Jacobs

Memorandum

Metrotower II – Suite 2100
4720 Kingsway
Burnaby, BC V5H 4N2
Canada
T +1.604.684.3282

www.jacobs.com

Subject	**Squamish River Water Quality Assessment**
Project Name	Eagle Mountain – Woodfibre Gas Pipeline Project
Attention	John Macleod, FortisBC Energy Inc. (FortisBC)
From	Brendan Doble, B.I.T., Jacobs Consultancy Canada Inc. (Jacobs)
Date	March 3, 2022
Copies to	Ilona Berbekar, FortisBC Energy Inc. (FortisBC)

1. Introduction

The EGP Project involves the construction of approximately 47 kilometres (km) of 24-inch outside diameter pipeline, including a 9-km tunnel (EGP Tunnel) from the BC Rail Properties Ltd. (BC Rail Site) to the proposed Woodfibre Liquefied Natural Gas Ltd. (WLNG) production facility (WLNG Site) in Squamish, BC. The EGP Project will expand FortisBC's existing natural gas transmission system to supply natural gas to the proposed WLNG Site, located southwest of Squamish, BC.

This memorandum is a summary of results attained from the Water Quality Assessment Program (the Program) conducted by Jacobs field staff within the Squamish River, located in Squamish, British Columbia (BC). Over an 11-month period, a total of six sampling events were conducted to capture seasonal variability in river water quality. These included a day in October 2020, and January, March, May, July, and August of 2021.

The Squamish River is a large river system that flows into Howe Sound just downstream of the assessment area; therefore, the sampling events were planned during various tidal times to better capture natural river conditions and any potential marine water influences. The assessment program was conducted to evaluate the background water quality of the river system and to determine if any assessed parameter exceeds the 2021 approved BC Water Quality Guidelines (BC WQGs) within freshwater systems for the protection of aquatic life.

2. Methods

The water quality assessment area on the Squamish River was within the downstream section of the river system and is shown on Figure 1. This area is located downstream of the confluence with the Mamquam River.

FORTIS BC

March 2022

FIGURE 1

SQUAMISH RIVER WATER QUALITY ASSESSMENT OVERVIEW

EAGLE MOUNTAIN - WOODFIBRE GAS PIPELINE PROJECT

- Assessment Area
- Public Walking Trails
- Railway
- Existing Transmission Line
- Existing NPS 10 FortisBC Pipeline

SCALE: 1:5,000

0 100 200 m

(All Locations Approximate)

JACOBS

JACOBS Project Number CE832900

UTM Zone 10 North. NAD 1983.
Assessment Area: Jacobs 2022; Existing Pipeline: FortisBC 2012; Public Walking Trails: District of Squamish: 6-15-2020; Railway: BC MLFNRO 2015 Provincial Park: BC MFLNRO 2008; Existing Transmission Line: BC Hydro; Base Imagery: Atlantic Group 2013; Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

Mapped By: SL | Checked By: DJN

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2.1 Water Quality Assessment

The Program was completed by Jacobs field staff and included water sampling at three depths during each sampling event to attain background water quality data for Squamish River. This involved collecting samples at 0.5 metres (m) below the water surface, mid-depth, and 0.5 m above the riverbed.

With the results of the assessment, a water quality profile was attained for the downstream area of the Squamish River. Water samples were also collected from the three depths during each sampling event and submitted to a Canadian Association of Environmental Analytical Laboratories-accredited laboratory for analysis (that is, ALS for the purpose of this Program).

ALS analyzed the collected samples for alkalinity, hardness, total suspended solids (TSS), total dissolved solids (TDS), chloride, sulphate, heterotrophic plate count (HPC), fecal coliforms, and total and dissolved metals. Total and dissolved metals were both captured in January 2021, while dissolved metals were acquired during each subsequent sampling event (March, May, July, and August of 2021).

Fecal coliform analysis was included for the 2021 sampling events since the Mamquam Wastewater Treatment Plant is located approximately 1.5 kilometres (km) upstream of the assessment area, at the confluence of the Mamquam River and the Squamish River.

Throughout the Program, water sampling was conducted on the river from a jetboat, operated by Squamish RiverJet based out of Squamish, BC. The sampling methodology during each water sampling event involved the following.

- Recording of the date, time, weather, closest high and low tidal times, approximate water depth at the sampling location, and discharge of the Squamish River.
  - Discharge was recorded from the online Hydrometric Station on the Squamish River near Brackendale (08GA022) at the time of sampling (ECCC 2021). This hydrometric station is located approximately 10.3 km upstream of the sampling location.
- Utilizing a YSI Professional Plus Quatro water quality meter with a 10 m cable and weighted guard head, in-situ water quality measurements were recorded. The instrument was calibrated prior to each sampling event, with in-field calibration of dissolved oxygen (DO) on-site. Within the generally fast flowing reach of the river, measurements were collected by coordinating a downstream drift with the Jetboat operator to the assessment area while the YSI was lowered to the three appropriate depths.
  - pH, DO (% saturation and milligrams per litre [mg/L]), temperature (°C), conductivity (microSiemens per centimetre [µs/cm]) and salinity (parts per thousand [ppt]) were recorded.
- Operating a Van Dorn sampling bottle (Kemmerer Acrylic 4.2 litre [L] Alpha Water Sampler), water samples were collected from the three depths. Water samples were also collected by coordinating a downstream drift with the jetboat operator to the assessment area while lowering the sampling bottle to the appropriate depths.
  - This Van Dorn bottle consists of a vertical plastic bottle fitted with a rubber cover on each end and attached to a 30 m line. The catch (closing mechanism) is activated by releasing a weighted messenger down the line while the bottle is at the appropriate depth. The rubber end closes and seals the bottle capturing water inside, which can then be pulled up to the surface.
- Using a LaMotte 2020e/2020we meter, turbidity was measured in-situ. The water samples that were collected from each depth were measured for turbidity, with appropriate rinsing and drying of the glass measuring tube to confirm accuracy of results.

- Collecting water samples from the Van Dorn sampling bottle was performed by filling the appropriate laboratory-supplied and sterilized containers (some with required preservatives).
  - Once filled, the sample containers were sealed and labelled with the date, time, project number, and the sample site identification. Each labelled bottle was placed in a cooler with ice packs to maintain a temperature of <10°C until the samples were submitted to ALS.

3. Results

The physical, chemical, and biological parameter results from the Program are provided in Table 1 and the results of the metals analyses are presented in Appendix A and Appendix B. Table 1 includes results of the field water quality parameters (pH, DO, temperature, conductivity, salinity, and turbidity), and lab-analyzed water quality parameters (alkalinity, hardness, TSS, TDS, chloride, sulphate, HPC, and fecal coliforms). Appendix A includes results of the January 2021 total metals analysis, while Appendix B includes results from the dissolved metals analyses (including January, March, May, July, and August of 2021).

Table 1. Field and Laboratory Results of Squamish River Water Quality Assessment Program

			Date Sampled	28-Oct-2020			22-Jan-2021			17-Mar-2021			19-May-2021			7-Jul-2021			4-Aug-2021		
			Time Sampled	13:45	14:30	14:15	10:40	11:20	11:00	11:45	12:00	12:15	12:30	12:45	13:00	10:00	9:45	9:30	11:15	11:00	10:50
			Tidal Times	Low Tide: 10:14 AM High Tide: 4:45 PM			Low Tide: 5:59 AM High Tide: 11:48 AM			High Tide: 8:40 AM Low Tide: 3:20 PM			High Tide: 10:30 AM Low Tide: 5:50 PM			High Tide: 3:12 AM Low Tide: 10:55 AM			Low Tide: 9:43 AM High Tide: 5:48 PM		
			Discharge[a]	314 m^3/s (at 2:15 PM)			46.4 m^3/s (at 11:00 AM)			40.3 m^3/s (at 12:00 PM)			294 m^3/s (at 12:15 PM)			548 m^3/s (at 9:45 AM)			352 m^3/s (at 10:30 AM)		
			Maximum Depth (approximate)	6.0 m			4.5 m			5.0 m			6.5 m			7.5 m			4.5 m		
			Depth Sampled	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed
			Sample ID:	SR-102820-01	SR-102820-02	SR-102820-03	SR-012221-01	SR-012221-03	SR-012221-02	SR-031721-01	SR-031721-02	SR-031721-03	SR-051921-01	SR-051921-02	SR-051921-03	SR-070721-01	SR-070721-02	SR-070721-03	SR-080421-01	SR-080421-02	SR-080421-03
Analysis	**Parameter**	**Units**	**BC WQG Freshwater Aquatic Life[c]**																		
Field	pH	-	Variable	5.66	6.26	6.26	6.23	6.44	6.28	6.85	7.06	7.06	5.7	6.23	6.06	6.88	6.50	7.04	6.73	6.43	6.16
	DO	mg/L	8.0 - 11.0	13.57	13.10	12.78	11.97	11.94	11.98	15.32	13.08	5.32	15.30	14.83	14.83	12.02	11.99	12.00	11.43	11.26	11.47
	Temperature	°C	Variable	4.7	4.7	4.7	2.7	2.8	2.7	4.5	4.5	4.5	6.4	6.4	6.3	11.4	11.4	11.7	11.7	11.7	11.7
	Conductivity	µs/cm	NS	19.7	19.7	19.9	38.4	38.6	38.2	72.5	72.3	72.6	17.5	27.5	28.3	13.7	13.2	14	14.9	16.8	16.7
	Salinity	ppt	NS	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Turbidity	NTU	Variable	12	15.6	13.7	0.98	0.92	1.04	0.47	0.74	0.51	12.9	13.5	11.1	61.0	67.7	61.8	73.5	78.4	72.3
Laboratory	Alkalinity	mg/L	NS	10.2	9.9	9.7	21.1	21.5	21.3	19.7	19.7	19.7	8.9	9.1	9.1	5.4	5.6	6.0	6.9	6.1	6.9
	Hardness (as $CaCO_3$), dissolved	mg/L	NS	12.3	11.7	11.2	22.2	22.2	22.1	23.2	22.8	22.7	10.5	10.3	10.7	5.20	5.30	5.82	6.48	6.34	6.33
	TSS	mg/L	Variable	76.1	86.9	91.1	<3.0	<3.0	<3.0	<3.0	<3.0	3.5	23.5	29.9	29.4	91.1	105	134	103	95.9	105
	TDS	mg/L	NS	27	25	52	64	51	51	64	61	53	34	32	29	24	24	28	23	22	26
	Chloride	mg/L	≤150 / ≤650	1.38	1.39	1.32	5.86	4.81	5.83	6.17	5.65	5.67	2.05	1.21	1.04	0.53	0.71	3.34	0.88	0.76	1.51
	Sulphate	mg/L	128 - 429[e]	3.38	3.44	3.29	6.17	6.13	6.21	7.33	7.22	7.20	2.97	2.8	2.80	1.27	1.42	1.76	1.69	1.55	1.69
	HPC	CFU/mL[b]	NS	260	80	50	8	9	11	12	12	24	3530	1960	1570	120	103	125	96	233	211
	Fecal Coliforms	CFU/mL[d]	NS	-	-	-	0.03	0.03	0.02	0.04	0.09	0.03	0.1	0.08	0.03	0.19	0.14	0.18	0.13	0.07	0.08

[a] Discharge (approximate) attained from the Hydrometric Station for Squamish River Near Brackendale (08GA022) [BC] (https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=08GA022) from the time of sampling.

[b] CFU: Colony-Forming Units are the number of viable bacteria cells in a sample. Viable is defined as the ability to multiply via binary fission (excludes dead cells).

[c] WQG for Freshwater Aquatic Life attained from: BC ENV 2021. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture – Guideline Summary. Water Quality Guideline Series, WQG-20. Prov. B.C., Victoria B.C.

[d] Lab results are provided in MPN/100 mL, where MPN = Most Probable Number. Results are converted to CFU/mL by: 1 MPN equivalent to 1 CFU and division by 100 for CFU/mL.

[e] Range for sulphate WQG dependent on water hardness (as mg/L $CaCO_3$) as described in Table 40 of BC ENV 2021

Notes:
/ # = Long-term Chronic / Short-term Acute WQG
- # = Range provided for WQG
$CaCO_3$ = calcium carbonate
CFU/mL = colony forming unit per millilitre
m^3/s = cubic metre(s) per second
NS = Not Specified
NTU = nephelometric turbidity unit

4. Discussion

The following section discusses the physical, chemical, biological, and metallic properties of Squamish River that were observed during the Program.

4.1 Physical properties

During the Program, water temperatures ranging from 2.7 and 6.4°C were observed throughout the water column from October through May. Water temperatures ranging from 11.4 to 11.7 °C were recorded during July and August. According to the BC WQGs for freshwater protection of aquatic life, short-term elevated temperatures above 10°C may be detrimental to some fish species during sensitive life stages (such as, spawning and incubation) (BC ENV 2021).

Turbidity levels varied significantly throughout the sampling season, with lowest turbidity levels seen during the winter months, and highest levels seen in the spring and summer months. This turbidity variance is likely due to the variable weather conditions observed during the 2020-2021 sampling program. January and March 2021 were during unusually dry weeks, without higher precipitation normally seen in the winter on the west coast. In addition, an accelerated spring freshet was likely associated with the elevated atmospheric temperatures that occurred during the 2021 summer heat waves across BC (Vancouver City News 2021).

Due to the accelerated and extended freshet season, higher flows and water levels were observed within the Squamish River resulting in elevated turbidity levels during the July and August 2021 sampling events. Turbidity level greater than 67 NTUs were recorded in July, and the highest of 78.4 NTU recorded in August. Higher turbidity levels are expected during spring freshet, especially near estuarine systems (Kennish 2019); however, the high turbidity observed, potentially above normal levels for Squamish River, could be attributed to the accelerated freshet. As expected, the TSS concentration varied with the Squamish River discharge, with highest TSS observed during high flow periods.

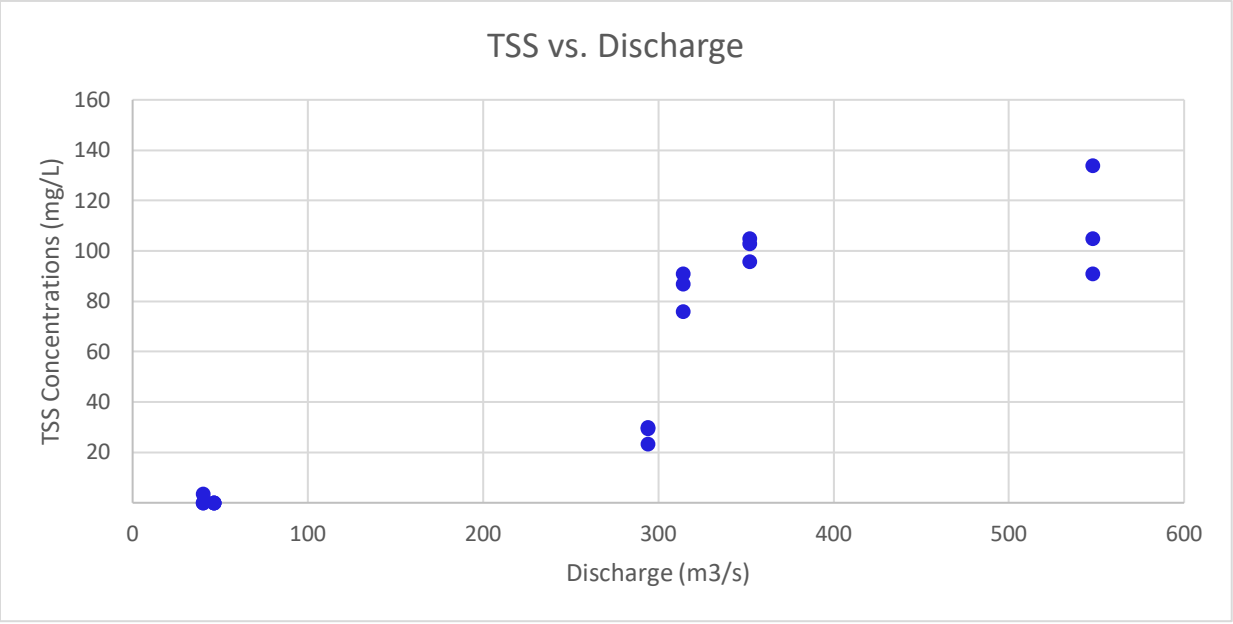

Figure 2. Total Suspended Solids vs. Discharge

The highest TSS concentrations were recorded in the summer months, likely an associated effect of the heat wave, enhanced flow, and increased water levels. Given results of the study, Squamish River experiences clear waters during the winter months, with elevated turbidity expected during the spring and summer months.

Low conductivity was seen throughout the water quality assessment program on the Squamish River, where conductivity ranged from 13.2 to 72.6 µs/cm. Most major river systems range from 200 to 1,000 µs/cm, with greater levels attributed to potentially elevated contaminant concentrations (DataStream 2021). The low levels recorded within the Squamish River potentially indicate pristine background conditions without elevated contaminants.

4.2 Chemical properties

During four out of the six sampling events, the Squamish River had a pH value ranging from 5.66 to 6.44, below more neutral levels. This included October 2020 and January, May, and August of 2021. The lowest pH measured within the assessment area was 5.66, measured near the surface in October 2020. There are natural conditions that may affect pH values, such as, surrounding geology and rainfall accumulation (US EPA 2021). Low pH values have been a common occurrence in previous Jacobs field studies around Squamish BC and a low pH is common in coastal areas, including Howe Sound.

DO concentrations in the river ranged from 11.26 to 15.32 mg/L. This relatively high concentration could be attributed to the abundant aquatic life, turbulence, and inputs from surrounding vegetation. The BC WQGs for DO for the protection of aquatic life in freshwater systems vary with sensitive early life stages of fish and can range from 5.0 to 11.0 over instantaneous or long-term durations. With the observed DO levels above the range of the BC WQGs within the assessment area, it is possible that this downstream tidally influenced area may not be optimal all early life stages of fish.

Chloride concentrations ranged from 0.71 mg/L to 6.17 mg/L throughout the sampling events. The low chloride concentrations reflect that the assessment area is likely above the saltwater wedge of the Squamish River estuary. The BC WQGs for chloride in freshwater systems for the protection of aquatic life vary with duration. Long-term concertation should be less than or equal to 150 mg/L, while short-term concentration less than or equal to 650 mg/L. Given the assessment results attained for chloride, this area of the Squamish River has suitable freshwater concentrations for the protection of aquatic life.

4.3 Biological properties

Bacteria in the Squamish River was measured through the analysis of fecal coliforms and HPC) in CFU/mL. The concentration of fecal coliforms ranged from 0.02 to 0.18 CFU/mL, while heterotrophic plate count ranged from 8 to 3,530 CFU/mL throughout the Program. The higher concentration of HPC was recorded in May 2021, ranging from 1570 CFU/mL near the riverbed and 3530 CFU/mL at the surface.

These elevated levels were recorded near the start of spring and are possibly attributed to the increased river flows and increasing temperatures observed. The low concentration of fecal coliforms may be associated with the adequate treatment of sewage at the Mamquam Wastewater Treatment Plant, which is located approximately 1.5 km upstream of the assessment area, at the confluence of the Mamquam River and the Squamish River.

At the treatment plant, treated effluent is diluted and discharged into the Squamish River, in compliance with the BC *Reg. 87/2021*, the *Municipal Wastewater Regulation* (Urban Systems 2015; District of Squamish 2018).

4.4 Metals analysis

In January 2021, a comprehensive total and dissolved metals analysis was attained for the Squamish River. In addition, a dissolved metals analysis was performed for each subsequent sampling event.

The full metals analysis of January 2021 did not reflect any exceedances over the existing BC WQGs for the protection of aquatic life. However, the dissolved metals analysis across the subsequent sampling events showed slight exceedances of the acceptable range for dissolved aluminum. Dissolved aluminum results ranged from 0.0461 to 0.0799 mg/L during May and July 2021 sampling events.

The BC WQGs for dissolved aluminum in freshwater systems for the protection of aquatic life ranges from 0.02 to 0.05 mg/L across long-term duration and is dependent on background pH levels. Although additional sampling would be required to confirm the chronic duration of elevated dissolved aluminum levels, any additional inputs to the system should be monitored for elevated dissolved aluminum for the protection of aquatic life.

5. Conclusion

The Program conducted on the Squamish River between October 2020 and August 2021 indicates that the background levels of the river system are suitable when compared to the BC WQGs for the protection of aquatic life. Some results that show deviations from more natural levels (such as, turbidity and dissolved aluminum) are likely attributed to the variances seen in weather systems across the province during the Program. From an abnormally dry winter to increased heat waves in the summer, the elevated results observed during the assessment program may not be typical for this river system. Overall, the background water quality of the Squamish River is in good condition.

6. References

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Appendix A
Total Metals Analysis Results

Results of Squamish River Water Quality Assessment Program: Total Metals

			Date:	22-Jan-21		
			Sample ID:	SR-012221-01 0.5 m below surface	SR-012221-03 Mid-depth	SR-012221-02 0.5 m above riverbed
		BC WQG for Freshwater Aquatic Life[a]				
Metal	**Units**	**Long-term Chronic WQG[b] (mean)**	**Short-term Acute WQG[c] (max)**			
Aluminum (Al)	mg/L	NS	NS	0.0912	0.0625	0.0573
Antimony (Sb)	mg/L	0.009[d]	NS	<0.00010	<0.00010	<0.00010
Arsenic (As)	mg/L	NS	0.005	0.00019	0.00019	0.00019
Barium (Ba)	mg/L	1.0	NS	0.0105	0.0108	0.0104
Beryllium (Be)	mg/L	0.00013	NS	<0.000100	<0.000100	<0.000100
Bismuth (Bi)	mg/L	NS	NS	<0.000050	<0.000050	<0.000050
Boron (Bo)	mg/L	1.2	NS	0.019	0.012	0.012
Cadmium (Cd)	mg/L	NS	NS	0.0000102	0.0000098	<0.0000050
Calcium (Ca)	mg/L	NS	NS	7.94	7.36	7.31
Cesium (Cs)	mg/L	NS	NS	0.000028	0.000025	0.000028
Chromium	mg/L	0.0089[e], 0.001[f]	NS	0.00012	0.00018	0.00024
Cobalt (Co)	mg/L	0.004	0.11	0.00014	0.00014	0.00013
Copper (Cu)	mg/L	0.0002 - 0.0089[g]	0.0002 - 0.0509[g]	0.00108	0.00233	0.00087
Iron (Fe)	mg/L	NS	1.0	0.367	0.333	0.329
Lead (Pb)	mg/L	0.004271 - 0.014058[h]	0.024624 - 0.275544[i]	0.000056	<0.000050	<0.000050
Lithium (Li)	mg/L	NS	NS	0.0021	0.0019	0.0020
Magnesium (Mg)	mg/L	NS	NS	3.03	1.11	1.10
Manganese (Mn)	mg/L	0.777 - 1.749[j]	0.970 - 3.405[k]	0.0191	0.0175	0.0175
Mercury (Hg)	mg/L	Calculated[l]	NS	<0.0000050	<0.0000050	<0.0000050
Molybdenum (Mo)	mg/L	1.0	2.0	0.000569	0.000575	0.000554
Nickel (Ni)	mg/L	0.025 - 0.150[m]	NS	<0.00050	<0.00050	<0.00050
Phosphorous (P)	mg/L	NS	NS	0.056	<0.050	<0.050
Potassium (K)	mg/L	NS	NS	1.52	0.914	0.900
Rubidium (Rb)	mg/L	NS	NS	0.00149	0.00148	0.00132
Selenium (Se)	mg/L	0.002	NS	<0.000050	<0.000050	<0.000050
Silicon (Si)	mg/L	NS	NS	5.54	5.47	5.38
Silver (Ag)	mg/L	0.00005	0.0001	<0.000010	<0.000010	<0.000010
Sodium (Na)	mg/L	NS	NS	26.6	5.10	5.51
Strontium (Sr)	mg/L	NS	NS	0.0688	0.0537	0.0558
Sulfur (S)	mg/L	NS	NS	3.38	1.97	2.01
Tellurium (Te)	mg/L	NS	NS	<0.00020	<0.00020	<0.00020
Thallium (Tl)	mg/L	0.0008	NS	<0.000010	<0.000010	<0.000010
Thorium (Th)	mg/L	NS	NS	<0.00010	<0.00010	<0.00010
Tin (Sn)	mg/L	NS	NS	0.00026	<0.00010	<0.00010
Titanium (Ti)	mg/L	NS	NS	0.00958	0.00190	0.00172
Tungsten (W)	mg/L	NS	NS	<0.00010	<0.00010	<0.00010
Uranium (U)	mg/L	0.0085	NS	0.000044	0.000036	0.000039
Vanadium (V)	mg/L	NS	NS	0.00129	0.00126	0.00120
Zinc (Zn)	mg/L	0.0075 - 0.135[n]	0.033 - 0.1605[o]	0.0035	<0.0030	<0.0030
Zirconium (Zr)	mg/L	NS	NS	<0.00020	<0.00020	<0.00020

Appendix A:

[a] British Columbia Ministry of Environment and Climate Change Strategy. 2021. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture - Guideline Summary. Water Quality Guideline Series, WQG-20. Prov. B.C., Victoria B.C.
Where Approved Guidlelines were not available; British Columbia Ministry of Environment and Climate Change Strategy. 2021.British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. Water Quality Guideline Series, WQG-08. Prov. B.C., Victoria B.C. was used.

[b] Long-term chronic (i.e., “average”) WQGs are intended to protect the most sensitive species and life stage against sub-lethal and lethal effects for indefinite exposures. An averaging period approach is used for these WQGs. This approach allows concentrations of a substance to fluctuate above and below the guideline provided that the short-term acute is never exceeded and the long-term chronic is met over the specified averaging period (e.g., 5 samples in 30 days).

[c] Short-term acute (i.e., “maximum”) WQGs are set to protect against severe effects such as lethality (e.g. LC50) or other equivalent measures (e.g., EC50) to the most sensitive species and life stage over a defined short-term exposure period (e.g., 96 hours).

[d] WQG is for antimony (III)

[e] WQG is for chromium (III)

[f] WQG is for chromium (VI)

[g] WQG is a sample-specific calculation which requires Dissolved Organic Carbon.

[h] Chronic WQG for lead = 3.31 + e^[1.273 ln(hardness) - 4.704]

[l] Acute WQG for lead = e^[1.273 ln(hardness) - 1.460]

[j] Chronic WQG for manganese = 0.0044(hardness) +0.605

[k] Acute WQG for manganese = 0.01102(hardness) + 0.54

[l] Chronic WQG for mercury = 0.0001 / (MeHg/totalHg), where MeHg is concentration of methyl mercury. Calculation requires methyl mercury concentration.

[m] Chronic WQG for nickel:
Hardness 0 to 60 mg/L CaCO3 = 25
Hardness 60 to 180 mg/L CaCO3 = e^[0.76 ln(hardness) +1.06]
Hardness > 180 mg/L CaCO3 = 150

[n] Chronic WQG for zinc:
Hardness < 90 mg/L CaCO3 = 7.5
Hardness > 90 mg/L CaCO3 = 7.5 + 0.75(hardness - 90)

[o] Acute WQG for zinc:Hardness < 90 mg/L CaCO3 = 33Hardness > 90 mg/L CaCO3 = 33 + 0.75(hardness - 90)

Notes:

% = percent

< = less than

mg/L = milligram per litre

NS = not specified

Appendix B
Dissolved Metals Analysis Results

Results of Squamish River Water Quality Assessment Program: Dissolved Metals

			Date:	22-Jan-21			17-Mar-21			19-May-21			7-Jul-21			4-Aug-21		
			Sample ID:	SR-012221-01	SR-012221-03	SR-012221-02	SR-031721-01	SR-031721-02	SR-031721-03	SR-051921-01	SR-051921-02	SR-051921-03	SR-051921-01	SR-051921-02	SR-051921-03	SR-051921-01	SR-051921-02	SR-051921-03
		BC WQG Freshwater Aquatic Life[a]		0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed	0.5 m below surface	Mid-depth	0.5 m above riverbed
Metal	**Units**	**Long-term Chronic WQG[b] (mean)**	**Short-term Acute WQG[c] (max)**															
Aluminum (Al)	mg/l	0.02 - 0.05[d]	0.047 - 0.1[e]	0.0244	0.0234	0.0227	0.019	0.0205	0.0239	0.0652	0.0665	0.069	0.0799	0.0494	0.0461	0.0418	0.0417	0.0412
Antimony (Sb)	mg/l	NS	NS	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)	mg/l	NS	NS	0.00021	0.0002	0.00021	0.00014	0.00016	0.00016	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.0001
Barium (Ba)	mg/l	NS	NS	0.0107	0.0111	0.0112	0.0092	0.00966	0.0104	0.00542	0.00551	0.00572	0.00437	0.00377	0.00382	0.00347	0.00354	0.00344
Beryllium (Be)	mg/l	NS	NS	<0.000100	<0.000100	<0.000100	<0.000020	<0.000020	<0.000020	<0.000100	<0.000100	<0.000100	<0.000100	<0.000100	<0.000100	<0.000100	<0.000100	<0.000100
Bismuth (Bi)	mg/l	NS	NS	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (Bo)	mg/l	NS	NS	0.012	0.012	0.012	0.013	0.013	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (Cd)	mg/l	0.0000941 - 0.0003954[f]	0.0001895 - 0.0014120[g]	0.0000068	0.0000093	0.0000088	<0.0000050	<0.0000050	<0.0000050	0.0000076	0.0000062	0.0000056	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Calcium (Ca)	mg/l	NS	NS	7.32	7.33	7.26	7.74	7.54	7.41	3.63	3.56	3.67	1.75	1.79	1.97	2.18	2.13	2.09
Cesium (Cs)	mg/l	NS	NS	0.000021	0.000022	0.000023	0.000026	0.000023	0.000024	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium	mg/l	NS	NS	0.0001	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (Co)	mg/l	NS	NS	0.00013	0.00013	0.00013	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)	mg/l	NS	NS	0.00115	0.00074	0.00072	0.0007	0.00078	0.00067	0.00139	0.00118	0.00107	0.00064	0.00046	0.00078	0.00054	0.00053	0.00069
Iron (Fe)	mg/l	NS	NS	0.23	0.223	0.228	0.12	0.121	0.119	0.041	0.044	0.044	0.06	0.036	0.037	0.034	0.031	0.032
Lead (Pb)	mg/l	NS	NS	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)	mg/l	NS	NS	0.002	0.002	0.002	0.0019	0.0019	0.0018	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Magnesium (Mg)	mg/l	NS	NS	0.952	0.937	0.961	0.952	0.96	1.03	0.349	0.353	0.372	0.202	0.202	0.22	0.252	0.249	0.269
Manganese (Mn)	mg/l	NS	NS	0.0174	0.0172	0.0175	0.0105	0.0107	0.0116	0.00454	0.00454	0.00469	0.0045	0.00389	0.00412	0.00438	0.00424	0.00414
Mercury (Hg)	mg/l	NS	NS	<0.0000050	<0.0000050	<0.0000050	-	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum (Mo)	mg/l	NS	NS	0.000504	0.000545	0.000538	0.000539	0.000534	0.000508	0.00032	0.000338	0.000339	0.00023	0.000217	0.000238	0.000273	0.000247	0.000245
Nickel (Ni)	mg/l	NS	NS	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Phosphorous (P)	mg/l	NS	NS	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Potassium (K)	mg/l	NS	NS	0.91	0.915	0.924	0.843	0.841	0.933	0.487	0.478	0.455	0.458	0.449	0.489	0.502	0.491	0.477
Rubidium (Rb)	mg/l	NS	NS	0.0013	0.00137	0.0013	0.00128	0.00124	0.00141	0.00074	0.00068	0.00068	0.00066	0.00058	0.0006	0.00071	0.00067	0.00073
Selenium (Se)	mg/l	NS	NS	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silicon (Si)	mg/l	NS	NS	5.14	5.19	5.16	4.75	4.77	4.77	2.14	2.09	2.21	1.23	1.2	1.4	1.53	1.4	1.38
Silver (Ag)	mg/l	NS	NS	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sodium (Na)	mg/l	NS	NS	4.1	4.03	4.02	4.52	3.91	4.51	1.11	1.15	1.24	0.676	0.701	0.762	0.849	0.882	1.08
Strontium (Sr)	mg/l	NS	NS	0.0528	0.0528	0.052	0.0613	0.0587	0.0579	0.0204	0.0203	0.0208	0.0113	0.0112	0.0124	0.0144	0.0132	0.0126
Sulfur (S)	mg/l	NS	NS	1.98	2.01	1.9	2.37	2.15	2.1	0.63	0.69	0.74	<0.50	0.52	0.58	0.52	0.58	<0.50
Tellurium (Te)	mg/l	NS	NS	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)	mg/l	NS	NS	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thorium (Th)	mg/l	NS	NS	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)	mg/l	NS	NS	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00015	0.00014	<0.00010	0.0002
Titanium (Ti)	mg/l	NS	NS	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00165	0.00176	0.00158	0.0041	0.0023	0.00211	0.00191	0.00188	0.00188
Tungsten (W)	mg/l	NS	NS	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Uranium (U)	mg/l	NS	NS	0.000034	0.000032	0.000035	0.000027	0.000031	0.000029	0.000042	0.000041	0.000038	0.000019	0.000018	0.000019	0.000014	0.000013	0.000014
Vanadium (V)	mg/l	NS	NS	0.00104	0.00101	0.00105	0.00088	0.0009	0.00099	<0.00050	<0.00050	<0.00050	0.00054	<0.00050	0.00054	0.00059	0.00053	0.00053
Zinc (Zn)	mg/l	NS	NS	0.0017	0.0018	0.0015	<0.0010	<0.0010	<0.0010	0.0021	0.0012	0.0012	0.0011	<0.0010	0.0027	<0.0010	<0.0010	<0.0010
Zirconium (Zr)	mg/l	NS	NS	<0.00020	<0.00020	<0.00020	<0.00030	<0.00030	<0.00030	<0.00020	<0.00020	<0.00020	<0.00030	<0.00030	<0.00030	<0.00020	<0.00020	<0.00020

Appendix B Notes:

[a] British Columbia Ministry of Environment and Climate Change Strategy. 2021. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture - Guideline Summary. Water Quality Guideline Series, WQG-20. Prov. B.C., Victoria B.C.
Where Approved Guidlelines were not available; British Columbia Ministry of Environment and Climate Change Strategy. 2021.British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. Water Quality Guideline Series, WQG-08. Prov. B.C., Victoria B.C. was used.

[b] Long-term chronic (i.e., "average") WQGs are intended to protect the most sensitive species and life stage against sub-lethal and lethal effects for indefinite exposures. An averaging period approach is used for these WQGs. This approach allows concentrations of a substance to fluctuate above and below the guideline provided that the short-term acute is never exceeded and the long-term chronic is met over the specified averaging period (e.g., 5 samples in 30 days).

[c] Short-term acute (i.e., "maximum") WQGs are set to protect against severe effects such as lethality (e.g. LC50) or other equivalent measures (e.g., EC50) to the most sensitive species and life stage over a defined short-term exposure period (e.g., 96 hours).

[d] Aluminum chronic WQG for pH < 6.5 = $e^{[1.6 - 3.327(pH) + 0.402(pH)^2]}$
Aluminum chronic WQG for pH > 6.5 = 0.050 mg/L

[e] Aluminum acute WQG for pH < 6.5 = $e^{[1.209 - 2.426(pH) + 0.286(pH)^2]}$
Aluminum acute WQG for pH > 6.5 = 0.100 mg/L

[f] Cadmium chronic WQG = e^[0.736 x ln(hardness) - 4.943]

[g] Cadmium acute WQG = e^[1.03 x ln(hardness) - 5.274]

Notes:

% = percent

< = less than

mg/L = milligram per litre

NS = not specified

NT = not tested