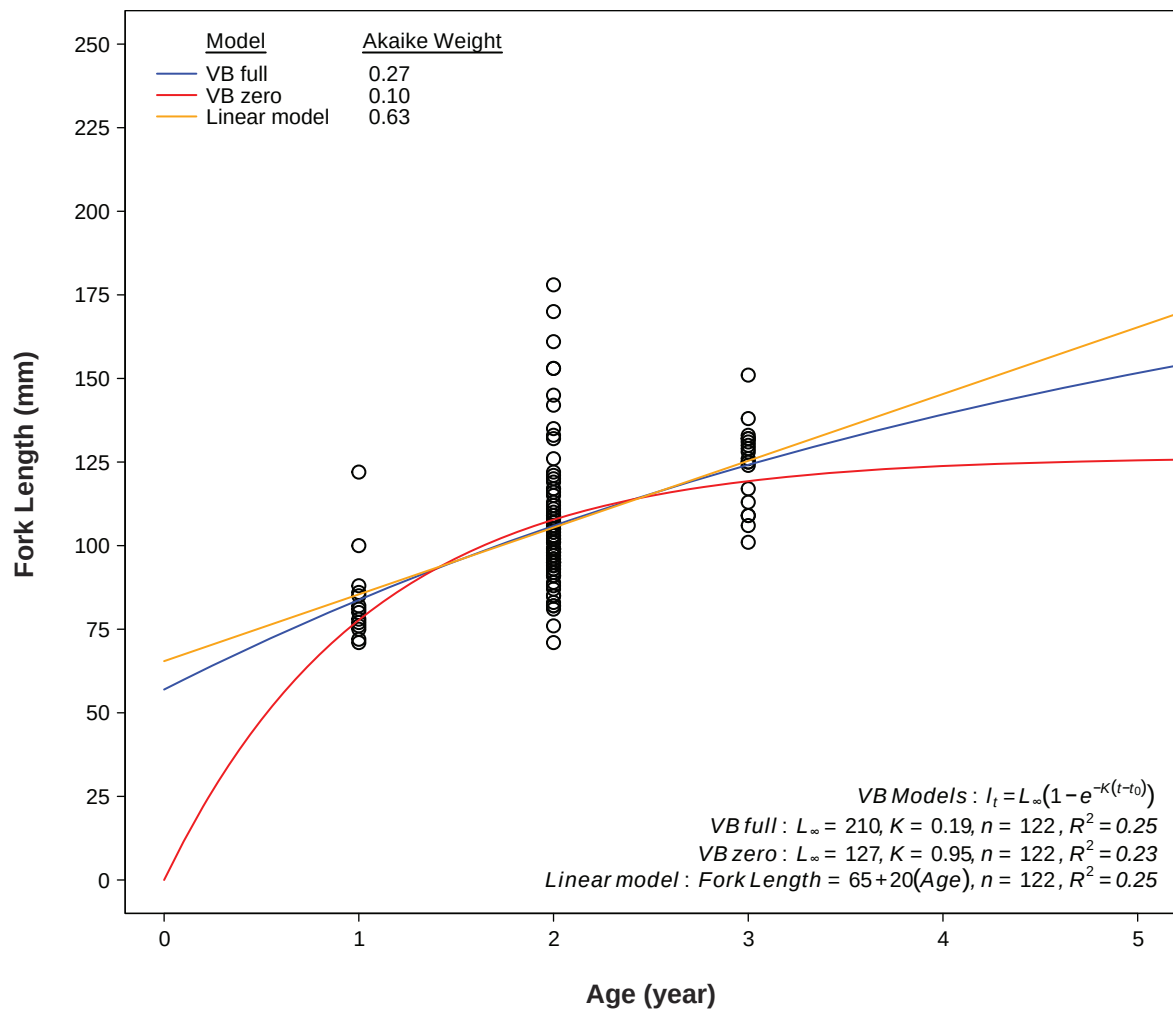
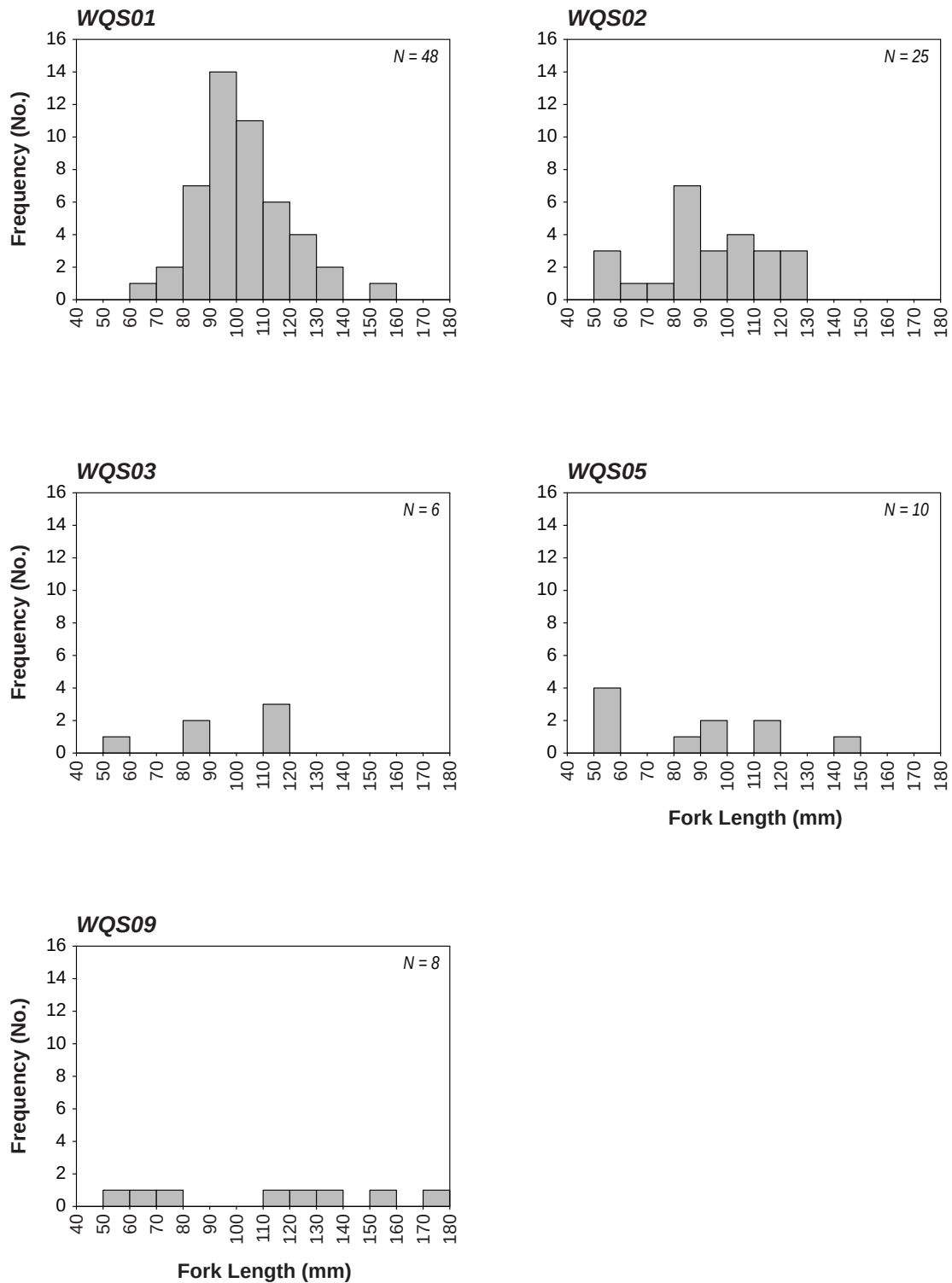


Figure 11.5-5

**Length-Frequency Distribution of Dolly Varden in
Tenas Project Waterbodies, 2017 and 2018**



Mean condition factor differed significantly among sites (ANOVA, $F_{6,95} = 5.855$, $P < 0.01$). Dolly Varden from site WQS03 (upper Four Creek) had significantly higher condition than fish from sites WQS01, WQS02 (Tenas Creek), and WQS05 (Goathorn Creek). However, upper Four Creek was only sampled in June 2018; thus, this result could be due to seasonal differences in fish size rather than differences in growing conditions among sites. There were no other significant differences in Dolly Varden condition among sites.

Weight-at-length of Dolly Varden was compared as another indicator of fish health and growth (Figure 11.5-6). The interaction between length and site on fish weight was significant (GLM, $P < 0.05$), which indicates that the relationship between weight and length differed among sites. As a result, the intercepts (weight-at-length) could not be compared directly among sites.

11.5.3.3 Coho Salmon

Juvenile coho salmon were captured mainly in the Telkwa and Bulkley Rivers in 2017 and 2018. Two individuals were captured in lower Goathorn Creek in 2017, while none were captured in Goathorn Creek in 2018. Due to high water levels in 2018, all of the coho captured at WQS08 (Telkwa River) were collected in 2017.

There were significant differences among sites in the mean length and weight of coho salmon; however, most of these differences could be attributed to the lack of sampling at WQS08 in 2018, which skews the size range for that site by including only fish measured at the end of the growing season. Coho collected at WQS09 (Telkwa River) were significantly smaller in length (ANOVA, $F_{4,112} = 4.86$, $P < 0.01$) and weight (ANOVA, $F_{4,95} = 5.04$, $P < 0.01$) than those captured at WQS08 (Telkwa River); however, they did not differ significantly from coho captured at any other sites. Length-frequency distributions for the four sites where the majority of coho were captured show that almost all of the fish captured were under 100 mm in length (Figure 11.5-7). At WQS09 (Telkwa River), where the most coho were captured, two modes in the distribution suggest two age classes, which is consistent with coho salmon life history, wherein juveniles spend one to two years in freshwater before migrating to the ocean.

There were no significant differences in coho salmon condition factor among sites (ANOVA, $F_{4,95} = 0.91$, $P = 0.46$). Similarly, when weight was regressed against length and compared among sites, there were no significant differences in the relationship between weight and length among sites (i.e., the slopes of the regressions), and no significant differences in weight-at-length among sites (GLM, $F_{5,94} = 390.4$, $P > 0.05$). Figure 11.5-8 shows the weight-length regressions for each site where enough coho were captured to derive a significant regression.

11.5.4 Tissue Metals

Analysis and QA/QC results for tissue metals are presented in Appendices 11-D and 11-E. Tissue metal concentrations for rainbow trout from the Bulkley River, Telkwa River, Goathorn Creek, and Tenas Creek were analyzed in October 2017 and June 2018. Table 11.5-3 summarizes the mean tissue metal concentrations for those metals among rainbow trout from each receiving environment site.

Figure 11.5-6

**Weight-Length Regressions for Dolly Varden in
Tenas Project Waterbodies, 2017 and 2018**

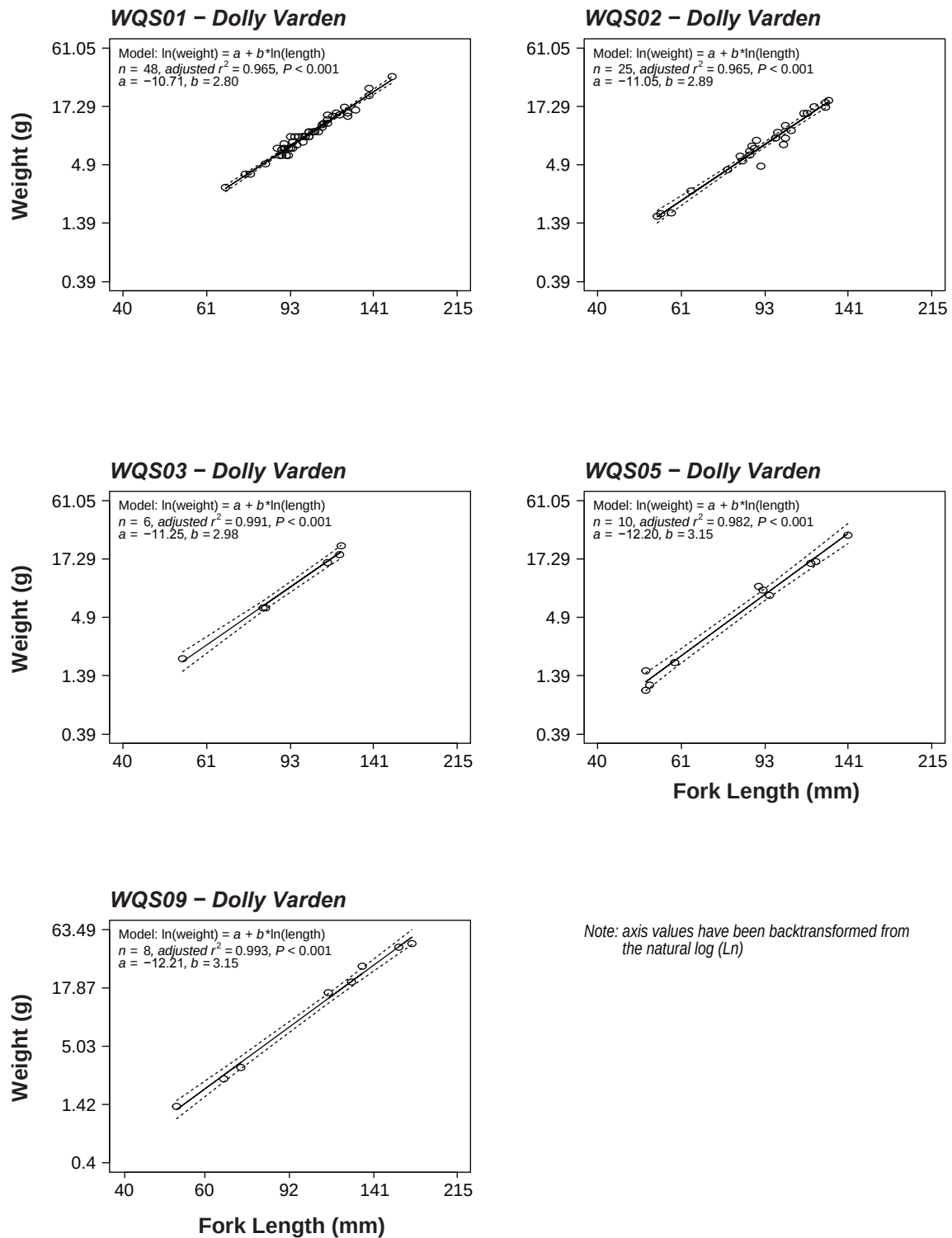


Figure 11.5-7

**Length-Frequency Distribution of Coho Salmon in
Tenas Project Waterbodies, 2017 and 2018**

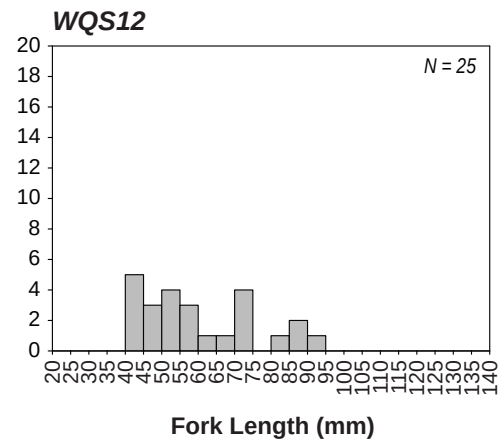
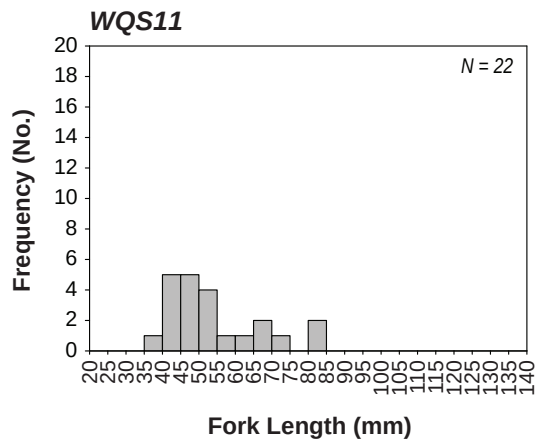
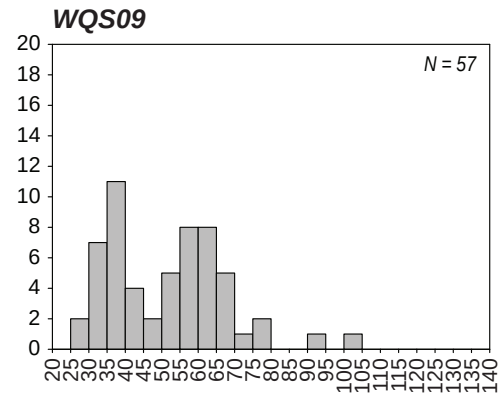
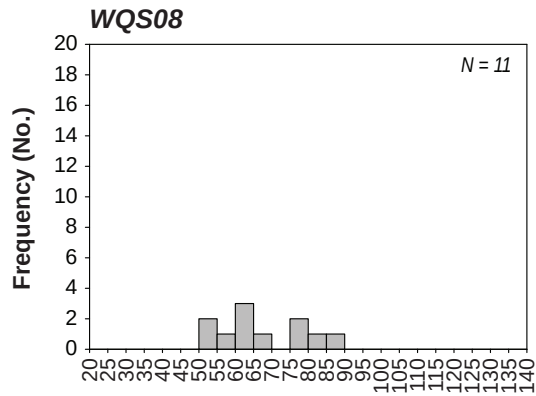
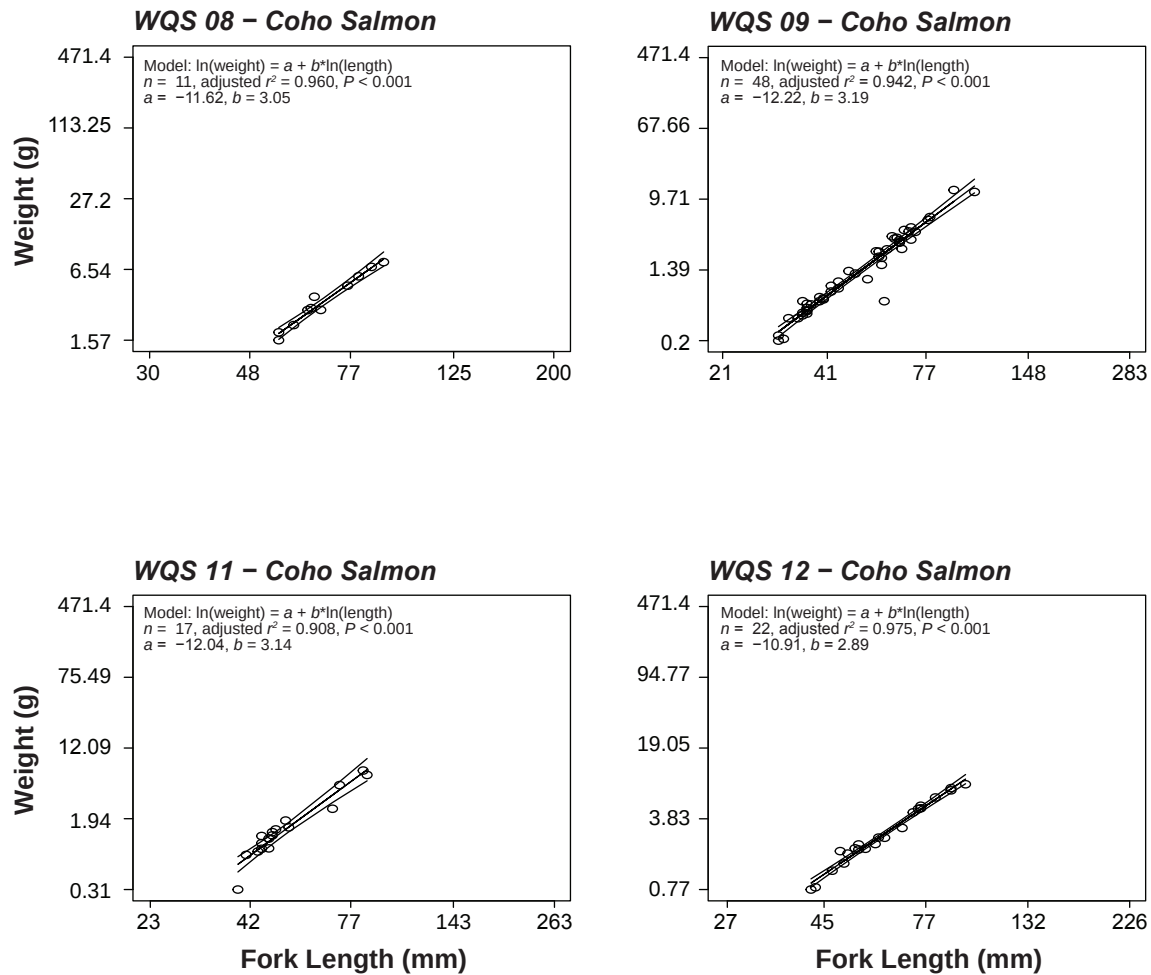


Figure 11.5-8

Weight-Length Regressions for Coho Salmon in
Tenas Project Waterbodies, 2017 and 2018



Note: axis values have been backtransformed from the natural log (Ln)

BC's tissue quality guideline for selenium is based on whole-body concentration and is reported for dry weight: 4 micrograms (μg)/g. An interim guideline for muscle tissue has also been established at the same concentration (BC MOE 2014). To compare selenium concentrations from tissue samples collected in the study area, the BC guideline was converted to a wet weight measurement using an average moisture concentration of 78% (moisture content in samples ranged from 76% to 81.3%, and averaged 78.3%). The resulting approximate guideline was 0.88 mg/kg wwt.

Muscle tissue selenium concentrations collected from rainbow trout in the study area ranged from 0.208 mg/kg to 0.710 mg/kg in 2017 and 0.176 mg/kg to 0.99 mg/kg in 2018. The average across all samples was 0.396 mg/kg in 2017 and 0.503 mg/kg in 2018. Two samples exceeded the interim BC tissue quality guideline for selenium in muscle tissue in 2018, both of which were in Tenas Creek. However, the interim guideline applies only to the mean concentration (of at least eight tissue samples) of selenium, which was lower than the guideline at all sites.

Tissue mercury concentrations did not exceed Health Canada guidelines (0.5 mg/kg wwt; Health Canada 2007) for any of the samples tested. Mercury concentrations ranged from 0.0097 mg/kg to 0.0681 mg/kg in 2017 and 0.0117 mg/kg to 0.0629 mg/kg in 2018.

Table 11.5-3. Summary of Rainbow Trout Tissue Metal Concentrations in the Tenas Project Area, 2017 and 2018

Site	Year	Aluminum						Antimony						Arsenic						Barium					
		n	Mean	Min	Max	SE	BDL	N	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	-	-	-	-	100%	8	-	-	-	-	100%	8	0.0306	0.0155	0.0472	0.0042	0%	8	0.165	0.097	0.230	0.019	0%
	2018	6	38.8	7.8	110.0	15.3	0%	6	0.0029	0.0016	0.0047	0.0005	33%	6	0.0649	0.0331	0.1150	0.0113	0%	6	1.865	1.230	3.660	0.366	0%
WQS02	2017	8	-	-	-	-	100%	8	-	-	-	-	100%	8	0.0382	0.0213	0.0527	0.0043	0%	8	0.157	0.071	0.337	0.030	0%
	2018	8	25.3	13.1	50.5	4.0	0%	8	0.0020	0.0012	0.0032	0.0002	38%	8	0.0871	0.0481	0.1290	0.0117	0%	8	1.333	0.996	1.790	0.080	0%
WQS05	2017	8					100%	8	-	-	-	-	100%	8	0.0321	0.0171	0.0966	0.0095	0%	8	0.237	0.125	0.381	0.037	0%
	2018	7	19.0	5.6	41.1	4.4	0%	7	0.0023	0.0006	0.0052	0.0006	43%	7	0.0577	0.0321	0.1400	0.0141	0%	7	1.823	0.984	3.150	0.257	0%
WQS08	2017	8	-	-	-	-	88%	8	-	-	-	-	100%	8	0.0209	0.0109	0.0519	0.0046	0%	8	0.313	0.153	0.672	0.065	0%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	-	-	-	-	100%	8	-	-	-	-	100%	8	0.0188	0.0125	0.0297	0.0020	0%	8	0.227	0.132	0.336	0.022	0%
	2018	7	61.0	11.3	119.0	16.7	0%	7	0.0031	0.0015	0.0047	0.0005	29%	7	0.0986	0.0486	0.1790	0.0188	0%	7	2.216	1.540	2.970	0.212	0%
WQS11B	2017	8	-	-	-	-	88%	8	-	-	-	-	100%	8	0.0316	0.0225	0.0451	0.0031	0%	8	0.303	0.179	0.513	0.038	0%
	2018	8	31.9	6.6	85.9	9.4	0%	8	-	-	-	-	63%	8	0.0878	0.0287	0.1540	0.0149	0%	8	2.356	1.530	3.890	0.319	0%
WQS12B	2017	8	1.0	0.2	4.1	0.5	50%	8	-	-	-	-	100%	8	0.0675	0.0327	0.1560	0.0151	0%	8	0.382	0.146	1.240	0.130	0%
	2018	8	75.5	38.2	154.0	13.9	0%	8	0.0034	0.0020	0.0055	0.0005	0%	8	0.0859	0.0513	0.1600	0.0137	0%	8	2.833	1.180	4.520	0.402	0%

Site	Year	Cadmium						Calcium						Cesium						Chromium					
		n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	0.0016	0.0006	0.0041	0.0004	63%	8	797	507	1,300	93	0%	8	0.2504	0.1930	0.3430	0.0188	0%	8	0.040	0.023	0.079	0.006	50%
	2018	6	0.0394	0.0134	0.0801	0.0101	0%	6	7,002	5,250	7,960	396	0%	6	0.1765	0.1610	0.2090	0.0069	0%	6	0.114	0.056	0.214	0.022	0%
WQS02	2017	8	0.0018	0.0011	0.0028	0.0002	75%	8	764	374	1,600	161	0%	8	0.1688	0.1320	0.2080	0.0096	0%	8	0.041	0.019	0.068	0.007	50%
	2018	8	0.0249	0.0172	0.0349	0.0021	0%	8	6,409	5,210	7,490	290	0%	8	0.0935	0.0396	0.1290	0.0093	0%	8	0.083	0.036	0.124	0.011	0%
WQS05	2017	8	0.0093	0.0023	0.0177	0.0020	0%	8	842	468	1,430	115	0%	8	0.0916	0.0785	0.1010	0.0027	0%	8	0.052	0.017	0.131	0.013	38%
	2018	7	0.0470	0.0146	0.0747	0.0079	0%	7	6,661	4,340	9,950	661	0%	7	0.0418	0.0277	0.0561	0.0033	0%	7	0.055	0.026	0.086	0.011	0%
WQS08	2017	8	0.0077	0.0011	0.0245	0.0027	13%	8	918	373	2,160	206	0%	8	0.0200	0.0148	0.0367	0.0026	0%	8	0.053	0.030	0.086	0.007	50%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	0.0059	0.0023	0.0108	0.0013	0%	8	708	464	1,200	81	0%	8	0.0306	0.0226	0.0527	0.0036	0%	8	0.050	0.020	0.118	0.011	38%
	2018	7	0.0663	0.0345	0.1540	0.0152	0%	7	6,336	5,590	7,260	249	0%	7	0.0200	0.0157	0.0261	0.0016	0%	7	0.088	0.028	0.160	0.021	0%
WQS11B	2017	8	0.0028	0.0018	0.0038	0.0003	25%	8	896	429	1,310	91	0%	8	0.0063	0.0038	0.0103	0.0007	0%	8	0.040	0.014	0.103	0.011	38%
	2018	8	0.0735	0.0312	0.1420	0.0144	0%	8	6,989	5,760	9,420	413	0%	8	0.0081	0.0021	0.0128	0.0015	0%	8	0.050	0.018	0.110	0.011	0%
WQS12B	2017	8	0.0028	0.0006	0.0092	0.0010	38%	8	802	465	1,680	140	0%	8	0.0081	0.0056	0.0106	0.0007	0%	8	0.036	0.019	0.083	0.007	38%
	2018	8	0.1063	0.0332	0.1550	0.0137	0%	8	6,038	5,140	6,860	210	0%	8	0.0109	0.0056	0.0182	0.0013	0%	8	0.099	0.053	0.201	0.017	0%

(continued)

Table 11.5-3. Summary of Rainbow Trout Tissue Metal Concentrations in the Tenas Project Area, 2017 and 2018 (continued)

Site	Year	Cobalt						Copper						Iron						Lead					
		n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	0.0141	0.0079	0.0201	0.0014	0%	8	0.377	0.341	0.444	0.013	0%	8	3.76	3.10	4.90	0.22	0%	8	-	-	-	-	100%
	2018	6	0.0519	0.0245	0.0895	0.0099	0%	6	0.849	0.754	1.040	0.042	0%	6	80.43	21.10	179.00	23.70	0%	6	0.0105	0.0023	0.0214	0.0028	17%
WQS02	2017	8	0.0139	0.0099	0.0222	0.0017	0%	8	0.432	0.339	0.531	0.029	0%	8	4.40	3.50	5.40	0.24	0%	8	-	-	-	-	100%
	2018	8	0.0462	0.0313	0.0642	0.0045	0%	8	0.929	0.757	1.070	0.039	0%	8	49.93	32.90	110.00	8.81	0%	8	0.0067	0.0037	0.0124	0.0009	13%
WQS05	2017	8	0.0345	0.0194	0.0485	0.0037	0%	8	0.339	0.201	0.487	0.035	0%	8	3.90	2.50	5.60	0.36	0%	8	-	-	-	-	100%
	2018	7	0.0757	0.0193	0.1260	0.0158	0%	7	0.980	0.609	1.170	0.068	0%	7	43.20	14.30	84.60	8.53	0%	7	0.0106	0.0048	0.0154	0.0014	0%
WQS08	2017	8	0.0281	0.0085	0.0792	0.0082	0%	8	0.283	0.183	0.335	0.020	0%	8	4.30	2.90	6.90	0.48	0%	8	-	-	-	-	100%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	0.0264	0.0152	0.0383	0.0035	0%	8	0.322	0.245	0.409	0.021	0%	8	4.25	2.90	5.90	0.34	0%	8	-	-	-	-	100%
	2018	7	0.0907	0.0523	0.1220	0.0103	0%	7	1.243	0.972	1.470	0.073	0%	7	107.94	32.20	212.00	27.11	0%	7	0.0451	0.0169	0.0614	0.0066	0%
WQS11B	2017	8	0.0090	0.0055	0.0119	0.0008	0%	8	0.313	0.278	0.355	0.011	0%	8	3.67	3.10	4.10	0.14	0%	8	-	-	-	-	100%
	2018	8	0.1045	0.0411	0.1780	0.0173	0%	8	1.336	0.884	1.850	0.107	0%	8	62.28	18.40	154.00	15.81	0%	8	0.0205	0.0059	0.0430	0.0043	0%
WQS12B	2017	8	0.0191	0.0061	0.0646	0.0067	0%	8	0.284	0.205	0.378	0.025	0%	8	4.73	2.10	15.00	1.49	0%	8	-	-	-	-	100%
	2018	8	0.1417	0.0685	0.1910	0.0165	0%	8	1.303	0.938	1.740	0.108	0%	8	141.90	65.00	267.00	24.93	0%	8	0.0376	0.0224	0.0560	0.0043	0%

Site	Year	Magnesium						Manganese						Mercury						Molybdenum					
		n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	267.88	252	281	3.95	0%	8	0.449	0.185	1.410	0.141	0%	8	0.0176	0.0121	0.0209	0.0012	0%	8	-	-	-	-	100%
	2018	6	337.83	305	389	12.32	0%	6	3.555	2.160	5.260	0.468	0%	6	0.0189	0.0153	0.0203	0.0008	0%	6	0.0111	0.0098	0.0125	0.0004	0%
WQS02	2017	8	266.50	232	295	8.55	0%	8	0.340	0.160	0.604	0.057	0%	8	0.0205	0.0145	0.0297	0.0016	0%	8	-	-	-	-	100%
	2018	8	340.88	308	394	9.64	0%	8	5.379	2.890	9.180	0.869	0%	8	0.0230	0.0154	0.0487	0.0044	0%	8	0.0120	0.0103	0.0148	0.0005	0%
WQS05	2017	8	253.88	233	263	3.80	0%	8	0.349	0.209	0.571	0.056	0%	8	0.0215	0.0172	0.0266	0.0012	0%	8	-	-	-	-	100%
	2018	7	340.43	258	377	14.45	0%	7	3.397	1.850	5.420	0.439	0%	7	0.0193	0.0117	0.0320	0.0027	0%	7	0.0132	0.0092	0.0182	0.0011	0%
WQS08	2017	8	258.25	241	279	3.92	0%	8	0.638	0.305	1.270	0.130	0%	8	0.0171	0.0129	0.0212	0.0012	0%	8	-	-	-	-	100%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	267.75	258	297	4.54	0%	8	0.452	0.326	0.658	0.035	0%	8	0.0172	0.0150	0.0236	0.0010	0%	8	-	-	-	-	100%
	2018	7	360.14	328	384	7.77	0%	7	7.984	4.270	13.000	1.056	0%	7	0.0146	0.0135	0.0165	0.0004	0%	7	0.0210	0.0131	0.0283	0.0020	0%
WQS11B	2017	8	283.00	250	309	7.12	0%	8	0.587	0.355	1.040	0.080	0%	8	0.0281	0.0097	0.0681	0.0073	0%	8	-	-	-	-	88%
	2018	8	349.75	326	400	7.87	0%	8	9.483	5.060	13.600	1.263	0%	8	0.0270	0.0148	0.0474	0.0036	0%	8	0.0158	0.0106	0.0238	0.0015	0%
WQS12B	2017	8	257.38	233	297	8.01	0%	8	0.731	0.264	1.810	0.194	0%	8	0.0236	0.0173	0.0318	0.0018	0%	8	-	-	-	-	100%
	2018	8	348.75	330	388	6.93	0%	8	14.013	7.340	18.000	1.466	0%	8	0.0246	0.0140	0.0629	0.0057	0%	8	0.0178	0.0145	0.0224	0.0010	0%

(continued)

Table 11.5-3. Summary of Rainbow Trout Tissue Metal Concentrations in the Tenas Project Area, 2017 and 2018 (continued)

Site	Year	Nickel						Phosphorus						Potassium						Rubidium					
		n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	-	-	-	-	100%	8	2,426	2,150	2,750	65	0%	8	3,826	3,570	4,010	52	0%	8	4.134	3.490	4.640	0.156	0%
	2018	6	0.070	0.043	0.130	0.013	0%	6	6,180	5,260	6,600	204	0%	6	3,163	2,870	3,450	86	0%	6	2.638	2.310	3.150	0.141	0%
WQS02	2017	8	-	-	-	-	88%	8	2,399	2,060	2,880	113	0%	8	3,939	3,590	4,290	90	0%	8	3.573	2.950	4.220	0.172	0%
	2018	8	-	-	-	-	75%	8	6,145	5,530	7,200	204	0%	8	3,343	2,960	3,730	87	0%	8	2.351	1.710	2.970	0.145	0%
WQS05	2017	8	-	-	-	-	88%	8	2,380	2,140	2,630	58	0%	8	3,881	3,630	4,160	62	0%	8	4.841	3.570	5.570	0.220	0%
	2018	7	0.038	0.010	0.086	0.011	57%	7	6,126	4,460	7,810	390	0%	7	3,241	2,730	3,500	112	0%	7	2.311	1.280	3.010	0.259	0%
WQS08	2017	8	-	-	-	-	100%	8	2,453	2,200	2,940	88	0%	8	3,920	3,790	4,090	32	0%	8	2.953	2.360	3.760	0.179	0%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	-	-	-	-	88%	8	2,329	2,110	2,690	62	0%	8	4,063	3,880	4,170	32	0%	8	3.773	3.170	4.900	0.203	0%
	2018	7	0.073	0.029	0.116	0.014	29%	7	6,119	5,490	6,590	145	0%	7	3,449	3,190	3,670	74	0%	7	2.039	1.840	2.300	0.054	0%
WQS11B	2017	8	-	-	-	-	88%	8	2,673	2,270	2,950	91	0%	8	3,848	3,480	4,230	102	0%	8	1.470	1.120	1.830	0.086	0%
	2018	8	0.052	0.016	0.118	0.012	38%	8	6,465	5,680	7,520	215	0%	8	3,476	3,110	3,840	80	0%	8	1.892	0.844	2.980	0.259	0%
WQS12B	2017	8	-	-	-	-	75%	8	2,411	2,010	2,730	93	0%	8	3,839	3,510	4,160	102	0%	8	1.935	1.400	2.710	0.185	0%
	2018	8	0.107	0.059	0.190	0.017	0%	8	5,654	5,280	6,100	119	0%	8	3,305	3,090	3,590	58	0%	8	1.931	1.130	3.050	0.212	0%

Site	Year	Selenium						Sodium						Strontium						Thallium					
		n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	0.549	0.395	0.687	0.034	0%	8	587.0	548.0	632.0	10.5	0%	8	0.654	0.344	1.250	0.105	0%	8	0.00330	0.00257	0.00429	0.00023	0%
	2018	6	0.594	0.509	0.731	0.035	0%	6	1,039.8	955.0	1,160.0	36.1	0%	6	5.857	4.510	6.770	0.342	0%	6	0.00348	0.00284	0.00454	0.00026	0%
WQS02	2017	8	0.544	0.429	0.710	0.033	0%	8	588.9	536.0	635.0	12.6	0%	8	0.620	0.277	1.450	0.158	0%	8	0.00382	0.00290	0.00483	0.00027	0%
	2018	8	0.698	0.356	0.990	0.071	0%	8	1,015.3	922.0	1,140.0	23.5	0%	8	5.014	4.010	5.940	0.243	0%	8	0.00466	0.00410	0.00522	0.00012	0%
WQS05	2017	8	0.350	0.305	0.394	0.013	0%	8	600.1	505.0	684.0	19.8	0%	8	0.610	0.282	1.300	0.120	0%	8	0.00489	0.00393	0.00609	0.00029	0%
	2018	7	0.432	0.268	0.665	0.047	0%	7	922.7	746.0	1,000.0	33.1	0%	7	4.921	3.580	9.010	0.702	0%	7	0.00582	0.00264	0.00820	0.00072	0%
WQS08	2017	8	0.401	0.283	0.545	0.032	0%	8	598.6	527.0	713.0	24.9	0%	8	0.784	0.266	1.730	0.176	0%	8	0.00217	0.00142	0.00292	0.00018	0%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	0.391	0.331	0.493	0.021	0%	8	672.4	591.0	736.0	16.8	0%	8	0.564	0.328	0.948	0.073	0%	8	0.00242	0.00174	0.00316	0.00020	0%
	2018	7	0.622	0.454	0.818	0.062	0%	7	986.4	904.0	1,070.0	21.9	0%	7	5.467	4.630	6.310	0.278	0%	7	0.00488	0.00378	0.00708	0.00040	0%
WQS11B	2017	8	0.275	0.208	0.335	0.015	0%	8	596.9	523.0	733.0	25.7	0%	8	0.829	0.378	1.170	0.086	0%	8	0.00166	0.00110	0.00208	0.00010	0%
	2018	8	0.336	0.183	0.398	0.026	0%	8	1,014.6	830.0	1,130.0	31.1	0%	8	6.456	4.530	9.700	0.700	0%	8	0.00413	0.00136	0.00611	0.00055	0%
WQS12B	2017	8	0.309	0.257	0.533	0.033	0%	8	570.1	509.0	722.0	24.1	0%	8	0.757	0.402	1.410	0.124	0%	8	0.00173	0.00134	0.00269	0.00015	0%
	2018	8	0.336	0.176	0.441	0.038	0%	8	934.3	889.0	984.0	10.9	0%	8	5.413	4.550	7.170	0.349	0%	8	0.00426	0.00236	0.00601	0.00040	0%

(continued)

Table 11.5-3. Summary of Rainbow Trout Tissue Metal Concentrations in the Tenas Project Area, 2017 and 2018 (completed)

Site	Year	Tin						Uranium						Vanadium						Zinc					
		n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL	n	Mean	Min	Max	SE	BDL
WQS01	2017	8	-	-	-	-	75%	8	-	-	-	-	100%	8	-	-	-	-	100%	8	6.69	5.50	9.50	0.46	0%
	2018	6	-	-	-	-	100%	6	0.00199	0.00075	0.00342	0.00043	0%	6	0.215	0.055	0.475	0.063	0%	6	25.75	23.00	29.50	0.99	0%
WQS02	2017	8	-	-	-	-	75%	8	-	-	-	-	100%	8	-	-	-	-	100%	8	6.26	5.02	8.53	0.39	0%
	2018	8	-	-	-	-	100%	8	0.00142	0.00063	0.00287	0.00023	0%	8	0.126	0.073	0.288	0.024	0%	8	25.41	21.60	28.10	0.80	0%
WQS05	2017	8	-	-	-	-	75%	8	-	-	-	-	100%	8	-	-	-	-	100%	8	6.73	5.42	10.00	0.56	0%
	2018	7	-	-	-	-	100%	7	0.00164	0.00098	0.00212	0.00017	14%	7	0.094	0.031	0.193	0.020	0%	7	25.84	19.10	30.30	1.39	0%
WQS08	2017	8	-	-	-	-	75%	8	-	-	-	-	88%	8	-	-	-	-	100%	8	6.06	4.57	7.76	0.44	0%
	2018	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
WQS09	2017	8	-	-	-	-	88%	8	-	-	-	-	100%	8	-	-	-	-	100%	8	5.41	4.27	6.81	0.28	0%
	2018	7	0.031	0.015	0.049	0.005	29%	7	0.00361	0.00164	0.00597	0.00061	0%	7	0.260	0.073	0.573	0.070	0%	7	26.04	21.90	29.20	1.04	0%
WQS11B	2017	8	-	-	-	-	88%	8	-	-	-	-	100%	8	-	-	-	-	100%	8	6.30	5.39	8.03	0.31	0%
	2018	8	0.021	0.011	0.033	0.003	50%	8	0.00432	0.00131	0.00981	0.00098	0%	8	0.152	0.032	0.361	0.039	0%	8	28.15	23.80	37.10	1.76	0%
WQS12B	2017	8	-	-	-	-	63%	8	-	-	-	-	88%	8	-	-	-	-	100%	8	6.30	4.51	9.99	0.58	0%
	2018	8	0.026	0.020	0.030	0.001	25%	8	0.00714	0.00330	0.01110	0.00088	0%	8	0.337	0.155	0.635	0.059	0%	8	22.64	20.30	26.00	0.78	0%

Site	Year	Zirconium					
		n	Mean	Min	Max	SE	BDL
WQS01	2017	8	-	-	-	-	88%
	2018	6	-	-	-	-	100%
WQS02	2017	8	-	-	-	-	88%
	2018	8	-	-	-	-	100%
WQS05	2017	8	-	-	-	-	100%
	2018	7	-	-	-	-	100%
WQS08	2017	8	-	-	-	-	100%
	2018	0	-	-	-	-	-
WQS09	2017	8	-	-	-	-	100%
	2018	7	0.055	0.034	0.076	0.006	29%
WQS11B	2017	8	-	-	-	-	100%
	2018	8	0.038	0.016	0.075	0.007	50%
WQS12B	2017	8	-	-	-	-	88%
	2018	8	0.066	0.041	0.104	0.008	0%

Notes:
n = sample size, Min = minimum, Max = maximum, SE = standard error, BDL = below detection limit.
Only sites with < 60% BDL were analyzed.
WQS08 was only sampled in 2017.
Silver was not analyzed in 2018.

12. VISUAL QUALITY

This chapter presents the methods and results of the visual quality baseline program. The purpose of the visual quality program was to collect Project specific baseline about the visual landscape and identify areas in the Bulkley Valley where the Project would be visible. An understanding of the visual setting will contribute to the effects assessment and may inform project design to mitigate impacts to visual quality.

The objectives of the 2017-2019 visual quality baseline were to:

- define a viewshed for the project;
- identify viewpoints within the viewshed that could potentially be influenced by the Project; and
- document visual disturbances currently present in the landscape.

The *Visual Impact Assessment Guidebook, Second Edition* (BC MOF 2001) was used for guidance in geographic extent, data collection standards and objectives. This methodology prescribes documenting the existing view from specific viewpoints looking towards the Project as well as assessing the Projects footprint relative to areas with defined visual quality management objectives.

12.1 STUDY AREA

The Project is located in the Bulkley Valley in the northwest Central Interior of British Columbia. It is approximately 10 km southwest of Telkwa and 20 km south of the Town of Smithers. The region is heavily utilized by anglers and hunters, as well as recreational tourists engaged in hiking, biking, canoeing, rafting, kayaking, bird watching and wilderness photography explorations during summer months. Outdoor recreational activities in the winter include cross-country, backcountry and downhill skiing, snowmobiling, ice climbing, and snowshoeing (RDBN 2017).

Given the spatial and temporal scale of the Project, it is reasonable to assume that any location in the surrounding landscape that has a direct line-of-sight to the Project could potentially experience a change to the visual resources, and should therefore be included in the Local Study Area (LSA). However, as outlined in the *Visual Landscape Inventory Procedures and Standards Manual* (BC MOF 1997), the further away from development the viewer is, the more difficult it is to identify patterns, shapes, and colours as distinct from the surrounding landscape. The distance at which landscape-level visual disturbances become too difficult to distinguish from the background is not clear, though some research for wind energy developments outlined in *A Visual Effects Assessment Guidebook for Wind Energy Developments in British Columbia* (BC MFLNRO, 2016) suggests impacts should be assessed for distances up to 35 km. It is reasonable to conclude that while the visual disturbance of these developments are not as concentrated as the Project, they typically span larger portions of the field of view, and could therefore be considered disturbances of a scale similar to the Project.

Adopting the largest study area identified in BC MFLNRO (2016), the Local Study Area (LSA) is defined as 35 km from the mine site footprint. Note that the access road and rail loop have a smaller footprint visual disturbances and therefore their maximum visible distances will fall within the LSA as determined from the mine site. The total area of the LSA is 4,142 km² (Figure 12.1-1).

The Regional Study Area (RSA) should encompass an area that establishes the context of the current and future state of visual resources in the region. The most relevant guidance for visual resources comes from the Bulkley Land and Resource Management Plan (LRMP), through each of its constituent Landscape Unit Plans (LSUP). Each LSUP contains some management directive for visual resources, and though those directives are often unique to each plan, their inclusion clearly indicates that visual resources are of importance to those areas. This suggests that these LSUP boundaries can be used to develop the RSA, wherein the only criterion for inclusion in the RSA is that there is a potential for a cumulative interaction with the Project, i.e. the Project may be visible from within the LSUP boundary. Therefore, the RSA is defined as the amalgamation of all Bulkley LRMP Landscape Unit Plans that have any portion of the plan area fall within the LSA. The total area of the RSA is 4,448 km² (Figure 12.1-1).

12.2 REGULATORY AND POLICY FRAMEWORK

The (Joint AIR for MA/EMA Permits (BC MEM and MOE 2016) has no formal requirement for visual quality reporting. However, the *Guide to Preparing Mine Applications for Aggregate Pit and Quarries in British Columbia* does recognize visual impact as an important consideration in developing positive community relationships (BC MEMPR 2010).

The Project occurs within two resource management plan areas: the provincial LRMP and the regional Bulkley Valley Sustainable Resource Management Plan (SRMP; BVLRRMP 1998; BVSRRMP 2005). They share the same viewpoints and objectives. The LRMP contains additional viewpoints associated with recreational use. The LRMP specifies that all development shall consider major corridors, recreation focus points, and specific viewpoints identified in Landscape Unit Plans.

12.3 EXISTING INFORMATION

Baseline studies began with a review of existing information on the visual quality environment in the study area, as described in Table 12.3-1.

12.4 METHODOLOGY

12.4.1 Overview

The methods used for this study follow the *Visual Impact Assessment Guidebook* (BC MOF 2001).

Figure 12.1-1
Visual Resources Local and Regional Study Area

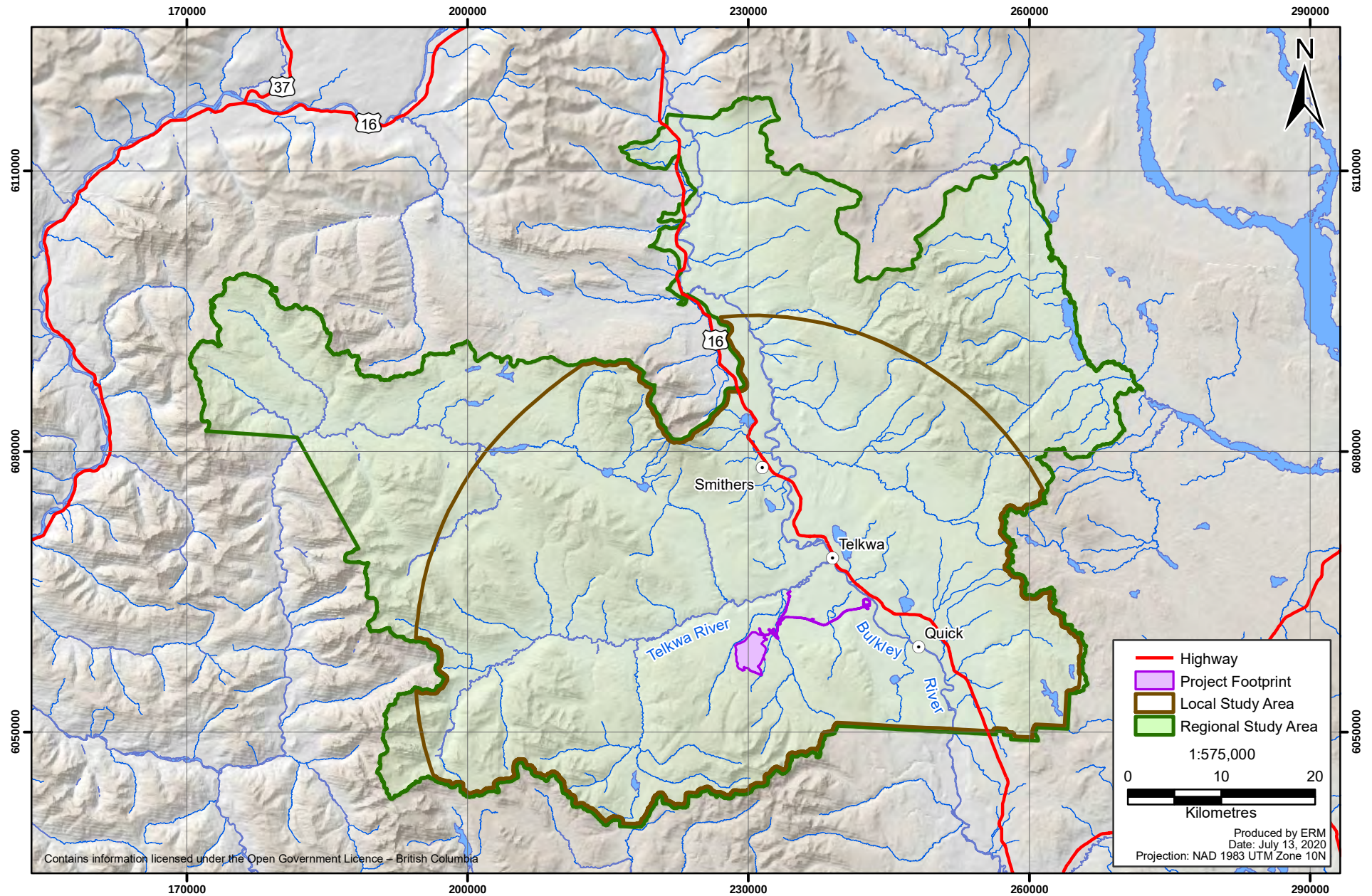


Table 12.3-1. Visual Quality Data Information Table

Documents Reviewed	• MCL. 1997. <i>Telkwa Coal Project: Application for a Project Approval Certificate – Volumes I-V</i>. Submitted by Manalta Coal Ltd. https://projects.eao.gov.bc.ca/api/document/5886a859eed3c0016f855d00/fetch (accessed December 2017) • TCPC. 1997. <i>Final Project Report Specifications for Manalta Coal Ltd.'s Proposed Telkwa Coal Project</i>. Prepared by the Telkwa Coal Project Committee, https://projects.eao.gov.bc.ca/api/document/5886a860eed3c0016f855d02/fetch (accessed April 2018). • BPM. 2008. <i>Davidson Project: Application for Environmental Assessment Certificate</i>. Submitted by Blue Pearl Mining Inc. https://projects.eao.gov.bc.ca/p/davidson/docs (accessed December 2017)
General Remarks	The nature of the analysis requires existing data specific to the current site that reflects the current appearance of both the project site and potential viewing locations. No existing information was found to be relevant to the current analysis. Several titles indicated within summaries of existing documents held by Allegiance may contain information useful in a historical context and may hold value in public discussions to progress the project. This data was available at the time of this report, but was not required for the analysis.
Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (Joint AIR for MA/EMA Permits)	Neither the EA nor the Joint AIR for MA/EMA Permits have formal requirements for Visual Quality reporting. However, the Guide to Preparing Mine Applications for Aggregate Pit and Quarries in British Columbia (BC MEMPR 2010) does recognize visual impact as an important consideration in developing positive community relationships.
Existing Data	There was no existing data available.
Existing Data Issues	The assessment framework for visual quality is targeted at forestry. Many of the objectives are unachievable for other development types. The planning processes (LRMP/SRMP) through which this system was intended to be developed was not finalized.
Missing Data	Heights of Project features
2017–March 2018 Baseline Program	The program focused on defining a viewshed for the project, and on providing current “baseline” photo documentation specific to viewpoints and viewing features defined provincially and regionally.
Key Issues	Intermittent impacts of haul truck activities are difficult to quantify in a meaningful way.
Other Comments	None.

12.4.2 Planning and Pre-field

12.4.2.1 Viewshed Development

The viewshed was developed using ESRI ArcGIS 10.7.1 Spatial Analyst Visibility tool to identify the areas that could potentially be viewed from the proposed Project location. An assumption in the analysis is that a person seen from the Project infrastructure can also view the Project infrastructure.

Vegetation heights were not taken into account for the baseline study. This is a more conservative approach, indicating possible views of the project from locations that, on inspection, have little or no opportunity to observe the Project area.

The viewshed is specific to the mine site area and does not include the rail loadout area. Smaller disturbance such as the access road and ancillary buildings will become imperceptible at “background” distances and are more likely to benefit from vegetative screening. The rail loadout was modelled separately to evaluate its viewshed and determine applicable viewpoints, because it has a small scale of disturbance and site infrastructure, limiting visibility to much smaller distances. The bypass road was not modelled for a viewshed as its impact is seen as intermittent, smaller scale, and as not having a significant effect in the beyond foreground and mid-ground view scales.

12.4.2.2 Viewpoint Screening and Identification

Viewpoints identified in Bulkley Land and Resource Management Plan and Landscape Unit Plan sub-documents (Table 12.4-1; Figure 12.4-1) were screened out from further study as they fell outside the viewshed, or following WMO (2006) guidance, were more than 35 km from the Project site (Grassy Mountain and Harvey Mountain Viewpoints from the Reisetser LUP).

Table 12.4-1. Summary of Viewpoints from the Bulkley Land and Resource Management Plan and Landscape Unit Plan Sub-documents Screened Out of Field Baseline Study

Viewpoint Name	Rationale for Preliminary Consideration	Viewpoint Association	Viewpoint of Project Area?
Telkwa/Hubert Rest Stop	Bulkley LUP/Provincial Dataset	Highway 16	No
Smithers Goat Statue	Bulkley LUP/Provincial Dataset	Highway 16	No
Smithers Airport	Bulkley LUP/Provincial Dataset	Highway 16	No
Adams Igloo	Bulkley LUP/Provincial Dataset	Highway 16	No
Evelyn Hall	Provincial Dataset	Highway 16	No
McDonnell Lake	Copper LUP	Forestry Recreation Site	No
Dennis Lake	Copper LUP	Forestry Recreation Site	No
Skihill	Copper LUP/Telkwa LUP	Recreation Tourism	No. Alternate established
Quick School	Deep Creek LUP/Bulkley LUP	Highway 16	No
Hungry Hill Reststop	Deep Creek LUP/Bulkley LUP	Highway 16	No
Grassy Mountain	Reisetser LUP	Hiking/Snowmobile Area	No
Harvey Mountain	Reisetser LUP	Hiking/Snowmobile Area	No. Alternate investigated
Aldrich	Telkwa LUP	Forestry Recreation Site	No
Jonas Creek Rec Site	Telkwa LUP	Forestry Recreation Site	No
Moseskin Johnny Lake	Telkwa LUP	Forestry Recreation Site	No

Table 12.4-2 contains a record of viewpoint sites considered and Figure 12.4-1 shows their distribution in relationship to the project and viewshed. The Landscape Unit Plan specifically names Highway 16, Telkwa High Road and the Bulkley River as corridors functioning as viewpoints along their route. Telkwa High Road also has a number of residences Tyhee Lake Road was also included as it is the natural extension of Telkwa High Road, it is associated with Tyhee Lake Provincial Park, and has at least one Bed and Breakfast along the road. Round Lake Road was included as the lake has a

community hall on its shoreline and both the lake and hall are used for community and recreation events. The trailheads of the Babine Mountain Park Trails Protected Area along Old Babine Lake Road were included as they are used in the winter by snowmobile groups and in the summer by hikers.

Table 12.4-2. Summary of Viewpoints Included in the Field Baseline Study

Viewpoint Name	Rationale for Preliminary Consideration	Viewpoint Association	Rationale for Inclusion in Baseline Study
PP1	LUP Travel Corridor	Telkwa High Road	Along travel corridor with residences
PP2	LUP Travel Corridor	Telkwa High Road	Along travel corridor with residences
PP3	LUP Travel Corridor	Telkwa High Road	Along travel corridor with residences
PP4	LUP Travel Corridor	Telkwa High Road	Along travel corridor with residences
PP5	LUP Travel Corridor	Tyhee Lake Road	Along travel corridor with residences
PP6	LUP Travel Corridor	Highway 16	Along travel corridor
PP7	LUP Travel Corridor	Highway 16	Along travel corridor
PP8	LUP Travel Corridor	Highway 16	Along travel corridor
PP9	Key recreation travel corridor	Babine Lake Road	Key recreation travel corridor
PP10	Community/recreation site	Round Lake Road	Community/ recreation site
PP11 (Hudson Bay Mountain)	Economic/recreation site	Hudson Bay Mountain	Economic/recreation site
PP11b (Hudson Bay Mountain)	Economic/recreation site	Hudson Bay Mountain	Economic/recreation site
PP12 (Piper Down)	Community/recreation site	Piper Down Recreation	Economic/recreation site
PP13	LUP Travel Corridor	Highway 16	Along travel corridor
PP14	Community/recreation site	Babine Mountain Trails	Community/ recreation site
PP15	Community/recreation site	Babine Mountain Trails	Community/ recreation site
PP16 (Eddy Park)	Community/recreation site/LUP Travel Corridor	Eddy Park	Along travel corridor
PP17	LUP Travel Corridor	Tyhee Lake Road	Along travel corridor
PP18	Community/recreation site	Cabin	Community/ recreation site

12.4.2.3 Visual Landscape Inventory

A summary of the various classifications and their objectives is provided in Table 12.4-3 and the current site layout is shown with the visual landscape inventory (VLI) polygons layer in Figure 12.4-2.

Figure 12.4-1
Tenas Project Viewshed Relative to Bulkley Land and Resource Management Plan Bulkley Landscape Unit Plan Derived Viewpoints,
Strategic Land and Resource Plan Non-legal Planning Feature Viewpoints and Project Specific Viewpoints

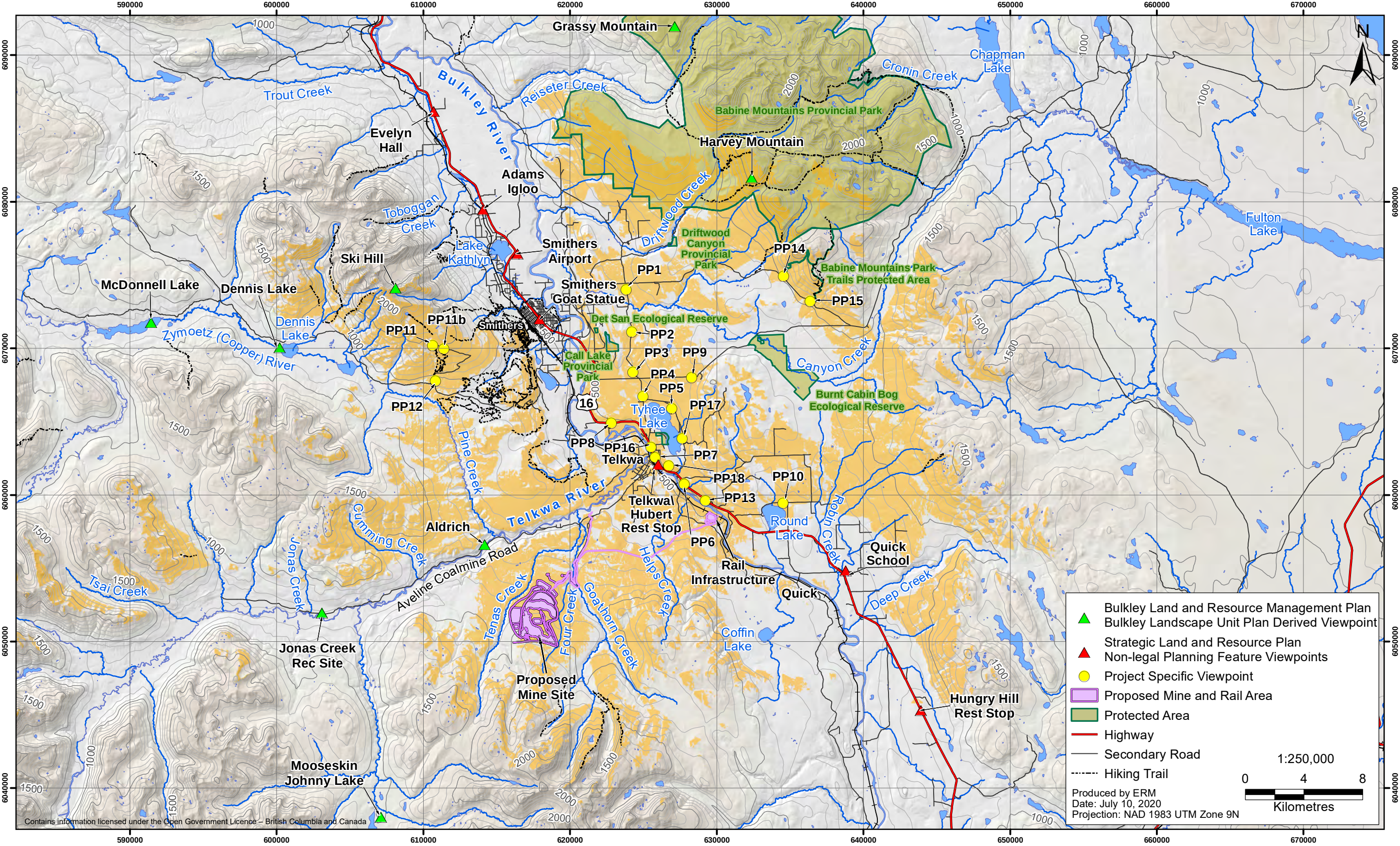


Figure 12.4-2
Tenas Project Relative to Provincial Visual Landscape Inventory (VLI), Visual Quality Objectives (VQO) and Visual Sensitivity Class (VSC)

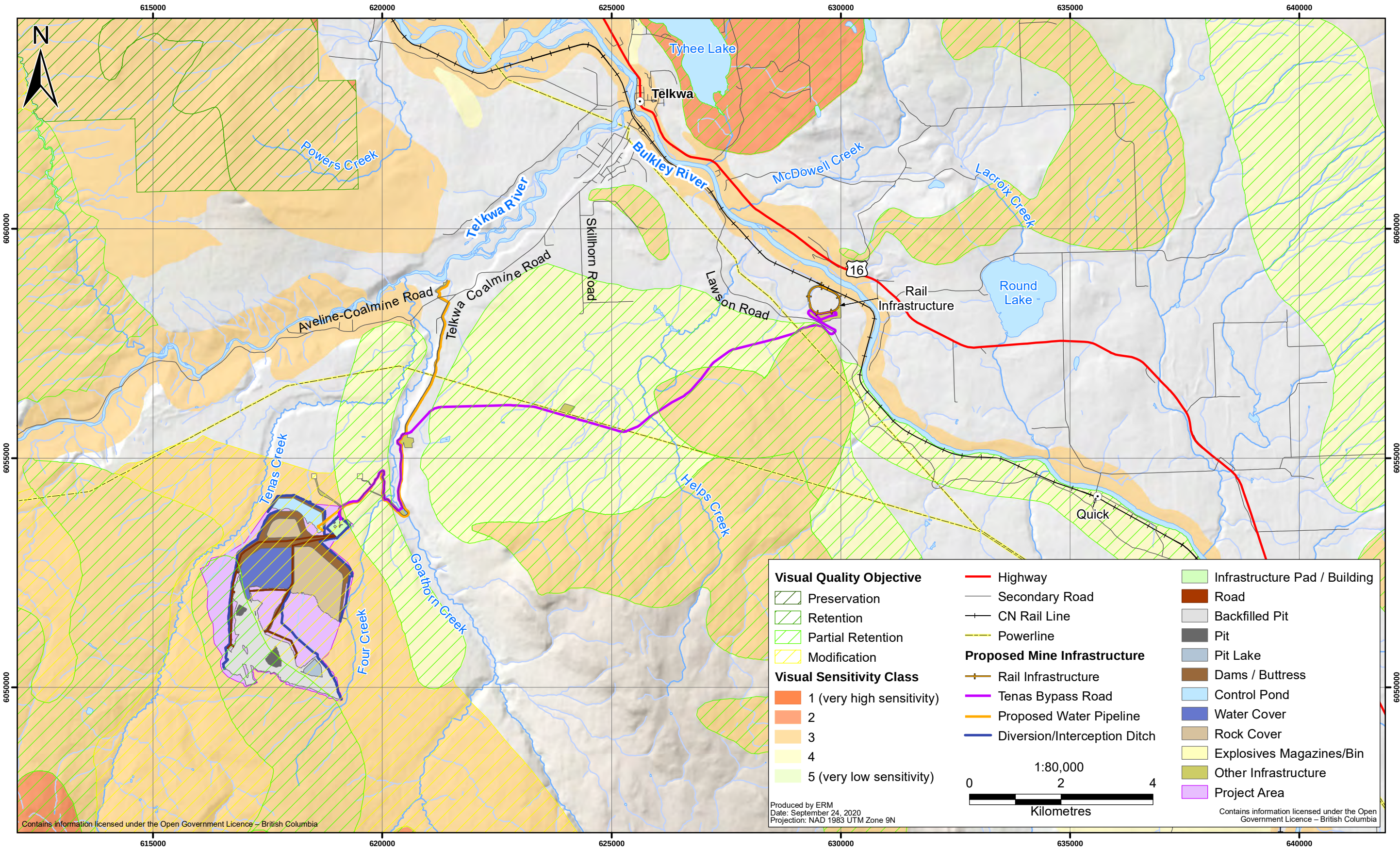


Table 12.4-3. Visual Quality Class and Visual Quality Objective Definitions¹

Class	Description
Preservation (P)	No visible human-caused alteration. Alteration, when assessed from a significant public viewpoint, is very small in scale, and not easily distinguished from the pre-development conditions.
Retention (R)	Human-caused alterations are visible, but not evident. Alteration, when assessed from a significant public viewpoint is: (i) difficult to see, (ii) small in scale, and (iii) natural in appearance.
Partial Retention (PR)	Human-caused alteration is evident, but subordinate and therefore not dominant. Alteration, when assessed from a significant public viewpoint, is (i) easy to see, (ii) small to medium in scale, and (iii) natural and not rectilinear or geometric in shape.
Modification (M)	Alteration, when assessed from a significant public viewpoint, (i) is very easy to see, and (ii) is (A) large in scale and natural in its appearance, or (B) small to medium in scale, but with some angular characteristics.
Maximum Modification (MM)	Alteration, when assessed from a significant public viewpoint, (i) is very easy to see, and (ii) (A) very large in scale, (B) rectilinear and geometric in shape, or (C) both.

Note:

¹ 2016. *Forest Planning and Practices Regulation*, Forest and Range Practices Act, BC Reg 14/2004, Part 1.1.

Under the Bulkley LRMP, the majority of site infrastructure is located within areas classified as moderately sensitive to alteration (*Modification*), while the part of the bypass road route and approximately 1/3 of the main site is in an area classified as *Partial Retention*. The proposed rail loop facility falls partially within a moderately sensitive VLI polygon associated with the Bulkley River. The portion of rail loop that occurs within this VLI area is parallel the existing rail in the background from the perspective on Bulkley River which is the associated “viewpoint” feature.

12.4.3 Photo Capture

Viewpoints were visited and information was gathered in site visits undertaken on September 27, 2017 and November 3, 2017. Further visits to existing sites and one additional location were subsequently completed on October 30, 2019. At each viewpoint, current conditions were recorded. Pictures were taken from the ground, using a Canon 5D 12.8-megapixel digital camera. On the September 27, 2017, additional photographs were taken in a 360° swath around the site from a helicopter hovering as close to the ground as possible above the proposed mine development site to further screen for visible signs of human use, following the assumption that locations visible from the site can conversely view the Project site.

Information gathered at each viewpoint included:

- GPS coordinates for the viewpoint (using a Garmin 60CX - Accuracy 3 - 5 metres, 95% typical - Wide Area Augmentation System (WAAS) accuracy in North America or <10 metres 95% typical where WAAS not available); and
- current weather conditions.

12.5 DATA SUMMARY

Fifteen sites from the Bulkley Land and Resource Management Plan and Landscape Unit Plan Sub-documents were screened out of field baseline studies. Nineteen sites along corridors identified by the Landscape Unit Plan that also fell within the Project's viewshed were selected for further study. Table 12.5-1 identifies the location of each viewpoint, as well as whether the viewpoint had a clear view of the Project.

Table 12.5-1. Viewpoint Locations

ID	Description	Easting	Northing	Elevation (m)	View of Project Area
PP1	Telkwa High Road at Old Babine Lake Road	623840	6074024	631	Yes
PP2	Telkwa High Road at Jollymore Road	624228	6071134	582	Yes
PP3	Telkwa High Road at Babine Lake Road	624304	6068409	592	Yes
PP4	Telkwa High Road at Tyhee Lake Road	624982	6066770	573	Yes
PP5	Tyhee Lake	626956	6065943	552	Yes
PP6	Highway 16 at Woodmere Road	627811	6060778	547	Yes
PP7	Highway 16 at Tower Street	625813	6062595	530	Yes
PP8	Highway at Good Road	622840	6064926	511	Yes
PP9	Babine Lake Road at Hillcrest Road	628306	6068057	796	Yes
PP10	Round Lake	634544	6059475	620	Yes
PP11	Hudson Bay Mountain Resort Main Lodge	610657	6070224	1501	Yes
PP11b	Hudson Bay Mountain Resort	611424	6070000	1441	Yes
PP12	Piper Recreation Area	610857	6067831	924	No
PP13	Highway 16 at Hubert Rest Stop	629245	6059643	5513	Yes
PP14	Onion Mountain Trail	634578	6074958	1006	No
PP15	The Onion 2	636405	6073240	1031	No
PP16	Eddy Park	625548	6063282	499	Yes
PP17	Tyhee Lake Road and Hislop Road	627655	6063860	524	No
PP18	Cabin	626745	6062016	578	Yes

The results of the field baseline studies for these 19 sites are presented in Figures 12.5-1 to 12.5-15. Note that the results of sites with no view of the Project due to vegetation screening are not presented in the figures.

Field photos show that visual landscape disturbance surrounding the Project site is almost exclusively in the form of forest cut blocks. The forest industry has been a key economic driver within the Bulkley Valley, and that is evident within the LSA, where there are over 10,000 hectares of cut blocks less than 20 years old. Land has also been cleared for agriculture in some areas, particularly around the Bulkley River, though those are relatively small and generally difficult to see from most of the viewpoints looking in the direction of the Project. Roads and transmission lines are generally not visible from most viewpoints as they are screened by trees, though there may be some locations from which the

linear clearing for these features would be identifiable (i.e. where the view aligns directly with the direction of the linear clearance).

12.5.1 Viewpoint Summaries

Field visits to Project viewpoints PP1 to PP17 occurred on September 27 (PP1-PP8, PP17) and November 4, 2017 (PP9-PP16). Follow-up visits to Viewpoints PP9 and PP13 were completed on October 30, 2019, as well as an initial visit to PP18. Conditions were sunny each day, with temperatures varying from 18 to 21°C during the September 2017 visits and -6 to -11°C during the November 2017 visits. At the time of the October 2019 field visit to PP18 and return to PP9 and PP13, there were overcast skies with some breaks in lower cloud cover with a temperature of 3°C, and light wind (4 to 8 km) from the northeast.

Visibility measurements taken from the Smithers and Smithers A local climate stations for each of the field days reported unlimited visibility. However, atmospheric haze is apparent in almost all of the images, limiting the amount of detail visible at distance. A summary of the locations is provided below.

12.5.1.1 Project Viewpoint PP1

Project Viewpoint PP1 (Figure 12.5-1) is located along Telkwa High Road, approximately 450 metres south of the intersection with Old Babine Lake Road at approximately 631 metres above sea level (masl). It is along a crest adjacent to a cleared field with a view in the direction of the Project.

12.5.1.2 Project Viewpoint PP2

Project Viewpoint PP2 (Figure 12.5-2) is located along Telkwa High Road, about halfway between the intersection with Babine Lake Road and the intersection with Old Babine Lake Road, with an approximate elevation of 582 metres. It is along a crest in the topography adjacent a cleared field in the direction of the Project, providing the most unobstructed view in this section of road.

12.5.1.3 Project Viewpoint PP3

Project Viewpoint PP3 (Figure 12.5-3) is located along Telkwa High Road, approximately 600 metres northwest of the intersection with Babine Lake Road, with an approximate elevation of 592 metres. It is along a crest in the topography adjacent a cleared field in the direction of the Project, providing the most unobstructed view in this section of road.

12.5.1.4 Project Viewpoint PP4

Project Viewpoint PP4 (Figure 12.5-4) is located along Telkwa High Road, approximately 230 metres north of the intersection with Tyhee Lake Road, with an approximate elevation of 573 metres. It is along a crest in the topography adjacent a cleared field in the direction of the Project, providing the most unobstructed view in this section of road.



TELKWA COAL
LIMITED

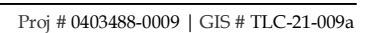


Figure 12.5-2
Visual Quality Photo Site PP2, Tenas Project

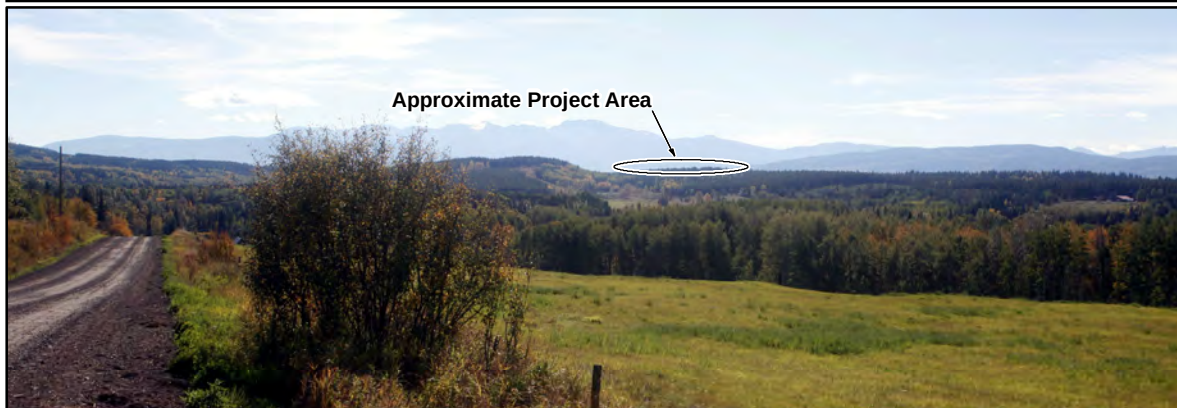
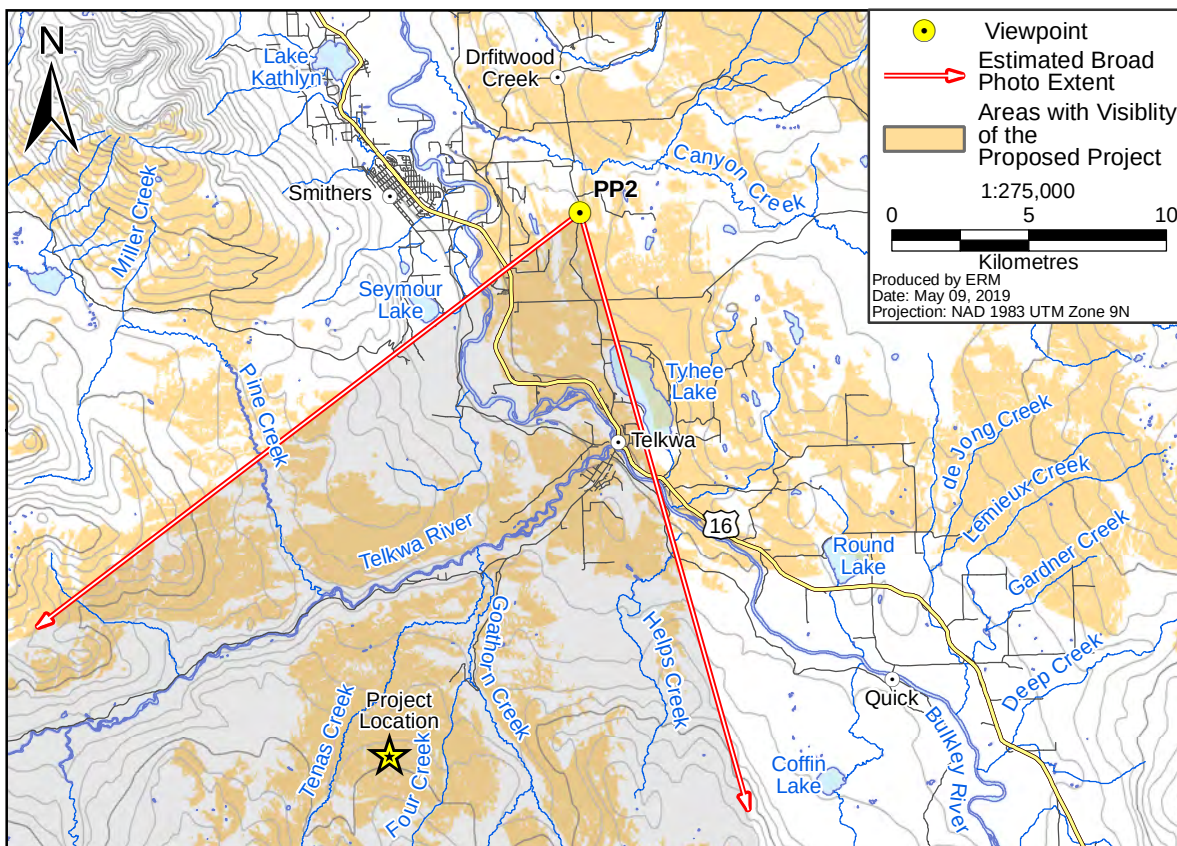


Figure 12.5-3
Visual Quality Photo Site PP3, Tenas Project

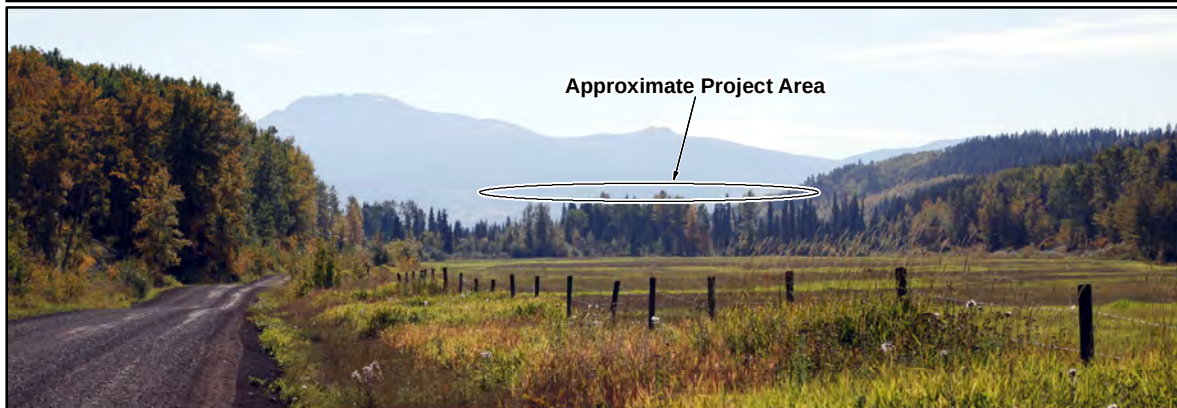
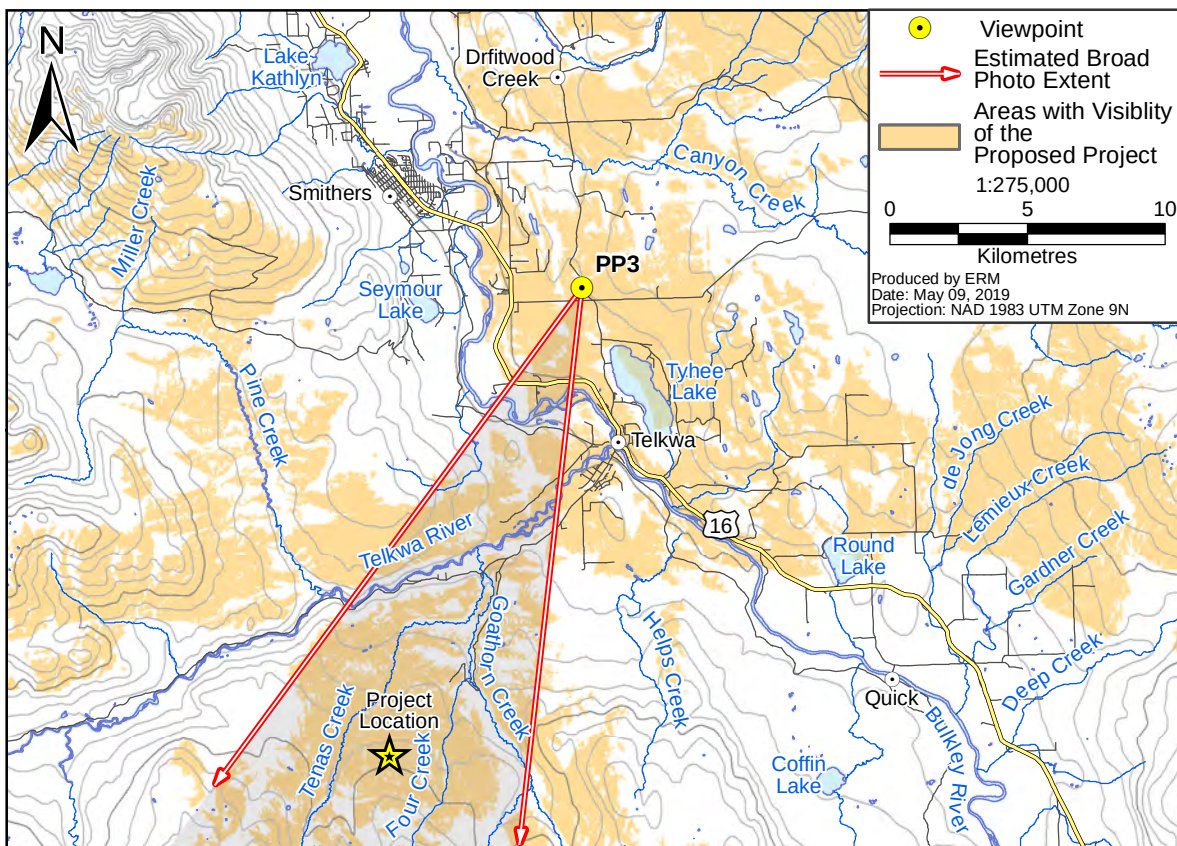
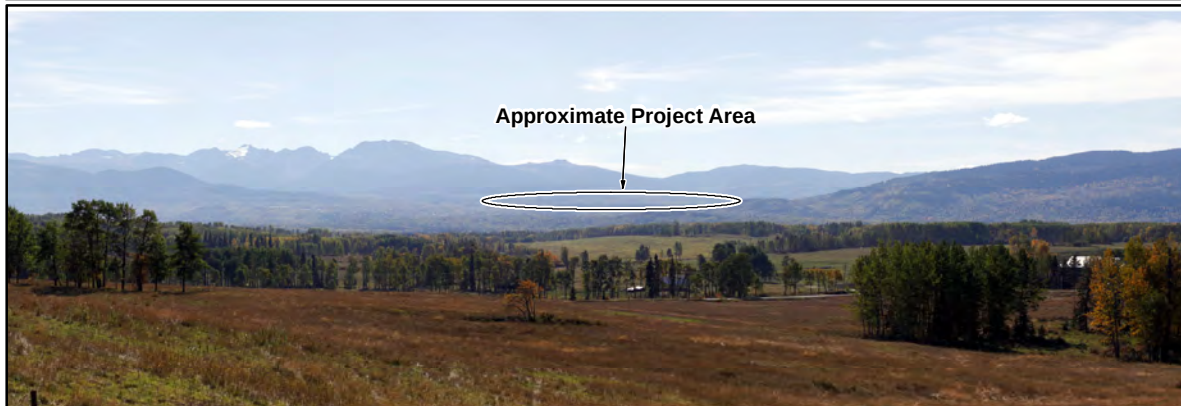
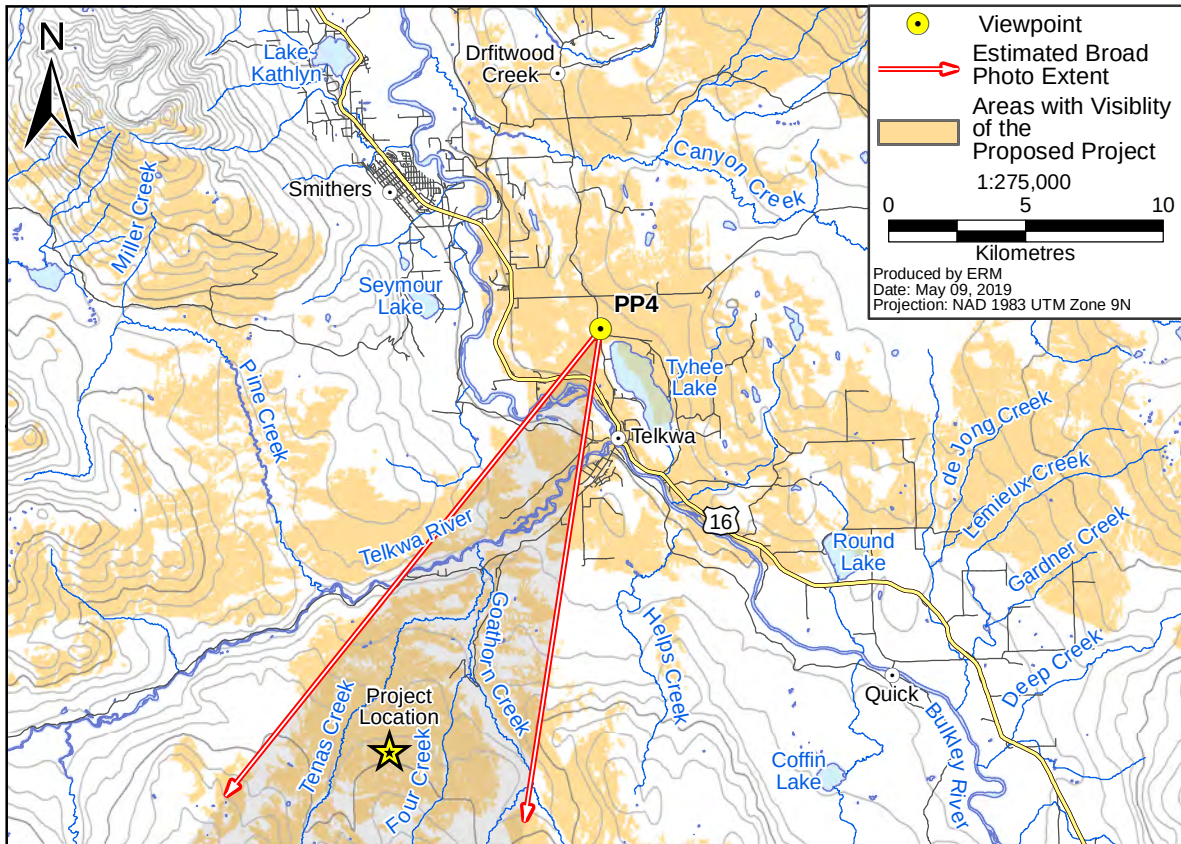


Figure 12.5-4
Visual Quality Photo Site PP4, Tenas Project



12.5.1.5 *Project Viewpoint PP5*

Project Viewpoint PP5 (Figure 12.5-5) is located along Tyhee Lake Road, approximately 180 metres southeast of the intersection with Hidber Road, with an approximate elevation of 552 metres. It is representative of much of the road around the backside of the lake with an unobstructed view towards the Project.

12.5.1.6 *Project Viewpoint PP6*

Project Viewpoint PP6 (Figure 12.5-6) is located along Highway 16, approximately 360 metres southeast of the intersection with Woodmere Road, with an approximate elevation of 547 metres. The site has an unobstructed view of the Project and was included as one of several Highway 16 associated sites. The site is not an area where people would typically stop.

12.5.1.7 *Project Viewpoint PP7*

Project Viewpoint PP7 (Figure 12.5-7) is located along Highway 16, approximately 190 metres northwest of the intersection with Tower Street, with an approximate elevation of 530 metres. The site has an unobstructed view of the Project and was included as one of several Highway 16 associated sites. The site is not an area where people would typically stop.

12.5.1.8 *Project Viewpoint PP8*

Project Viewpoint PP8 (Figure 12.5-8) is located along Highway 16, approximately 4 kilometres northwest of Telkwa at the intersection with Good Road, with an approximate elevation of 511 metres. The site has an unobstructed view of the Project and was included as one of several Highway 16 associated sites. The site is not an area where people would typically stop.

12.5.1.9 *Project Viewpoint PP9*

Project Viewpoint PP9 (Figure 12.5-9) is located along Babine Lake Road, approximately 3.6 kilometres east of the intersection with Telkwa High Road, with an approximate elevation of 796 metres. This is a main road accessing much of the recreational back country. The specific location was chosen for its unobstructed view of the Project.

12.5.1.10 *Project Viewpoint PP10*

Project Viewpoint PP10 (Figure 12.5-10) is located along Round Lake Road, approximately 300 metres west of the intersection with Woodmere Road, with an approximate elevation of 620 metres. The site was chosen based on the surrounding topography and vegetation, where it provided the most unobstructed view of the Project.

Figure 12.5-5
Visual Quality Photo Site PP5, Tenas Project

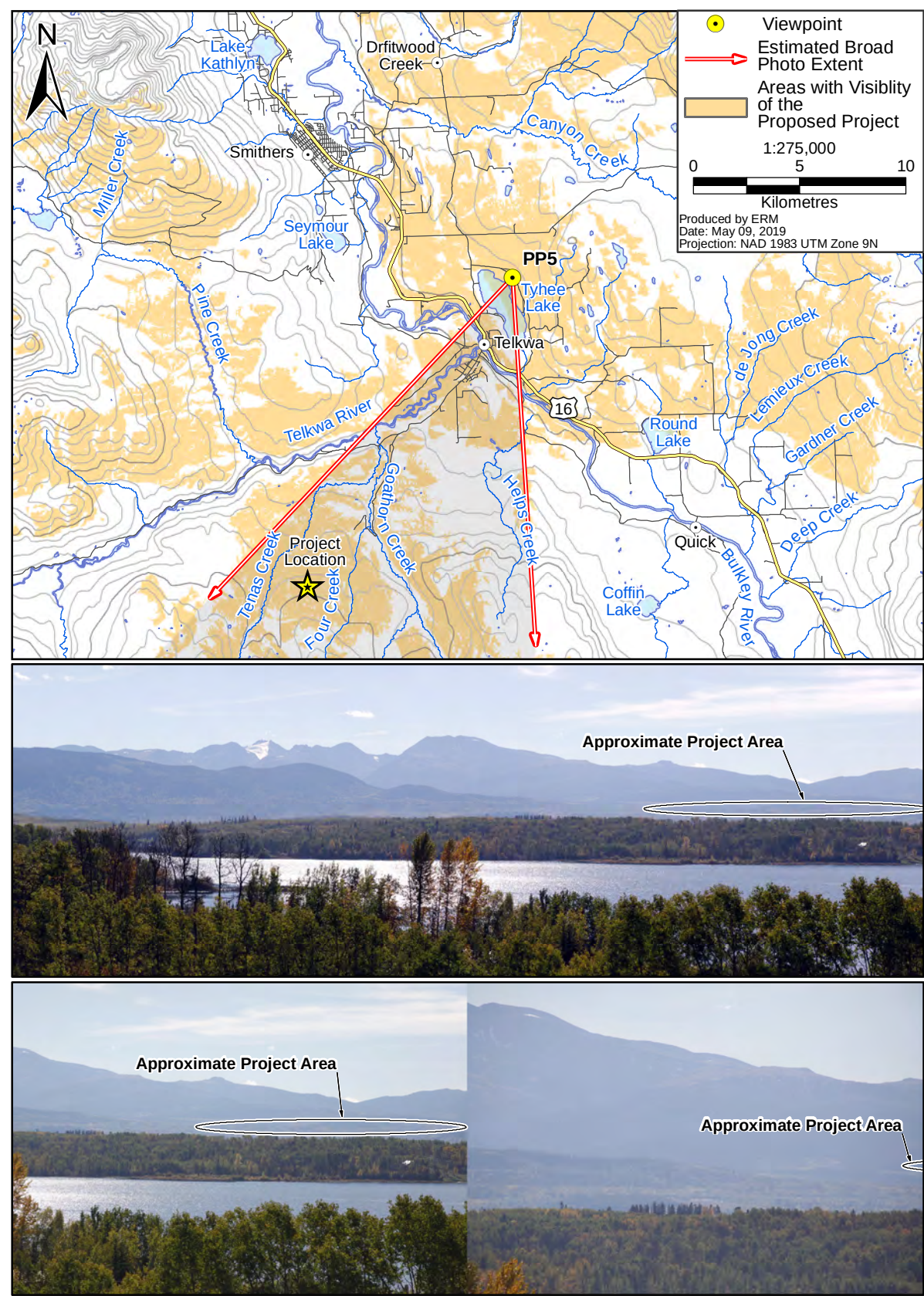


Figure 12.5-6
Visual Quality Photo Site PP6, Tenas Project

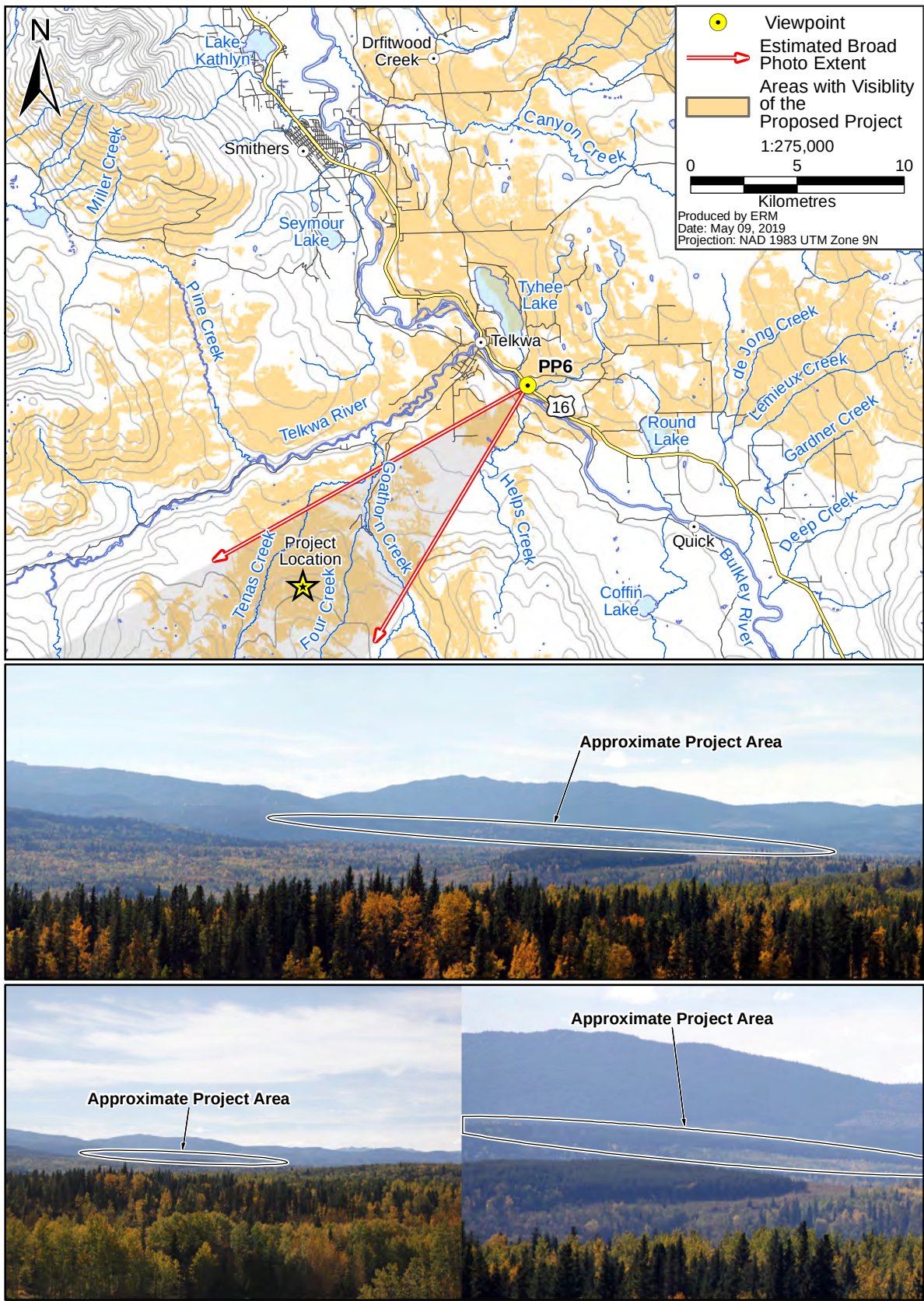


Figure 12.5-7
Visual Quality Photo Site PP7, Tenas Project

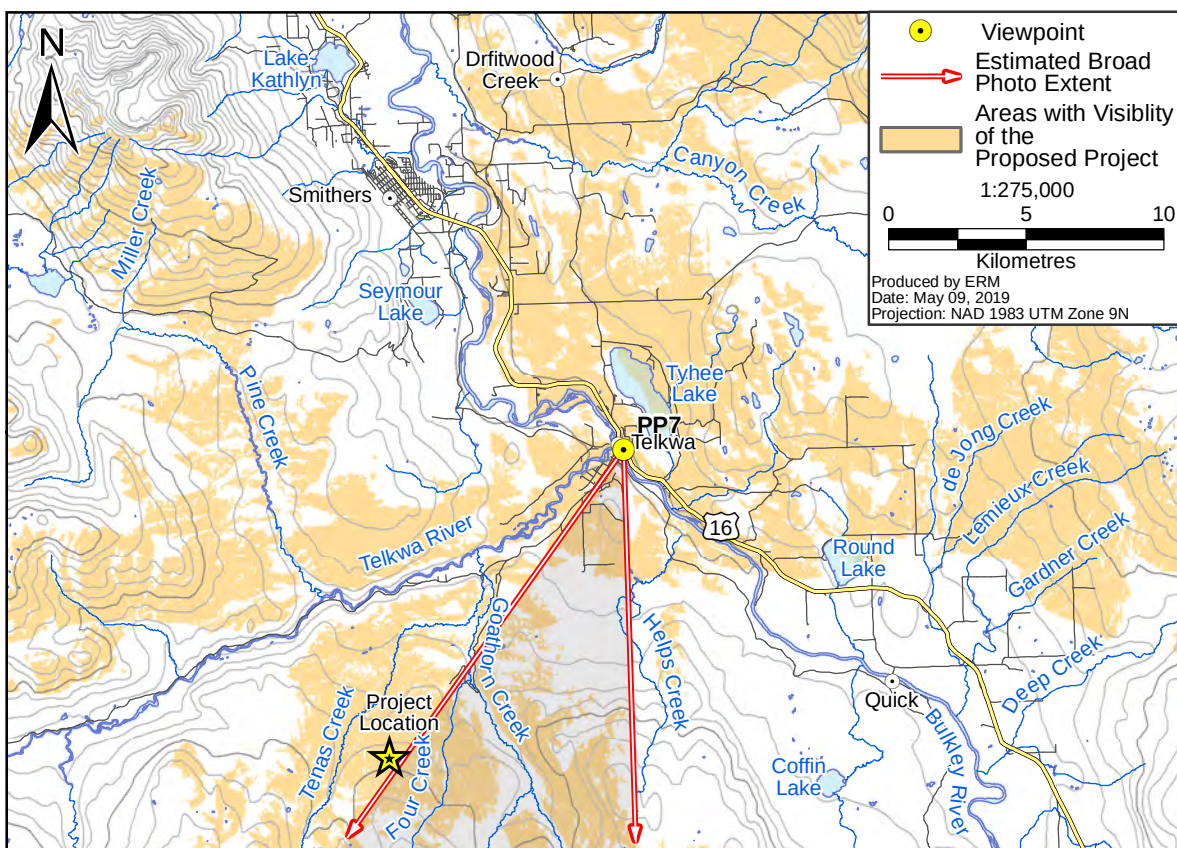


Figure 12.5-8
Visual Quality Photo Site PP8, Tenas Project

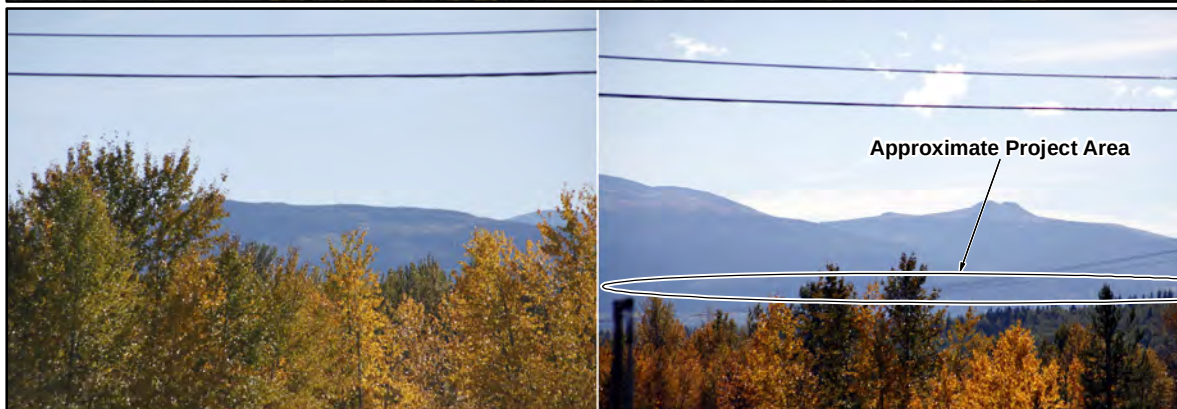
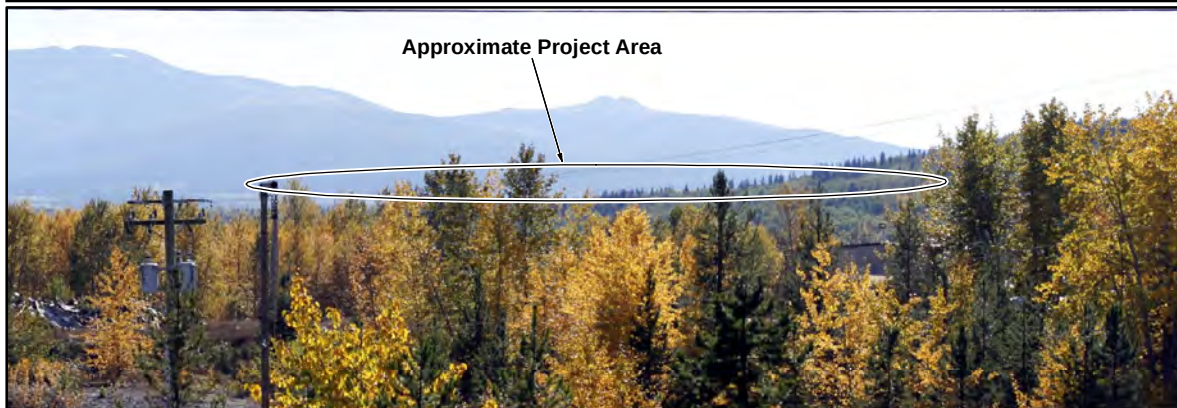
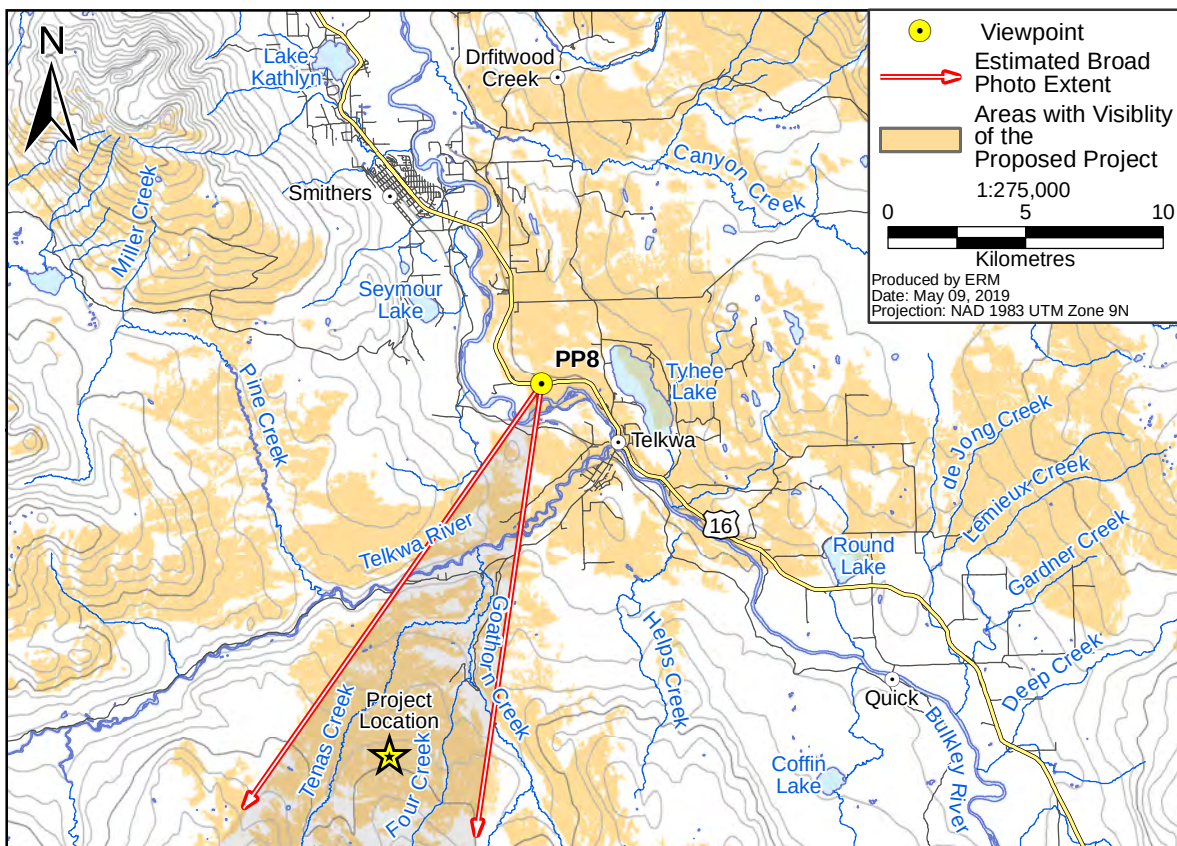


Figure 12.5-9
Visual Quality Photo Site PP9, Tenas Project

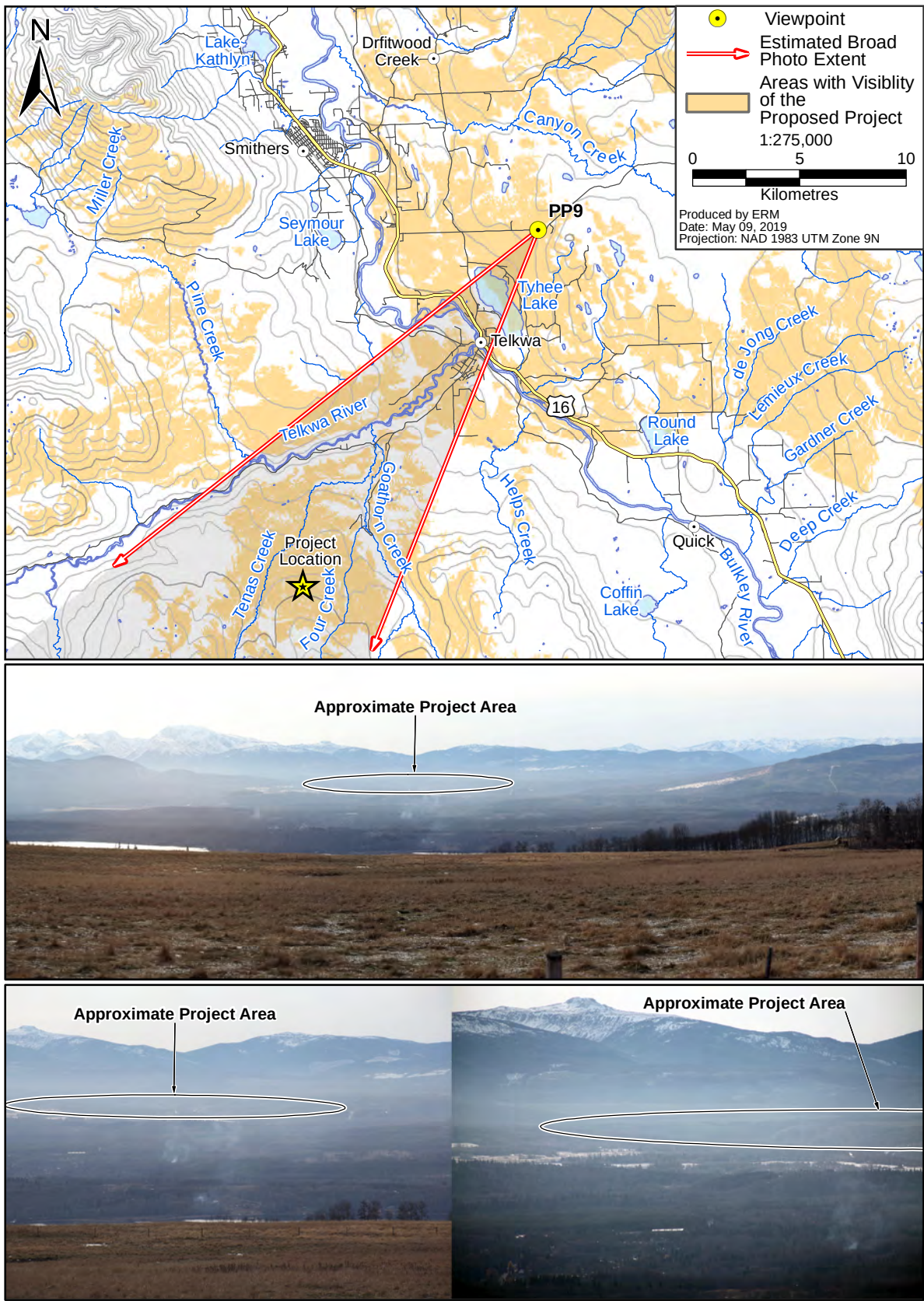
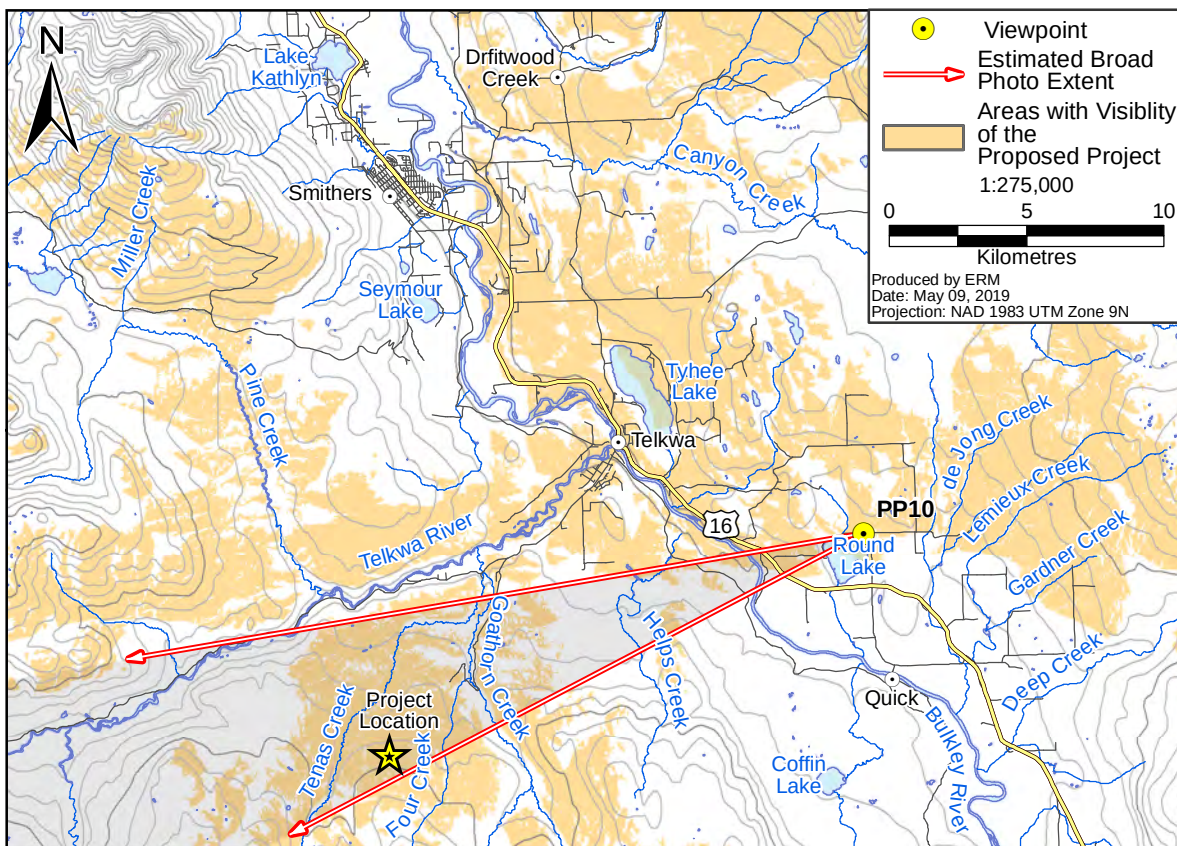


Figure 12.5-10
Visual Quality Photo Site PP10, Tenas Project



12.5.1.11 *Project Viewpoint PP11*

Project Viewpoint PP11 (Figure 12.5-11) is located within the Hudson Bay Mountain Resort at the northwest corner of the Piper Down Recreation Site. It is near the base of the Prairie T-Bar, with an approximate elevation of 1,501 m.

12.5.1.12 *Project Viewpoint PP11b*

Project Viewpoint PP11b (Figure 12.5-12) is located within the Hudson Bay Mountain Resort bordering the Piper Down Recreation Site. It is near the main lodge and the base of the Panorama T-Bar, with an approximate elevation of 1,430 m.

12.5.1.13 *Project Viewpoint PP12*

Project Viewpoint PP12 is located at the base of the Piper Down Recreational Site along the road accessing Hudson Bay Mountain, at approximately 924 metres elevation. This site is used for hiking, mountain biking, and snowmobiling, and was selected because it fell within the Project viewshed. Upon visiting the site, it was apparent that vegetative screening obscured any view of the potential Project area.

12.5.1.14 *Project Viewpoint PP13*

Project Viewpoint PP13 (Figure 12.5-13) is located along Highway 16, approximately 985 metres northwest of the intersection with Hubert Road at a recently reconfigured highway rest-stop. The site has an approximate elevation of 551 metres.

12.5.1.15 *Project Viewpoints PP14 and PP15*

Project viewpoints PP14 and PP15 are located at two trailheads of the Babine Mountain Park Trails Protected Area along Old Babine Lake Road, 5.9 and 3.3 km from the intersection with Babine Lake Road, at approximately 1,006 and 1,031 metres elevation. These sites are used for hiking, mountain biking, and snowmobiling.

Upon visiting the sites, it was apparent that terrain and vegetative screening obscured any view of the potential Project area. No identifiable terrain features were visible looking through the vegetation towards the Project.

12.5.1.16 *Project Viewpoint PP16*

Project Viewpoint PP16 (Figure 12.5-14) is located just off Highway 16 in Telkwa, on Howson Avenue in the parking area at Eddy Park. This community park runs along the edge of the Bulkley River and is adjacent to several commercial lodging facilities. The viewpoint has an approximate elevation of 499 metres.

The site's view is unobstructed by vegetation in the foreground; however, the treeline on the far edge of the river masks any potential view of the site. The park walkway continues north along the river from this site where the view of the proposed Project becomes increasingly unlikely.

Figure 12.5-11
Visual Quality Photo Site PP11, Tenas Project

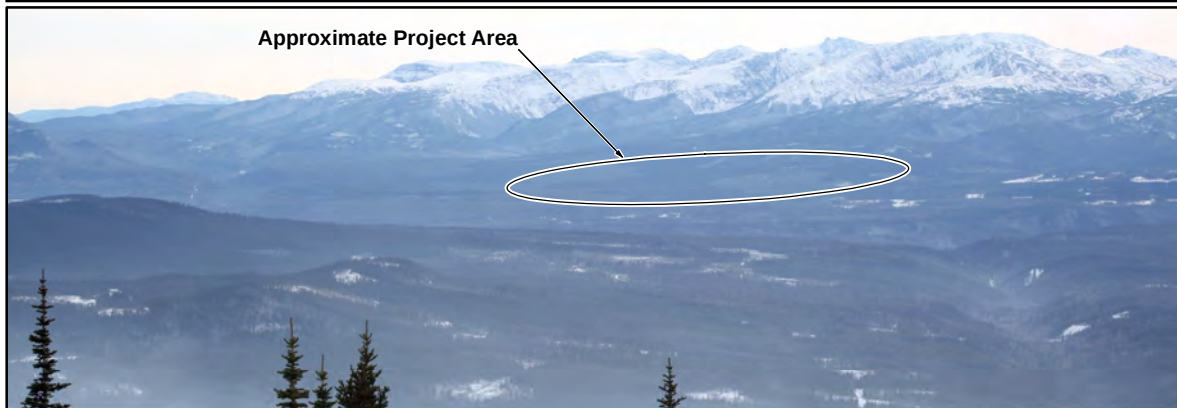
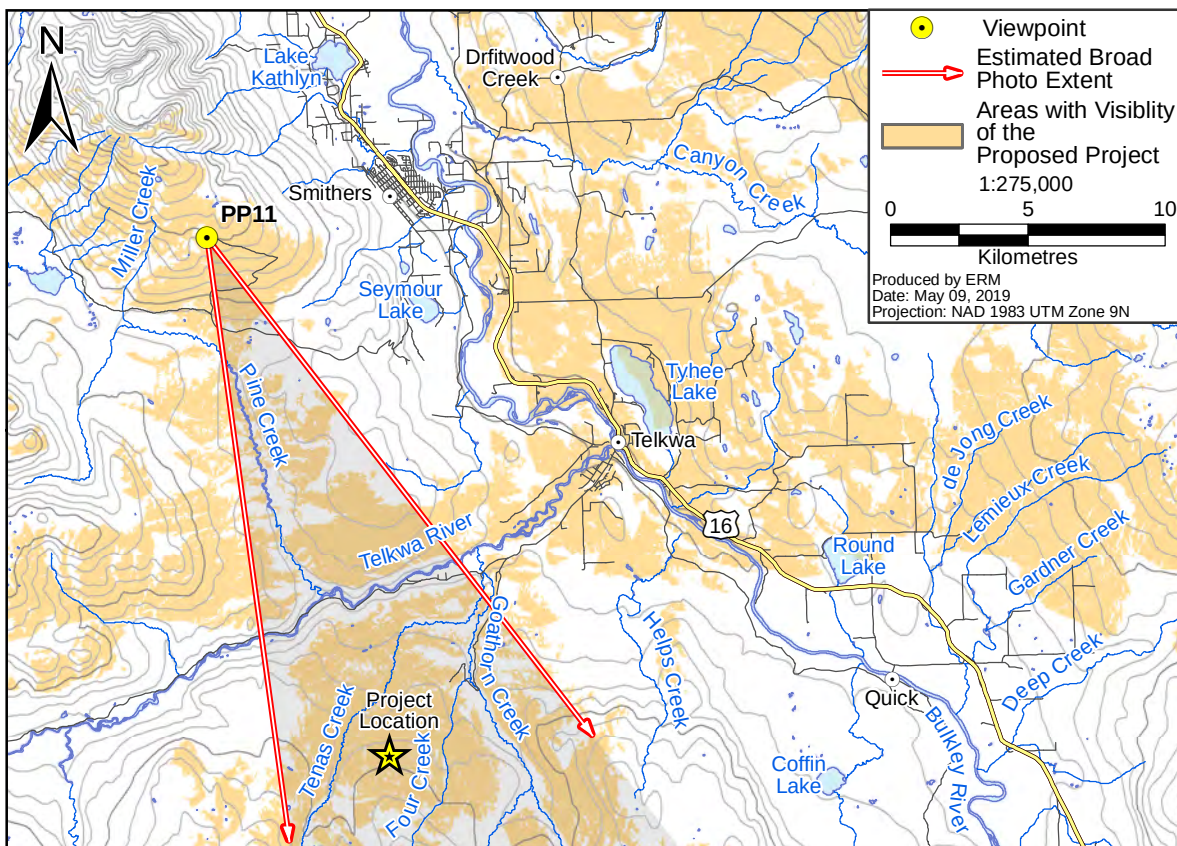


Figure 12.5-12
Visual Quality Photo Site PP11b, Tenas Project

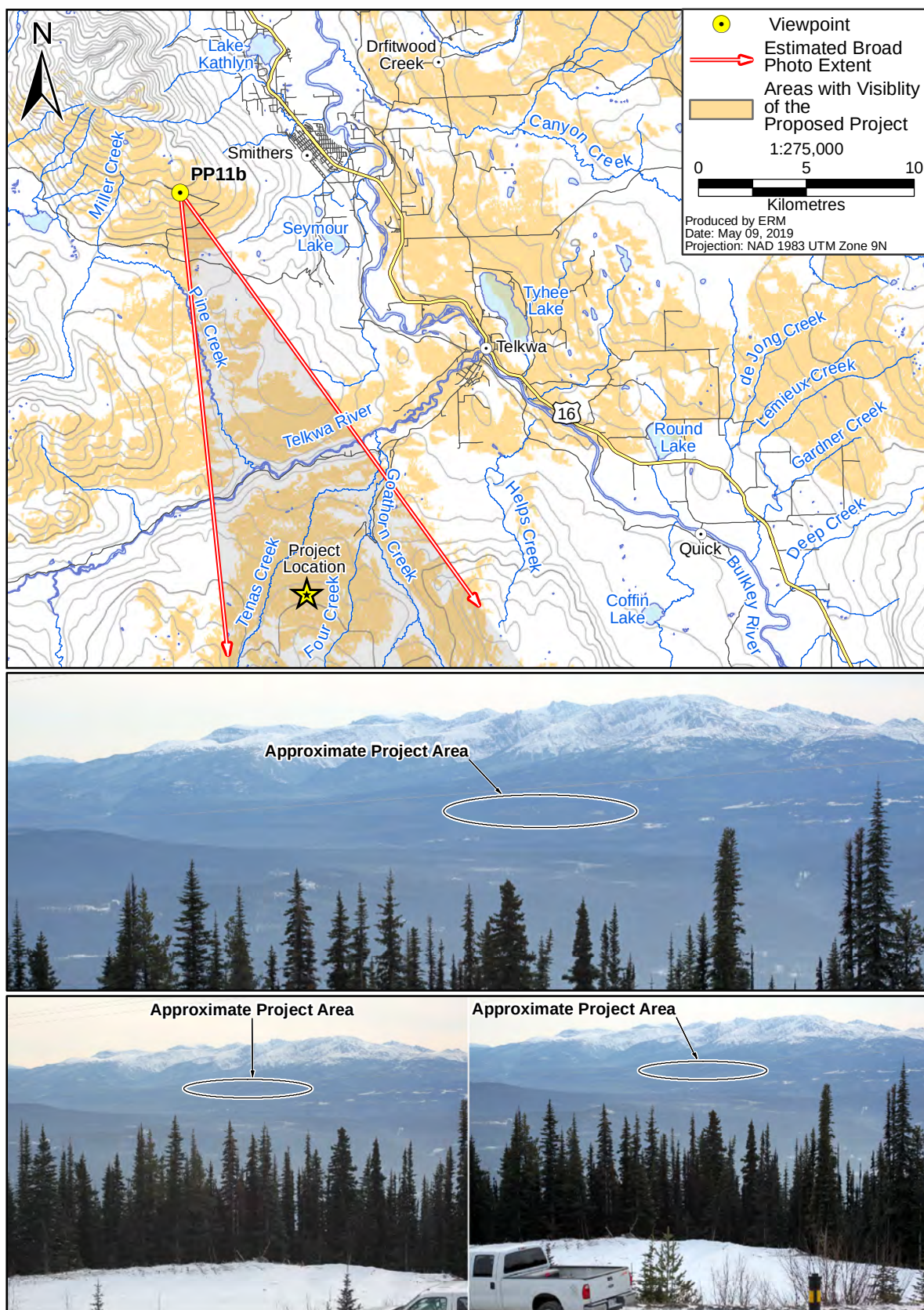


Figure 12.5-13
Visual Quality Photo Site PP13, Tenas Project

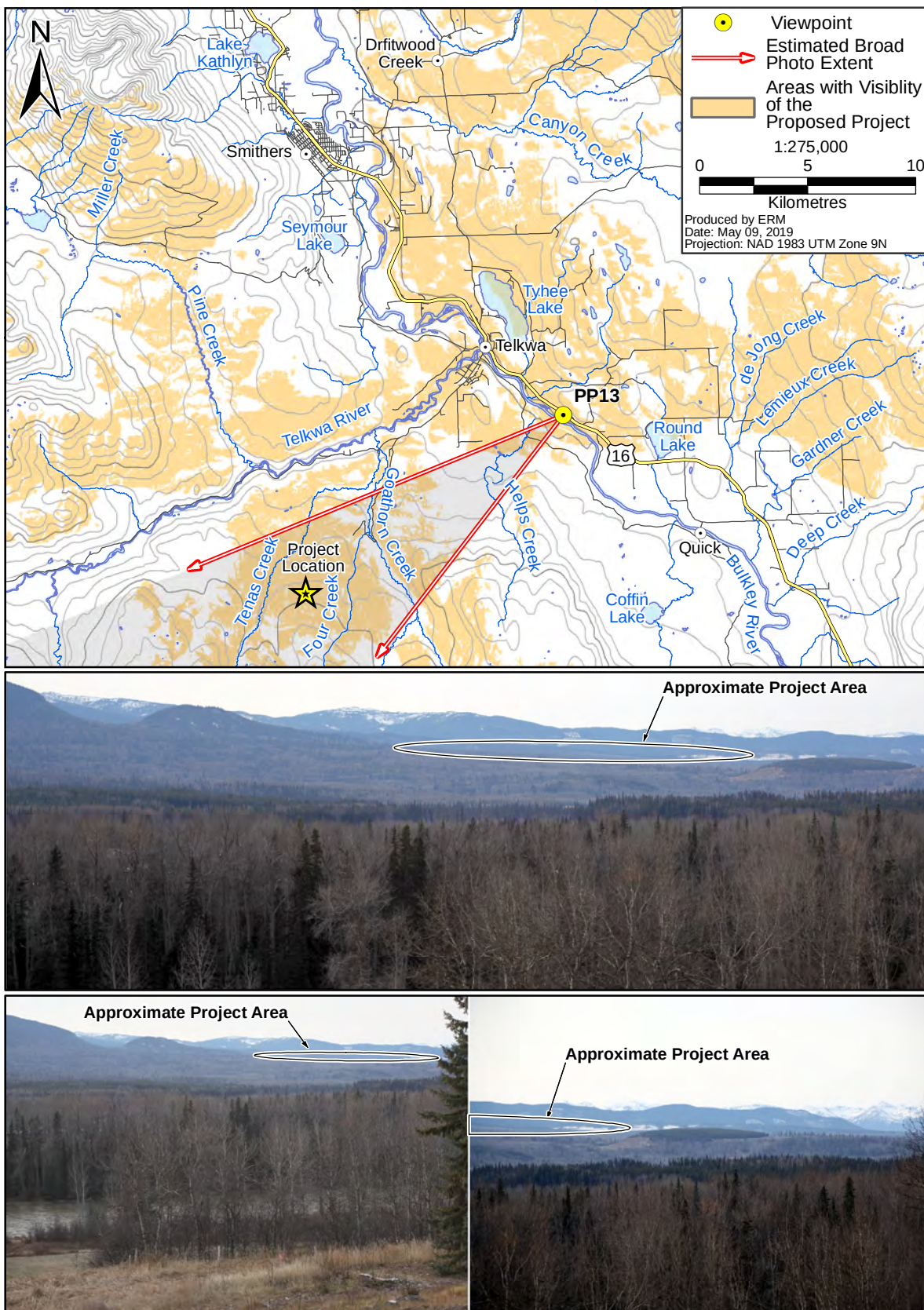
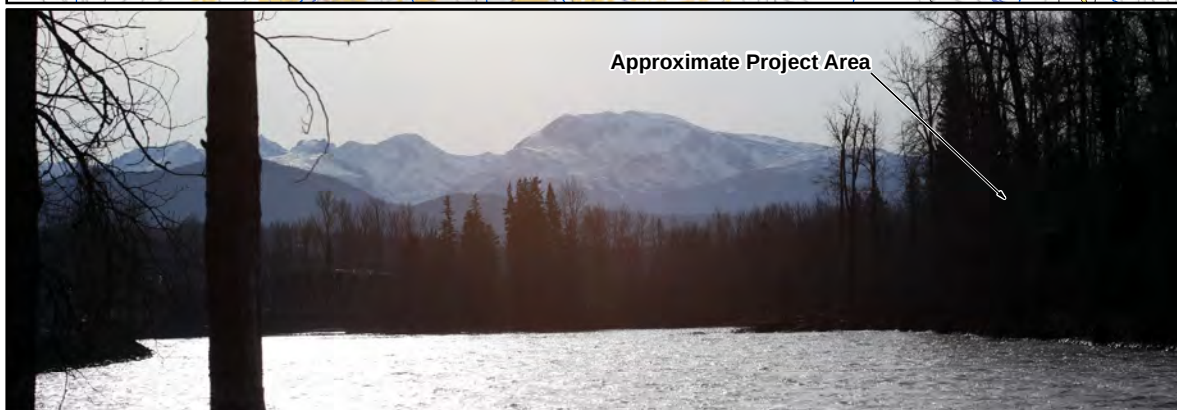
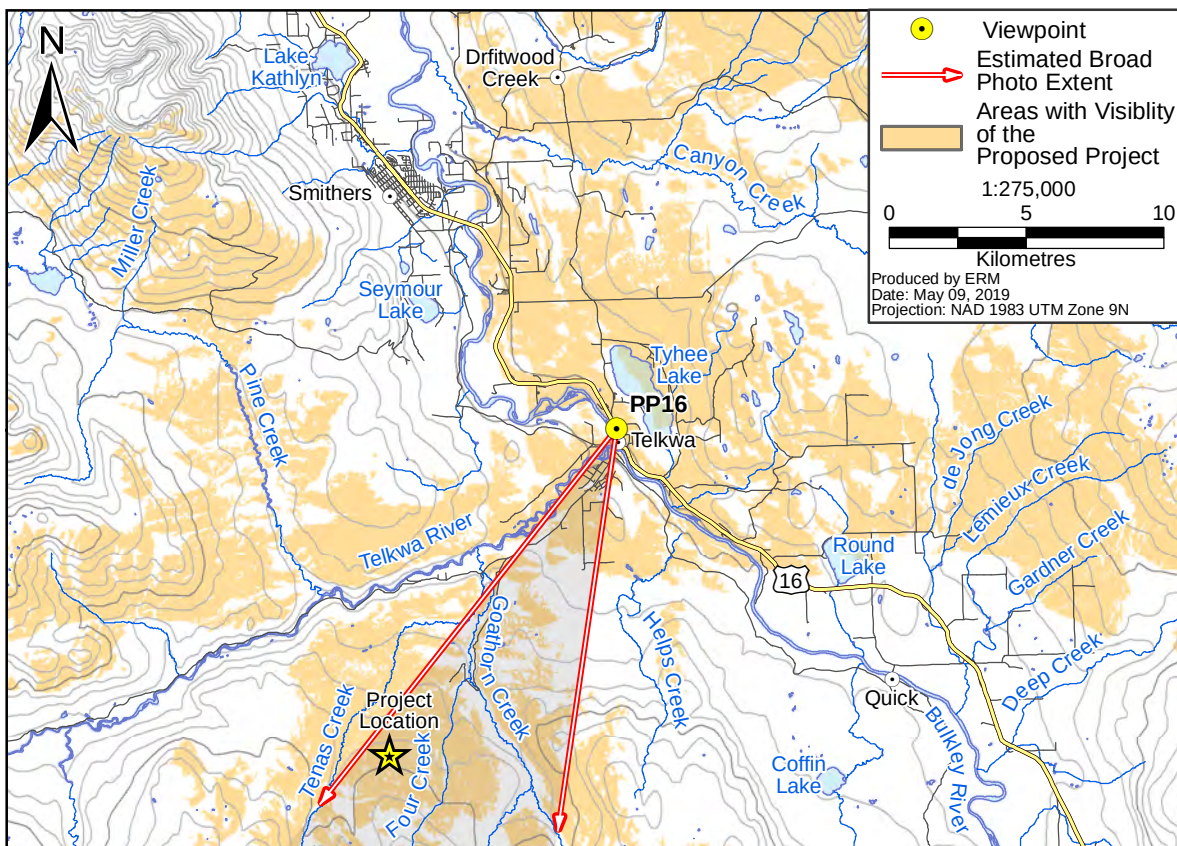


Figure 12.5-14
Visual Quality Photo Site PP16, Tenas Project



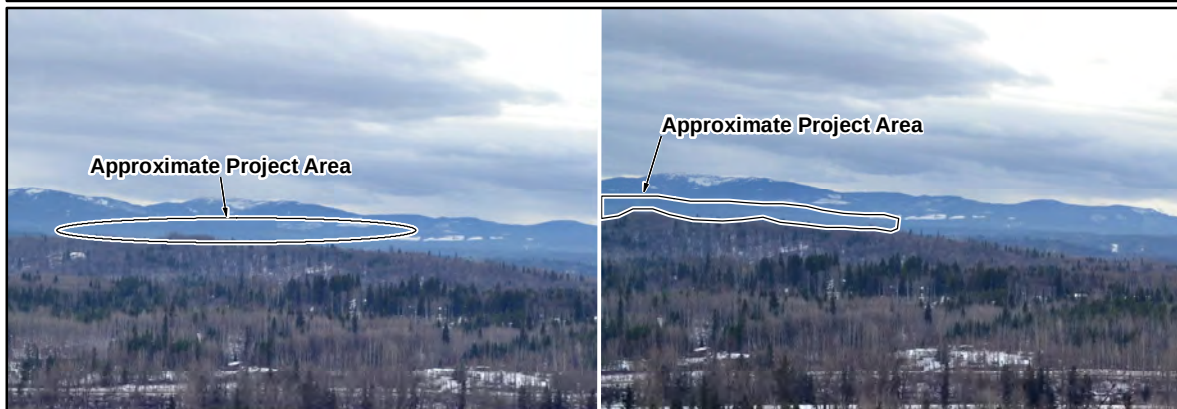
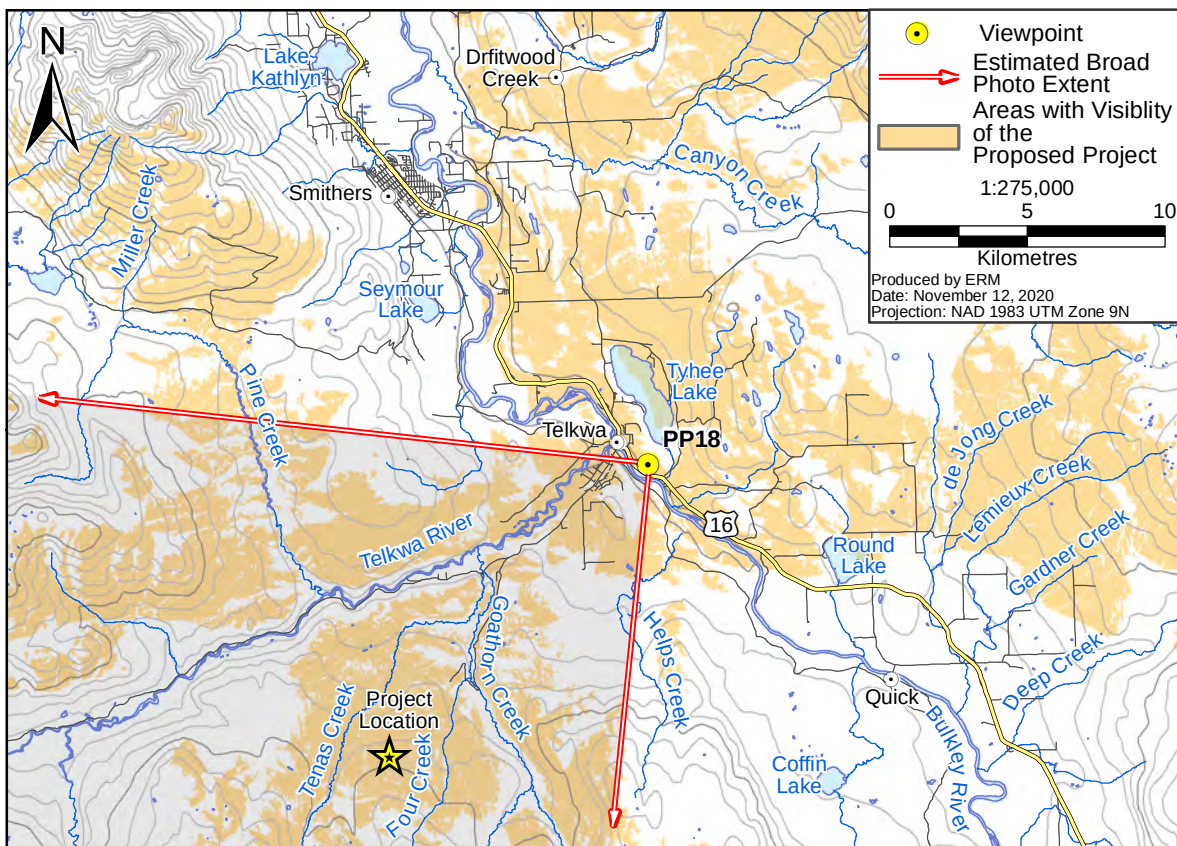
12.5.1.17 Project Viewpoint PP17

Project Viewpoint PP17 is located adjacent a residential bed and breakfast along Tyhee Lake Road, 370 metres north of the intersection with Hislop Road. The viewpoint has an approximate elevation of 524 metres. The area is heavily treed, and no view of the site was possible.

12.5.1.18 Project Viewpoint PP18

Project Viewpoint PP18 (Figure 12.5-15) is located on a gated road accessing a new water tower site for the community. The road is accessed from the Tower residential area ending at the water tower and potential cabin site. The specific location of the site was not known, so the location for the images was chosen based on the clearest views towards the Project area. This was to the south of the water tower on a flat treed area overlooking the highway. The viewpoint has an approximate elevation of 578 metres.

Figure 12.5-15
Visual Quality Photo Site PP18, Tenas Project



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