Eagle Mountain - Woodfibre Gas Pipeline Project

Water Management Plan – EGP Tunnel East Shaft Dewatering

Rev. 0

June 2021

FortisBC Energy Inc.
16705 Fraser Highway
Surrey, British Columbia
V4N 0E8
T: 250.380.5707

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ACRONYMS AND ABBREVIATIONS

BC	British Columbia
BC OGC	British Columbia Oil and Gas Commission
BC WQG	British Columbia Water Quality Guideline
CSM	Conceptual Site Model
DB	Design Build
East Shaft WMP	East Shaft Water Management Plan
EFN	Environmental Flow Needs
EGP Project	Eagle Mountain – Woodfibre Gas Pipeline Project
FortisBC	FortisBC Energy Inc.
K	hydraulic conductivity
km	kilometre(s)
km^2	square kilometre(s)
L/min	litre(s) per minute
m	metre(s)
m/d	metre(s) per day
m/m	metre(s) per metre
m/s	metre(s) per second
m^2	square metre(s)
m^3/d	cubic metre(s) per day
m^3/s	cubic metre(s) per second
MAD	mean annual discharge
masl	metre(s) above sea level
mbgs	metre(s) below ground surface
MJA	McMillen Jacobs Associates
POD	Point of Diversion
QEP	Qualified Environmental Professional
RFP	Request for Proposal
Site	BC Rail Site
TBM	tunnel boring machine
WLNG	Woodfibre LNG Limited
WMA	Wildlife Management Area
WMP	Water Management Plan

1. INTRODUCTION

FortisBC Energy Inc. (FortisBC) submitted a Water Licence Application to the British Columbia (BC) Oil and Gas Commission (BC OGC) for the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel) (Tracking Number: 100321882, BC OGC File# 20015865) on July 3, 2020. During the review of the Application, the BC OGC determined that a *Water Sustainability Act* Authorization is required for dewatering activities for the construction and operation of the East Shaft.

To support the *Water Sustainability Act* Authorization, FortisBC is including the East Shaft dewatering as a separate Point of Diversion (POD) within the main Water Licence Application. This Water Management Plan (WMP) is specific to dewatering activities for the construction and operation of the East Shaft (East Shaft WMP). The information included in the East Shaft WMP has been prepared to meet the information requirements determined in consultation with the BC OGC and is an addendum to the main EGP Tunnel WMP included with the initial Water Licence Application.

The information presented herein includes the following:

- East Shaft project description (Section 2)
- Physical description of the East Shaft location and Hydrogeological Assessment (Section 3)
- Details on East Shaft construction and sequencing (Section 4)
- Analysis to determine hydraulic connectivity of the aquifer with nearby streams (Section 5)
- Water quantity and quality (Section 6)
- Environmental Flow Needs (EFN) assessment for hydraulically connected streams (Section 7)
- Qualified Environmental Professional (QEP) assessment to indicate if the dewatering activities could cause adverse effects to hydraulically connected streams (Section 7)
- Description of water management activities (that is, water storage, treatment, and discharge) (Section 8)
- QEP assessment to indicate if the dewatering activities could cause impacts to Water Rights Holders (Section 9)
- Summary of Indigenous nations consultation (Section 10)
- Conclusions (Section 11)
- Professional authentication (Section 12)
- Background data (Appendices A and B)

2. PROJECT DESCRIPTION – EAST SHAFT

A described in the EGP Tunnel WMP, the EGP Tunnel was identified as a solution for the last 9 kilometres (km) of the alignment of the EGP Project to address Indigenous nation and public concerns regarding impacts to the sensitive Squamish River Estuary, as well as to avoid steep, difficult terrain in the area of Monmouth Ridge.

FortisBC has selected the Design Build (DB) procurement approach for the EGP Tunnel. The DB Contractor will be provided with a Reference Design developed by McMillen Jacobs Associates (MJA) as Owner's Engineer for the EGP Tunnel, and will prepare a final design as part of the DB contract. The Request for Proposal (RFP) process is underway at the time of writing this East Shaft WMP. The EGP Tunnel Reference Design Drawings are included in Appendix A of the EGP Project WMP.

The Reference Design for the EGP Tunnel shows an alignment starting from a shaft located on the BC Rail Site west of Industrial Way in the District of Squamish (East Shaft), and terminating in a portal structure at the future Woodfibre LNG Limited (WLNG) production facility. The eastern portion of the EGP Tunnel crosses under the Squamish River Estuary and is referred to as the Soft Ground Tunnel.

The East Shaft would be located within the BC Rail Site (the Site) (located at 39500 Government Road) in the District of Squamish Industrial Park at the following location: Universal Transverse Mercator Zone 10, N = 5507305.12, E = 488432.40 as shown on Figure 1. While the Reference Design includes a shaft to provide access to the tunnel invert depth, the DB Contractor may propose to modify this structure for operational considerations. It is anticipated that the DB Contractor will use support of excavation to create a decline or ramp structure to provide access for tunnelling operations and pipe installation. For the purposes of this document, the structure will be referred to as the East Shaft.

The East Shaft will be as shallow as practicable to reduce groundwater inflows, while maintaining enough overburden for tunnelling operations. For reference, an indicative design of the East Shaft using decline or ramp structure is illustrated on Figure 2. Examples of typical decline structures are shown on Figures 5 and 6 in Section 4.

Figure 1. EGP Tunnel East Shaft Location

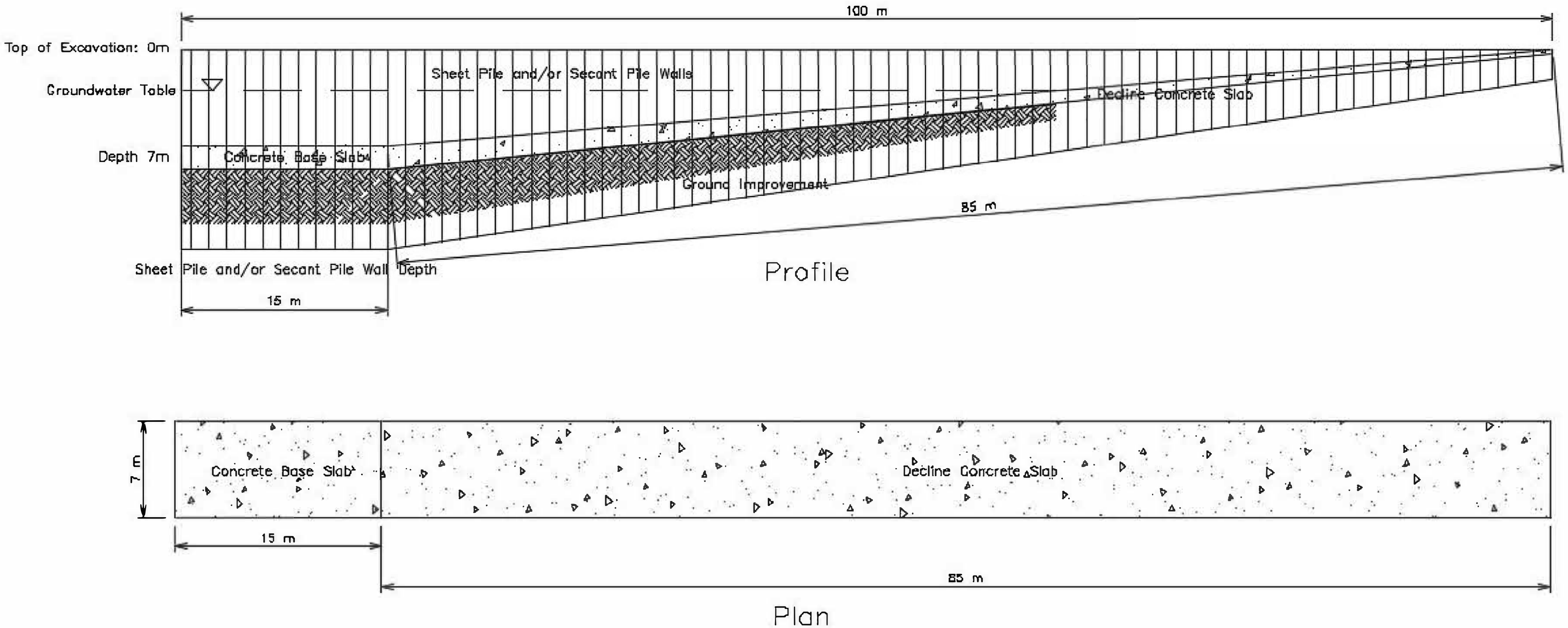

Figure 2. Preliminary Design Dimensions

3. BACKGROUND

This section includes a description of the topography and geology of the Site within the regional context as well as a Hydraulic Assessment (that is, an assessment of surface water) and a Hydrogeological Assessment (that is, an evaluation of groundwater conditions in both the regional and local context) of the region.

The topography, geology, surface hydrology, and hydrogeology information included in subsections 3.1, 3.2, and 3.3 were used as inputs to complete a local and regional Conceptual Site Model (CSM) of groundwater and surface water flow presented in subsection 3.4.

3.1 PHYSICAL DESCRIPTION

3.1.1 TOPOGRAPHY

The Squamish River Valley is a long, narrow, relatively flat strip of land, located on the north end of the Howe Sound fjord, in the Coastal Mountain Range. The Squamish River and its tributaries form a drainage channel of approximately 3,300 square kilometres (km^2) (Gazetteer of Canada 1953), discharging to Howe Sound. Figure 3 presents a topographic map of the region, showing the mountainous areas, and the limited and flat valley bottom of the river system. A valley glacier occupied the Squamish Valley and much of Howe Sound until 11,300 years before present (Armstrong 1981). Currently, alpine glaciers cover approximately 11 percent of the drainage basin (Brooks 1994).

The Squamish River originates at the toe of the Pemberton Icefield, flowing 80 km south from the glacier, until it discharges to Howe Sound. The first two tributaries join the Squamish River from the west. Approximately 22 km southwest of its source, the Squamish River meets its first and largest tributary, the Elaho River, and approximately 25 km further downriver, the Ashlu River, the second-largest tributary of the Squamish River joins. The remaining tributaries join the Squamish River from the east. The Cheakamus River joins the Squamish River 16.5 km downstream from the Ashlu, followed by the Mamquam River another 5 km downstream, and approximately 5 km below the confluence with the Mamquam River, the Squamish River discharges into Howe Sound.

Mountains west of the Squamish River include Mount Sedgwick, Red Tusk, Serratus Mountain, and Mount Tantalus. Mountains east of the Squamish River include Sky Pilot Mountain, Anif Peak (including the Stawamus Chief), Round Mountain and Mount Garibaldi. These surrounding peaks reach heights of between 2,000 metres above sea level (masl) (Mount Sedgwick) and 1,600 masl (Round Mountain), while the valley bottom is relatively flat, between sea level and 40 masl.

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FIGURE 3

TOPOGRAPHY OF THE SQUAMISH REGION

EAGLE MOUNTAIN-WOODFIBRE GAS PIPELINE PROJECT WATER MANAGEMENT PLAN - EGP TUNNEL EAST SHAFT DEWATERING

- Kilometre Post (KP)
- Proposed Squamish Compressor Station
- Proposed Tunnel Route
- Existing FortisBC Pipeline

SCALE: 1:145,000

0 2 4 6 km

(All Locations Approximate)

JACOBS

Jacobs Project Number CE777000

UTM Zone 10 North. NAD 1983.
Tunnel KP: Jacobs, 04-01-2021 ; Proposed Tunnel Route: (UPI) 10-24-2019; Existing Pipeline: FortisBC 2012; Proposed Squamish Compressor Station Siting Area: Jacobs 05-28-2020; NTS 250K Topo: NRCan 2012.

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.

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3.1.2 GEOLOGY

The regional surficial geology of the Squamish Valley features the gravel-bed of the Squamish River meandering within the Squamish Valley. Along its course, the river flows upon an intact (un-incised) valley-fill deposit extending from the Elaho-Squamish confluence to the Squamish Delta. In simpler terms, the depositional environment of the Squamish Valley suggests that these valley-fill deposits form a single unit from the confluence of the Elaho and Squamish Rivers to Howe Sound.

The valley-fill is contained by the steep bedrock sides of the Squamish Valley (Brooks 1994). The quaternary deposits in the region are reworked glacial sediments transferred and deposited as valley-fill deposits of the watershed (comprising five major tributary valleys of the watershed) (Friele and Clague 2002).

The Squamish Valley has been infilled with a mix of glaciofluvial, fluvial and possibly glacial sediments. Borehole records from the Site identify sand, silty sand, and cobbly sand and gravel (Piteau 2016). Sandy silt and clay layers confine deeper granular sediments in some areas of the valley, and woody debris has been identified in some boreholes (Piteau 1994). At the upper end of the valley, the deepest borehole reached 36.6 metres (m) (120 feet) and did not encounter bedrock. Based on the steep valley walls, sediments likely extend to much greater depths than the 36.6 m identified to date (Piteau 1994). Reports by Brown (1960-1965) identify a rotary test hole on the Squamish tidal flats encountering granitic bedrock at 202.7 m (665 feet). In 2019, four boreholes were advanced to depths ranging from 40.8 m to 50.6 m, with a single borehole advanced to 200.2 metres below ground surface (mbgs) (TetraTech 2019). Borehole logs confirm fine to coarse sand and gravel throughout the length of the boreholes with organics and wood pieces to depths of 27 m. The deepest of the boreholes, reaching 200.2 mbgs encountered silty and gravelly lenses with organic material throughout the 200 m column of unconsolidated sands and gravels.

The sand and gravel sediments that dominate the Squamish Valley floor form a very productive unconfined aquifer. The presence of the fine-grained sediments may confine some portions of the aquifer; however, with the exception of some localized areas where the fine sediments may be very thick and extensive, an unconfined aquifer is interpreted to be present beneath the entire Squamish Valley (Piteau 1994).

The local geology of the Site is that of alluvial floodplain silts, sands and gravels of indeterminate depth (Piteau 2016). Most of the Site has been filled, resulting in the upper 3.0 m of material on-site being fill (sand, gravel, silt and wood debris), underlain by up to 2.0 m of discontinuous silt interbedded with fine sand. These materials are underlain by a continuous sand or sand and gravel, to the maximum depth drilled on-site (200.2 m).

3.2 HYDRAULIC ASSESSMENT

The Squamish River network presents a trellis drainage pattern, with the general alignment reflecting bedrock structure joints and faults within the Coast Plutonic Complex (Holland 1964). Five major tributary valleys are occupied by the Ashlu, Cheakamus, Elaho, Mamquam, and the Upper Squamish rivers. Given the depositional nature of these river valleys (discussed in subsection 3.1), it is likely that they are hydraulically connected. Quaternary rocks of the Garibaldi Volcanic Belt extend discontinuously across the drainage basin in a north-northwest direction from the head of Howe Sound (Green et. al. 1988), resulting in the single confined aquifer of the sequence, Aquifer No. 397 (refer to subsection 3.3).

Due to the relatively steep topography of the river valleys (controlled by steep mountain topography and relatively fast flowing rivers) and the large basin that contributes surface water to the river(s), the water levels in the Squamish River can drastically rise and drop over short periods of time. Typical flow in the Squamish River ranges between 100 and 500 cubic metres per second (m^3/s), depending on the season. During the large flood of 2003, the river peaked at 3,140 m^3/s, and was the largest recorded flood in more than 100 years. Average high-water events range from 1,200 to 1,600 m^3/s, which translates to approximately a 6 to 7 m change in water level.

Jacobs Consultancy Canada Inc. (Jacobs) prepared a Hydrological Report as part of a short-term use approval application to withdraw water from the Squamish River for the EGP Project (BC OGC File No: 100111735, Document No. P-00763-ENV-REP-1001). In that report, the estimated mean annual discharge (MAD) for the Squamish River (based on the mean monthly flows measured at the WSC Station 08GA022) was calculated to be 238 m^3/s (2.0×10^7 cubic metres per day [m^3/d]). Mean monthly flows ranged from a low of 88 m^3/s to a high of 482 m^3/s in February and July, respectively. The reference measuring point (WSC Station 08GA022) is located upstream of the Site, and upgradient of the confluences of both the Cheakamus and Mamquam Rivers with the Squamish River; meaning that the volume of the Squamish River at the Site is considerably greater than the 238 m^3/s MAD calculated from the mean monthly flows reported at WSC Station 08GA022.

3.3 HYDROGEOLOGICAL ASSESSMENT

The primary source of potable water to the District of Squamish is from a well field (consisting of seven groundwater production wells) at Powerhouse Springs, drawn from the Ring Creek Aquifer (Aquifer Nos. 397 and 398). These aquifers are reportedly recharged by infiltration from Ring Creek and Skookum Creek. Surface water from Mashiter Creek and Stawamus River provide emergency back up water supply to the District of Squamish. The well field is located approximately 5 km east of the Site.

In 1994, the BC Government began a map-based Aquifer Classification system to map and register aquifers, supporting groundwater management in the Province. Because the Aquifer Classification system is intended to manage use of the groundwater resource, the system has focused on classifying aquifers near regions of dense population. It is therefore understood that this classification system does not identify or classify all aquifers present in the Province, rather focusing on the aquifers present in developed or populated areas.

It is important to identify that north of the District of Squamish, the transportation corridor (and the associated population) follows Highway 99 up the eastern arm of the Squamish Valley (following the Cheakamus River). The result is that the potential aquifer extends up the western arm of the Squamish Valley (following the Squamish, Elaho, and Ashlu Rivers) has not been classified.

Figure 4 presents the locations of the six documented aquifers in the Squamish region: Aquifer Nos. 396 through 401. As shown on Figure 4, the six classified aquifers form a contiguous water-bearing unit that discharges to Howe Sound.

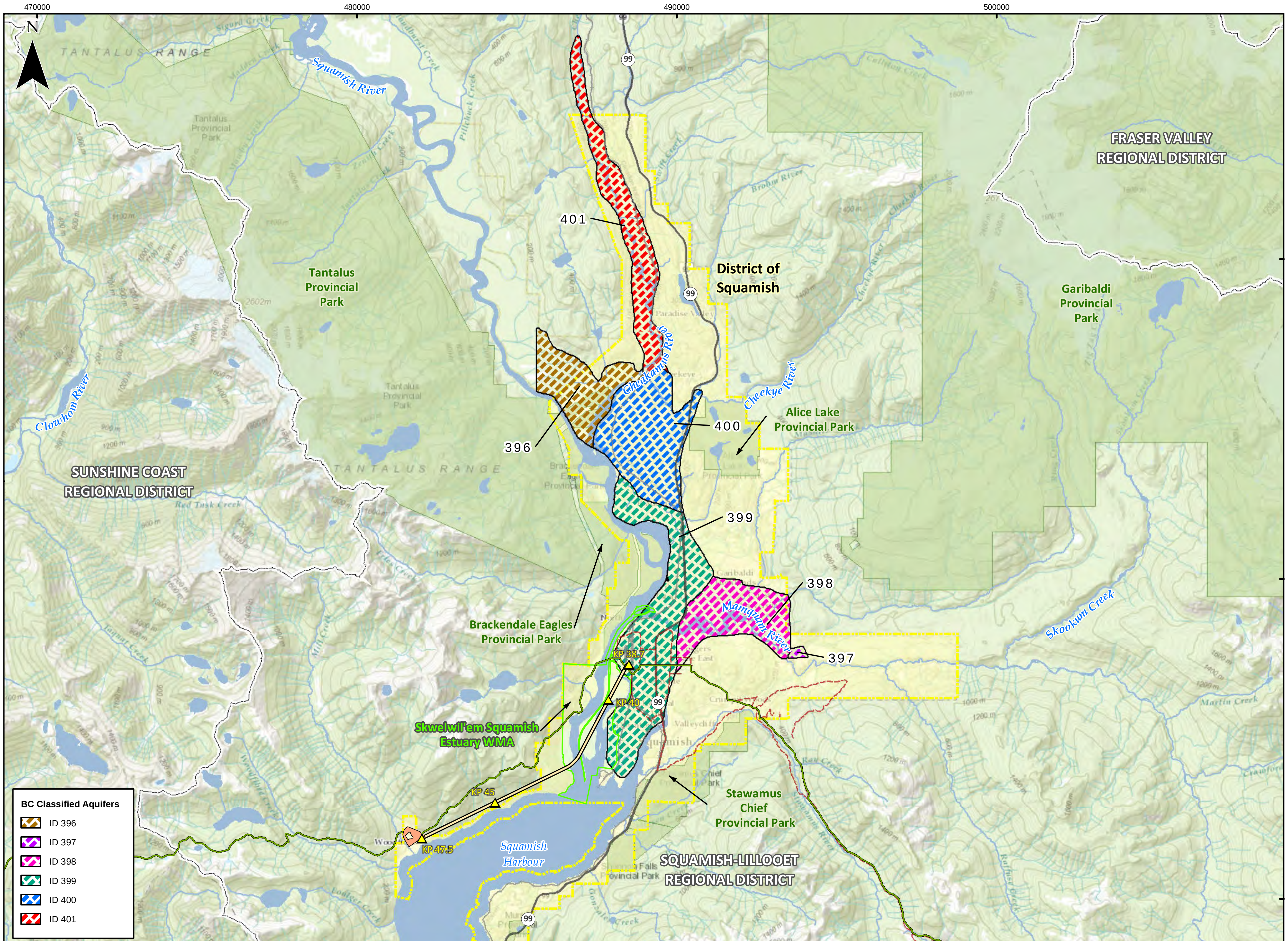

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FIGURE 4

BC CLASSIFIED AQUIFERS IN THE SQUAMISH REGION

EAGLE MOUNTAIN-WOODFIBRE GAS PIPELINE PROJECT WATER MANAGEMENT PLAN - EGP TUNNEL EAST SHAFT DEWATERING

- Kilometre Post (KP)
- Proposed Tunnel Route
- Proposed Squamish Compressor Station Siting Area
- Existing FortisBC Pipeline
- Access Road
- Highway
- Railway
- Watercourse
- Waterbody
- Regional District
- Municipality
- Park and Protected
- Wildlife Management Unit

SCALE: 1:115,000

0 1 2 3 4 5 km

(All Locations Approximate)

Jacobs

Jacobs Project Number CE777000

UTM Zone 10 North. NAD 1983.
Tunnel KP: Jacobs, 04-01-2021 ; Proposed Tunnel Route: (UPI) 10-24-2019; Existing Pipeline: FortisBC 2012; Proposed Squamish Compressor Station Siting Area: Jacobs 05-28-2020; Roads: NRCan 2014; Railways: BCGov 2019; Hydrography: NRCan. 2009 and BC MFLNRO 2008; Municipal Boundaries, Regional Districts: BC MFLNRO 2017; Parks, Wildlife Management Areas: BC MFLNRO 2008; Aquifer: Ministry of Environment and Climate Change Strategy, Jan 2020 Base Map Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, 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.

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Table 1 provides additional details about the six classified aquifers in the region.

Table 1. Summary of Aquifer Characteristics

Characteristic	Aquifer No. 396	Aquifer No. 398	Aquifer No. 399	Aquifer No. 401	Aquifer No. 400	Aquifer No. 397
Location	Cheekye Fan	Mamquam Valley	Squamish River, Squamish to Brackendale	22 km north along the Cheakamus River	At the confluence of Squamish and Cheakamus Rivers	Powerhouse Springs Mamquam northeast of Squamish
Size (km^2)	5.1	6.0	12.0	6.4	8.7	0.2
Productivity	High	High	High	High	Moderate	High
Vulnerability	High				Moderate	
Subtype	Unconfined sand and gravel aquifer – medium stream system				Unconfined sand and gravel – alluvial or colluvial fan	Confined sand and gravel – glacial

The Site is located in Aquifer No. 399. Of the six aquifers identified in the region, five (including Aquifer No. 399) are described as unconfined sand and gravel aquifers, with high to moderate productivity, and no concerns regarding water quality. Given their proximity and the depositional environment of the region, there is some degree of hydraulic connection between aquifers as water flows from one aquifer into the downstream aquifer, as the valley basin discharges to Howe Sound. Additional details on these six classified aquifers are provided in Appendix A.

The total area of these six aquifers (38.4 km^2) accounts approximately 1 percent of the total area of the Squamish Basin (3,300 km^2). The volume of water (both surface and groundwater) moving from these mountains through both rivers and valley-based aquifers is another indicator that other aquifer zones are present further up the valley and are hydraulically connected. Only one of the six aquifers (Aquifer No. 396, the northern-most aquifer) has publicly available information regarding a licence for annual withdrawal (3,543 cubic metres per year).

The location of Aquifer No. 399 is defined in the classification system as being bounded to the north by the Cheekye Fan (Aquifer No. 396), to the west by the Squamish River and to the south by Squamish Harbour (Howe Sound). The eastern boundary of the aquifer is defined by geology, borehole records, and information from Buchanan (1985 and 1991) and Piteau (1994 and 1995); however, Figure 4 shows that Aquifer No. 398 bounds Aquifer No. 399 to the east.

The depth to the water table within Aquifer No. 399 ranges from 1.22 to 13.4 mbgs (BC Aquifer Mapping Report for Aquifer No. 399). The primary groundwater flow is identified to be downgradient, following the topography of the Squamish Valley. According to the BC Aquifer Mapping Report for Aquifer No. 399, recharge of the aquifer is likely from surface infiltration over the upland area to the north (including upland areas including Aquifers Nos. 396, 400, and 401) and east as well as directly onto Aquifer No. 399. Given the area of the capture basin for the Squamish River, recharge from the upland areas likely constitutes a substantial component of recharge.

Reports by Brown (1960-1965) concerning a 202.7 m (665 feet) deep rotary test hole on the Squamish River tidal flats (where Aquifer No. 399 discharges, as shown on Figure 4) state that, from the electro-log and driller report, all aquifers penetrated to the final depth were brackish. The low gradient of the Squamish Valley, combined with the presence of organic content in the sediments, result in a poorly flushed aquifer with reducing conditions. Elevated iron concentrations are common in this type of hydrogeological environment (Piteau 1994).

According to Piteau 2016, the water table at the Site is present in the fill or silt layers. The sand and gravel below the fill and silt layers is also saturated and hosts a productive aquifer that follows the Squamish Valley. Aquifer No. 399 extends from Squamish to Brackendale, but based on the regional geology, and the contiguous nature of the Classified Aquifers (Aquifer Nos. 396, 400, and 401) hydraulic connection to other water-bearing units (aquifers) likely extends further up the valleys of all five of the rivers that make up the drainage basin that contributes water to the Squamish River.

Near surface sediments are recharged by infiltrating precipitation. The groundwater flow direction in the upper unit (fill and silt materials) had no overall consistency in horizontal flow direction (Piteau 2016). Lower sands and gravels (Aquifer No. 399) are recharged in part by infiltration from the upper fill aquifer, but given the large recharge area upgradient of the Site, lateral flows from upgradient within the aquifer (and other aquifers upgradient of Aquifer No. 399) likely provides the greatest proportion of recharge to the aquifer on-site.

Nested well pairs located on-site installed in 2020 confirm this hypothesis, identifying a vertical upwards gradient between wells screened at depths of 15 mbgs and 6 mbgs. This upward gradient in Aquifer No. 399 results from the large catchment basin in the upper reaches of the Squamish Valley.

Hydraulic conductivity has been evaluated at the Site by completing two small-scale pumping tests (completed using submersible pumps in the available 2-inch monitoring wells, resulting in pumping rates of 14 litres per minute (L/min) from the wells), and by completing single well rising and falling head slug tests. It is important to note that the hydraulic conductivity (K) values calculated using these methods provide hydraulic conductivity information that is limited to small areas surrounding the two-inch monitoring wells, and do not characterize the wider hydraulic conductivity of the aquifer. It is helpful to note that hydraulic conductivity tests to date have all resulted in comparable high hydraulic conductivities, meaning that water flows easily through the geologic materials of Aquifer No. 399. Hydraulic conductivities calculated from data collected during field tests are presented in Table 2.

Table 2. Summary of Hydraulic Conductivities Calculated in Aquifer Materials On-Site

Type of Test	Unit Screened	Minimum K value (m/s)	Maximum K value (m/s)	Geometric Mean (m/s)
Slug Tests	Upper fills, silt, and sands	2×10^{-6}	1×10^{-4}	1×10^{-5}
Slug Tests	Sand and Gravel (Aquifer No. 399)	3×10^{-4}	5×10^{-3}	2×10^{-3}
Small-Scale Pumping Test	Sand and Gravel (Aquifer No. 399)	2.6×10^{-4}	$1.3 \times 10^{-3+}$	Insufficient data

m/s = metre(s) per second

Groundwater flow at the Site is generally to the southwest, sub-parallel to the Squamish River (Piteau 2016), resulting in a limited volume of groundwater discharging from the aquifer to the river. In the area where the East Shaft will be advanced, the horizontal hydraulic gradient is calculated to range from 0.1 and 0.2 percent to the southwest. Linear groundwater velocity (ʋ), as calculated by Piteau in 2016 is estimated to range from 0.2 to 0.4 metres per day (m/d).

The volumetric flux (Q) of an aquifer is calculated by:

$$Q = \upsilon A$$

Where:

A = the cross-sectional area of the aquifer (A) (perpendicular to flow), and
υ = the linear velocity of groundwater

The Site is located on the western edge of Aquifer No. 399, immediately north of where the aquifer narrows (due to the presence of a wetland west of the aquifer). The width of Aquifer No. 399, perpendicular to groundwater flow is approximately 1,200 m (as measured from the Aquifer Factsheet for Aquifer No. 399). Given the geological evaluation completed in subsection 3.1, and for the purposes of this calculation, the depth of the aquifer is assumed to be 30 m (a conservative assumption since the aquifer is likely more than 30 m deep). The depositional environment of the fjord suggests that the cross-sectional area of the aquifer is best approximated by a triangle shape, resulting in the cross-sectional area of Aquifer No. 399 to be 18,000 square metres (m^2), immediately downgradient of the Site.

Using the values presented to calculate the volumetric flux within Aquifer No. 399 just downgradient of the Site:

- Cross-sectional area of Aquifer No. 399 = 18,000 m^2
- Calculated flow rates (υ) at Site ranging from 0.2 m/d to 0.4 m/d
- The Volumetric flux (Q) of Aquifer No. 399 in the vicinity of the Site range from a:
  - minimum of 3,600 m^3/d (0.04167 m^3/s), to a
  - maximum of 7,200 m^3/d (0.08333 m^3/s)

3.4 CONCEPTUAL SITE MODEL

Based on the physical setting details (topography, geology), the Hydraulic Assessment of the Squamish Valley, and the Hydrogeological Assessment of the Site and the Squamish Valley, Figure 5 presents a visual CSM of groundwater and surface water flow for the region as it relates to these same flows at the Site.

The main source of the Squamish River is snow and glacial melt from the Pemberton Glacier. The catchment basin for the Squamish River (and its tributaries) includes an area of approximately 3,300 km^2. Precipitation from this area discharges to Howe Sound via surface water flow from the rivers and through the hydraulically connected aquifers, including the six documented aquifers in the region, with varying degrees of hydraulic connection between them and other, non-classified aquifers in areas both less developed and with less population.

The Site acts as a regional groundwater discharge area. Horizontal hydraulic gradients mapped by Piteau (2016) and Jacobs (2021) range from 0.00015 to 0.002 metres per metre (m/m), mimicking topography and sloping both towards the Squamish River and Howe Sound. Lateral groundwater flow is directed west/southwest across most of the Site and to the southwest at the southern part of the Site (near the East Shaft location), linear flow velocities are calculated to be between 0.2 to 0.4 metres per year. Based on Site data, groundwater flow through Aquifer No. 399 is estimated to range from 3,600 and 7,200 m^3/d, depending upon the season.

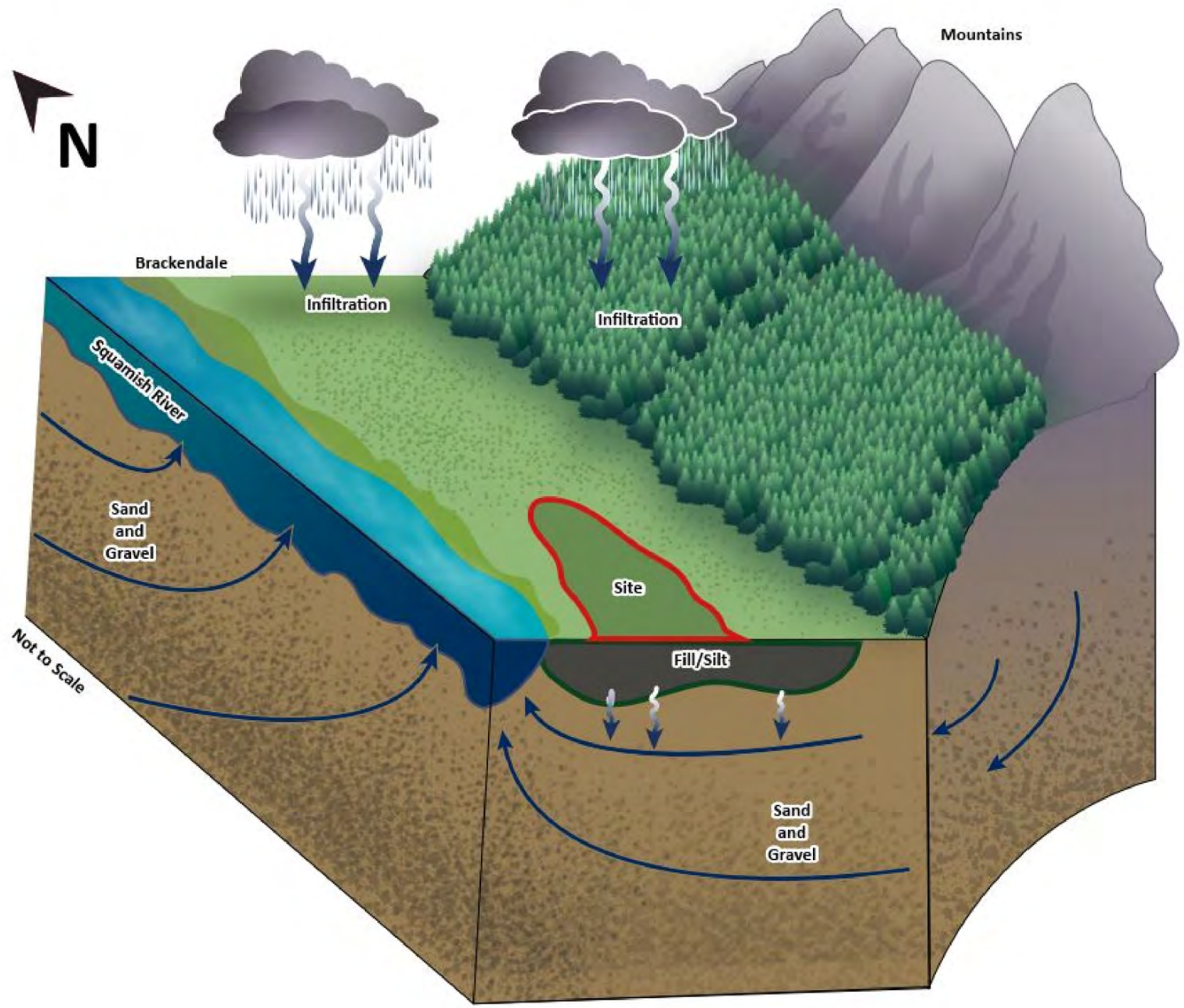
Vertical hydraulic gradients are approximately 0.01 to 0.06 m/m directed upward. Upward groundwater flow was inferred from historic water level records from closely spaced monitoring wells completed with 1.5 to 3 m long screens within 1 to 16 m depths, and vibrating wire piezometer records (Piteau 2016; Tetra Tech 2019; Jacobs 2021). The vertical gradients discharge to surface water in the area where the upward gradients intersect the narrow base of the river bottom, creating a limited discharge area, so while Aquifer No. 399 does contribute to the baseflow of the Squamish River, that contribution is limited in both volume and the overall percentage of contribution.

Table 3. Comparing Measured and Calculated Flow Rates

Location		Flow Rate (m^3/d)	Flow Rate (m^3/s)	Percentage of Flow in Squamish River (%)
Measured Flow in Squamish River at WSC Station 08GA022		20.5 Million	238	100
Aquifer No. 399	Estimated Minimum Flow	3,600	0.04	0.017
	Estimated Maximum Flow	7,200	0.08	0.035

To add clarity, the annual mean flow in the Squamish River (approximately 26 km upstream of the Site and without contribution from both the Cheakamus and Mamquam Rivers) is 238 m^3/s, which is approximately three to four orders of magnitude greater than the volume of groundwater flowing past the Site in Aquifer No. 399.

Based on this information, of the 3,600 to 7,200 m^3/d of water flowing in Aquifer No. 399 near the Site, it contributes less than one hundredth of a percent of the total volume flowing in the Squamish River. Based on these data, the water levels and water quality of the Squamish River are not anticipated to be unduly influenced by groundwater dewatering activities within Aquifer No. 399. Information on anticipated dewatering volumes is included in Section 6.



June 2021

FIGURE 5

CONCEPTUAL SITE MODEL OF SURFACE WATER AND GROUNDWATER INTERACTION

EAGLE MOUNTAIN-WOODFIBRE GAS PIPELINE PROJECT WATER MANAGEMENT PLAN - EGP TUNNEL EAST SHAFT DEWATERING

Jacobs Project Number CE777000

UTM Zone 10 North. NAD 1983.
Proposed Pipeline Route, KP: Universal Pegasus International (UPI) 10-28-2020 (Route 1023c); Existing Pipeline: FortisBC 2012; Proposed Squamish Compressor Station Siting Area: Jacobs 05-28-2020; Roads: NRCan 2014; Railways: BCGov 2019; Hydrography: NRCan. 2009 and BC MFLNRO 2008; Municipal Boundaries, Regional Districts: BC MFLNRO 2017; Parks, Wildlife Management Areas: BC MFLNRO 2008; Coquitlam Conservation Reserve: Metro Vancouver 07-02-2017, Morgan Stewart and Company, 1995 provided by Fortis BC 2019 (modified by Jacobs 05-12-2020); .

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.

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4. EAST SHAFT CONSTRUCTION

As described in Section 2, it is anticipated that the DB Contractors will modify the shaft structure included in the Reference Design and propose a decline or ramp structure. The ramp excavation will slope upwards to the northeast where it meets existing ground level. Gasketed steel sheet or secant piles, or both, will be used for sidewall support along the length of the excavation. Both of these methods provide control of groundwater inflows and, with quality installation practices, will result in minimal inflow across these boundaries.

In terms of construction sequencing, it is anticipated that the sheet piles and/or secant piles will first be drilled or vibrated into place to form the perimeter of the excavation. After installation of the vertical support of excavation, soil replacement or other ground improvement techniques (such as, jet grouting) will be used along the base of the excavation below the groundwater table. This will confirm stability during excavation and minimize the amount of water ingress and floor heave. The shaft will be excavated in the dry to the target depth using an excavator and/or crane with clamshell attachment.

Some dewatering may be required to complete the excavation in this method, though water ingress will be limited due to the watertight nature of the walls and floor of the excavation. Sump pumps will be used during excavation, should localized dewatering be required, to facilitate the work and for use during operations of the East Shaft. Collected water will be routed to the water treatment plant prior to discharge (see subsection 6.2 Water Quality). Once the excavation is complete, a concrete base slab will be cast to seal the base of excavation, create a structural platform for tunnel boring machine (TBM) mobilization and prevent basal heave (uplift) for the duration of construction.

An alternative approach to ground improvement along the base of the excavation would be to maintain equilibrium between the water level in the excavation and the surrounding natural conditions (water table at approximately 3.0 mbgs) and excavate the ground “in the wet”. By maintaining the water head in the excavation, limited water flow through the base of the excavation would be anticipated. In this approach, a base slab would be poured in the wet using tremie pipes to deliver the concrete to the base of the excavation. Once cured, the structure would be dewatered with minimal ingress through the support of excavation.

The DB Contractors are also considering sloped excavation walls for the shallowest section of the decline. These slopes would be protected by a geomembrane and are not anticipated to impact the groundwater regime as they would lay above the water table.

The final construction schedule will be determined by the DB Contractor. Based on the current understanding of the DB Contractors’ East Shaft construction approaches, the anticipated construction durations are as follows.

Table 4. East Shaft Construction Timelines

Component	Duration (Months)
Steel Sheet Pile and/or Secant Pile Wall Installation	2.5
Excavation Floor Ground Improvement	1.5
Excavate East Shaft Decline	1
Cast Concrete Base Slab	1
Total	**6**

East Shaft will be open and require dewatering (to remove precipitation as well as groundwater ingress) for approximately 30 months of EGP Tunnel construction. After completion of tunnelling works and pipeline installation, the shaft will be backfilled with clean earth material.

Figure 6. Plan View of Decline Structure for TBM Launch and Pipeline Installation; Humber River, United Kingdom

Figure 7. TBM Launch in Decline Structure with Steel Sheet Pile Walls, Steel Strut Support and Concrete Base Slab; Narrows Crossing, Australia

5. HYDRAULIC CONNECTION BETWEEN GROUNDWATER AND SURFACE WATER

The source of the Squamish River is glacial melt from the Pemberton Glacier, combined with contribution from infiltration of precipitation on the catchment basin and its tributaries, an approximate area of 3,300 km^2. The background for this statement is presented in the topography, geology, hydrogeology and surface hydrology information included in subsections 3.1, 3.2, and 3.3, and culminates in the CSM of groundwater and surface water flow in both the region and at the Site presented in subsection 3.4.

Calculations indicate that groundwater flow through Aquifer No. 399 ranges from 3,600 to 7,200 m^3/d, and hydraulic gradients indicate both a vertically upwards component, and a westward horizontal component at the Site.

The mean annual flow in the Squamish River is conservatively estimated to be 238 m^3/s, (considered conservative because that volume does not include the contributions from both the Cheakamus and Mamquam Rivers). This flow (238 m^3/s) is estimated to be three and four orders of magnitude greater than the volume flowing in Aquifer No. 399.

Groundwater flow directions were described as sub-parallel to the Squamish River in the description of Aquifer No. 399 provided in Piteau 1994. Assuming that some of this water discharges to the Squamish River, and some discharges to Howe Sound, a conservative assumption would be 50 percent of the volume flowing in the aquifer discharges directly to the Squamish River within 500 m of the Site. This assumption is conservative because Piteau 1994 identifies that groundwater flow in Aquifer No. 399 is sub-parallel to the Squamish River, meaning that only a portion of the aquifer discharges to the Squamish River.

Using the conservative assumptions presented above, Aquifer No. 399 contributes a volume that is less than 0.01 percent of the total volume of the Squamish River. Based on this result, while there is a hydraulic connection between Aquifer No. 399 and the Squamish River, the proportion of the total river volume that Aquifer No. 399 contributes to the Squamish River is limited. Given the low contribution of Aquifer No. 399 to the total flow of the Squamish River, it can be extrapolated that there will be a negligible effect on the volume or quality of the surface water as well as limited impacts to fish and wildlife from dewatering activities.

6. WATER QUANTITY AND QUALITY

The hydraulic conductivities calculated from the small-scale pumping test align with the hydraulic conductivities calculated using the slug tests, reported by Piteau 2016 and Jacobs 2021. Hydraulic conductivities in the sand and gravels below the water table range from a low value of 2.6 x 10-4 m/s, to a maximum value of 1.3 x 10-3 m/s. These hydraulic conductivities are consistent with grain size distributions observed in the boreholes.

In conversations with the BC OGC regarding the Water Licence Application, FortisBC was instructed to provide a worst-case estimate for dewatering rates during all phases of construction. With additional construction details, the worst-case consideration could then be refined, and reduced.

It is anticipated that during construction, there would be four phases relating to dewatering. The phases and anticipated durations would include the following:

1) Mobilization and Site preparation, 3 months duration
2) East Shaft construction of the support of excavation, 6 months duration
3) Construction of the Soft Ground Tunnel, 24 months duration
4) Backfilling and demobilization, 3 months duration

The phases of construction and durations presented above are based on estimates from projects of similar scope and are subject to change. The final construction schedule will be developed by the DB Contractor and will be shared with relevant stakeholder and Indigenous nations.

Anticipated dewatering rates for each phase of construction are included in Table 5. Of the four phases of construction, groundwater dewatering rates are anticipated to be the greatest during the construction of the support of excavation, which is anticipated to last 6 months. Once Soft Ground Tunnel construction begins, dewatering volumes are anticipated to reduce substantially.

Dewatering volumes will be monitored by the DB Contractor and verified by FortisBC. Should dewatering volumes approach the estimated volumes included in Table 5, the DB Contractor will be required to modify their groundwater diversion activities to reduce dewatering volumes.

6.1 WATER QUANTITY

For the proposed excavations, the groundwater inflow rates will be dependent on how the excavation shoring is designed and installed. From a theoretical perspective, groundwater inflow rates would be low as the excavation will have sealed sheet piles, secant pile walls, and a jet grout and concrete pad base. These materials theoretically have very low hydraulic conductivity values. As such, the theoretical groundwater inflow rate would be low.

It is anticipated that groundwater will enter the excavation through discontinuities in the excavation shoring, for instance, at locations where the concrete pours are segregated, where tiebacks for secant pile anchors pierce the wall, construction joints between the elements, or where a sheet pile becomes bent during installation. Consequently, a practical perspective has been applied to estimate groundwater inflow using inflow rates from similar projects in the context of the Site location described as follows.

The groundwater inflow rates from recent local projects, including the Second Narrows Water Supply Tunnel (North Vancouver, BC) and the Annacis Island Wastewater Treatment Plant Outfall System (New Westminster, BC), have been used to develop a practical estimate of the likely range of groundwater inflow. The measured inflow rates for these projects range from approximately 10 to 100 m^3/d. These values are broadly in line with published case studies. Given this information, a value of 200 m^3/d is recommended to be an appropriate groundwater inflow rate during East Shaft construction for the following reasons:

- There remains flexibility associated with the Contractor's final design and selection of construction methods;
- The coarse grained soils at the project site may make some construction tasks more challenging; and
- A higher value provides short-term flexibility to seal discontinuities in the excavation.

Estimated quantities of dewatering for the construction and operation of the East Shaft are included in Table 5.

Table 5. East Shaft Dewatering Water Quantities

Construction Phase	Estimated Rate		Duration (months)	Description
	L/min	m^3/d		
East Shaft Construction: • Steel Sheet Pile and/or Secant Pile Wall Installation • Excavation Floor Ground Improvement • Excavate East Shaft Decline • Cast Concrete Base Slab	140	200	6	• East Shaft under construction: Reflects leakage of groundwater into the East Shaft through joints in the support of excavation and excavation floor/base slab.
Tunnelling	70	100	24	• East Shaft operations: Reflects leakage of groundwater into the East Shaft through joints in the completed support of excavation and poured concrete floor and following the sealing of more significant leaks. Note, minimal to no inflows are anticipated from the Soft Ground Tunnel itself based on the presence of gasketed, pre-cast concrete liner.
Note: All rates and durations are approximate				

Groundwater dewatering rates during the mobilization and Site preparation and backfilling and demobilization phases are anticipated to be negligible.

6.2 WATER QUALITY

FortisBC has collected groundwater samples quarterly (since December 2020) from groundwater monitoring wells installed at the Site. Groundwater analytical data are presented in Tables 1 and 2 of Appendix B, and show analytical results of organic and inorganic analyses from groundwater samples collected from 14 monitoring wells in December 2020 and March 2021. For the purposes of this report, the data are compared to the BC Water Quality Guidelines (BC WQGs) for Short-Term Acute and Long-Term Chronic exposure.

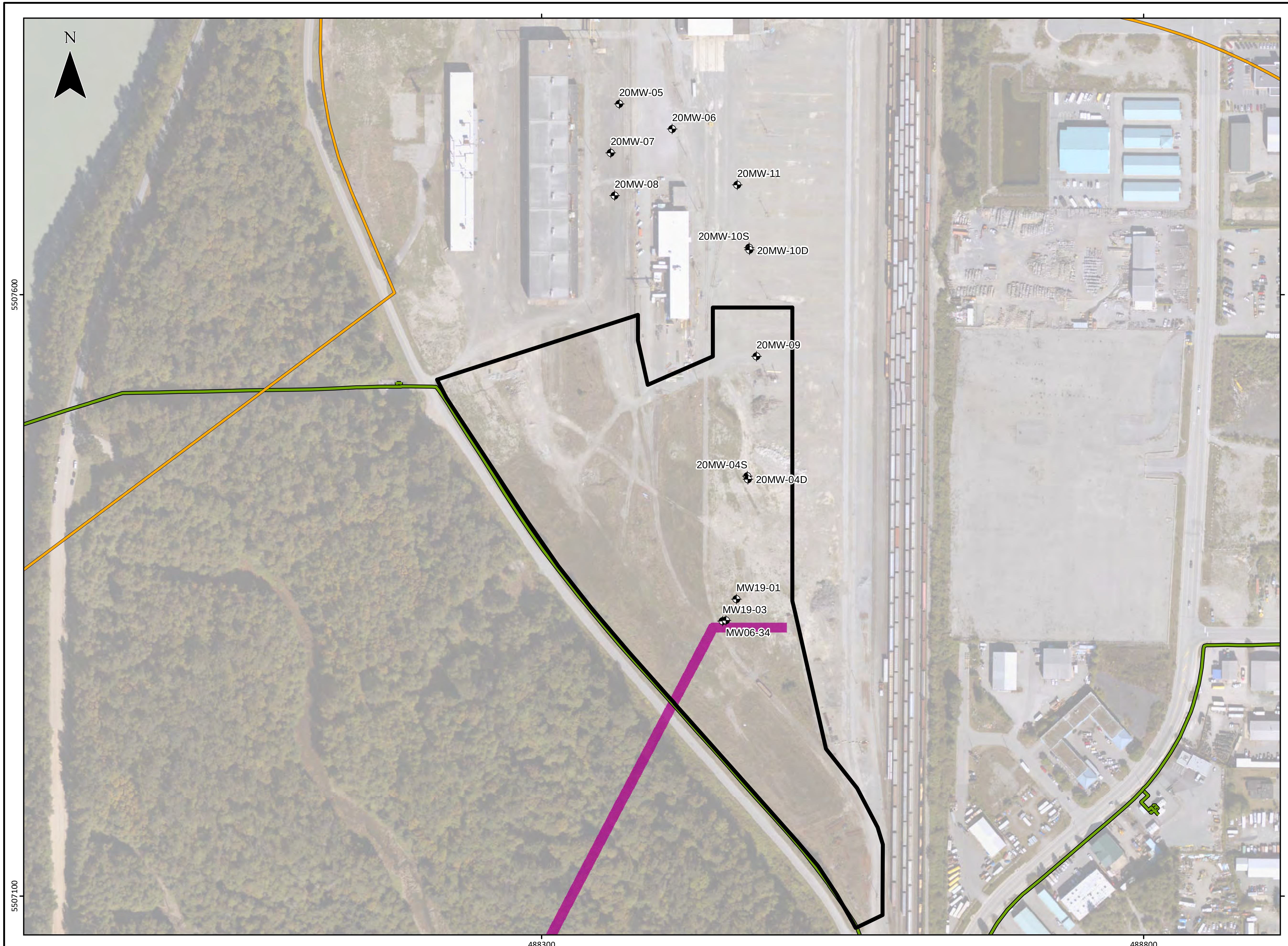
Table 1 in Appendix B presents the groundwater results for organic compounds and compares the results to the BC WQGs. In summary, of the 14 wells sampled:

- Two wells contained concentrations of organic parameters at concentrations in excess of the BC WQGs for Freshwater Aquatic life:
  - the December sample from monitoring well 20MW-04D contained a measurable concentration of chloroform
  - the March quarterly sample from that same well, chloroform concentrations were not measurable
- The second well contained concentrations of organic compounds in excess of the BC WQGs in both sampling events (December and March) was MW06-34. Groundwater from that well contained ethylbenzene, toluene and select polycyclic aromatic hydrocarbon compounds at concentrations in excess of the BC WQGs for freshwater aquatic life
- Laboratory analyses from the remaining 12 wells did not contain measurable concentrations of organic compounds

Table 2 in Appendix B presents the groundwater results for inorganic compounds (metals), and similarly, compares the results against the BC WQGs or Freshwater Aquatic life. The same 14 wells were analyzed for dissolved metals. All wells except 20MW-04D contained iron at a concentration exceeding either short-term or long-term exposure. Additionally, other metals present at concentrations exceeding one, or both short-term or long-term exposure for BC WQGs include arsenic, copper, lead, manganese, selenium, and zinc.

Arsenic exceedances are only present in groundwater from MW06-34. Copper is present exceeding BC WQGs in groundwater from 20MW-04S and D, 20MW-07 through 20MW-11 (including both the shallow and deep wells at 20MW-10), MW19-01, and MW19-03. Manganese concentrations exceeded the guidelines in water from 20MW-04D, 20MW-5, 20MW-8, through 10, including the shallow/deep pair at 20MW-10. A single selenium exceedance was noted on one occasion in MW06-34. Zinc concentrations exceeded BC WQGs in two wells; the shallow deep pair of 20MW-10.

The location of the monitoring wells installed at the Site is included on Figure 8.



FORTIS BC

June 2021

FIGURE 8

INVESTIGATION LOCATIONS

EAGLE MOUNTAIN-WOODFIBRE GAS PIPELINE PROJECT WATER MANAGEMENT PLAN - EGP TUNNEL EAST SHAFT DEWATERING

- Monitoring Well
- Existing NPS 10 FortisBC Pipeline
- BC Rail Site Lease Area
- Proposed OGAA Application Corridor
- Tunnel Easement and Workspace

SCALE: 1:3,000

0 60 120 m

(All Locations Approximate)

JACOBS

JACOBS Project Number CE777000

UTM Zone 10 North. NAD 1983. Proposed Pipeline Route: Universal Pegasus International (UPI) 10-28-2020 (Route 1023c/4001c); Pipeline Application Corridor: Jacobs 8-30-2019 (Revision 15); Existing Pipeline: FortisBC 2012;Tunnel Easement and Workspace: Jacobs, 2020; Monitoring Well: McMillen Jacobs Associates 2020, Tetra Tech 2019, Piteau Associates, Nov 2014; Base Imagery: Atlantic Group 2013; .

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

\\JACOBS.COM\COMMON\SHARES\CNR\GIS_PROJ3\CE734000_FORTIS_EGP\GIS_PRODUCTS\2021\RECLAMATION\WATERMGMTPLAN\EGP_WATERMGMTPLAN_FIG8_INVESTIGATIONLOC.MXD SLAW3 5/27/2021 3:02:50 PM

7. ENVIRONMENTAL FLOW NEEDS ASSESSMENT

While there is a hydraulic connection between Aquifer No. 399 and the Squamish River, the data evaluation completed in subsection 3.4 and Section 5 identify that the aquifer contributes less than 0.01 percent to the flow in the Squamish River at the Site. Based on this result, a reduction in the volume of water discharging to the Squamish River because of construction activities on the Site will not affect water quality or quantity in the Squamish River. As such, dewatering activities at the Site would not cause adverse effects to hydraulically connected streams.

8. WATER MANAGEMENT ACTIVITIES

FortisBC submitted a Waste Discharge Authorization under the *Environmental Management Act* under permit PE 110163 (Application Number 388398) to the BC OGC on December 7, 2020. The water discharge associated with East Shaft construction has been included in the Waste Discharge Authorization submitted to the BC OGC under PE 110163. The following subsections detail the plans for water storage, treatment, and discharge.

8.1 WATER TREATMENT

Water treatment at the Site is expected to consist of sedimentation/storage ponds, flocculant addition, filtration, and oil water separation at a minimum. Depending on the actual quality of the water, additional treatment in the form of specialized equipment can be added in line.

As part of the RFP package for the EGP Tunnel, the following performance specifications have been developed for the management of water quality:

- Section 02 71 00 – Water Treatment and Disposal
- Section 31 23 19 – Groundwater Management

The Water Treatment and Disposal specification includes minimum requirements for collecting, handling, treating, sampling, testing, and disposing of groundwater and stormwater encountered in accordance with applicable regulatory requirements.

The DB Contractor is required to submit a Water Treatment Plan for collecting, handling, treating, measuring, and disposing of groundwater and other wastewater generated from construction activities. The Water Treatment Plan will include drawings and designs, treatment goals, and detailed process descriptions with a corresponding flowchart. All treatment measures to be implemented will be required to satisfy the applicable approved BC WQGs for discharge of treated water to the environment. The Water Treatment Plan will include details on the means and methods of treatment, frequencies of monitoring water quality to check compliance with regulatory requirements prior to discharge, a water quality monitoring program, and contingency plans.

The Groundwater Management Specification includes requirements for designing, documenting, and furnishing all labour, materials, tools, equipment, and incidentals for installation, maintenance, operation, and removal of temporary dewatering systems and water handling systems associated with controlling water infiltration during construction activities. The DB Contractor will be required to prepare a Groundwater Management Work Plan for each dewatering system.

Any potential water discharge from the EGP Tunnel will be managed in accordance with applicable regulatory requirements and Best Management Practices. Prior to initial discharge, the water will be sampled, tested, and treated to verify that it meets approved BC WQGs and BC OGC criteria.

8.2 WATER STORAGE

Wastewater storage at the Site will consist of above ground storage tanks and/or ponds. The tanks and/or ponds will serve as storage buffering capacity for the water treatment facility to ensure a consistent rate of flow thru the treatment plant and to discharge. The final capacity and footprint of these tanks will be selected by the DB

Contractor based on anticipated wastewater generation rates from the following sources precipitation entering excavation, water ingress, tunnelling wastewater, and tunnel spoil dewatering amongst others.

8.3 WATER SAMPLING AND ANALYSIS

Water quality sampling (lab samples and field samples) will be conducted prior to discharge to ensure effective treatment of the water and compliance with the Waste Discharge Authorization. Water quality monitoring (field samples and visual observations) will be conducted prior to discharge, throughout discharge and post discharge. All water quality sampling will be conducted according to the BC Field Sampling Manual.

A Sampling and Analysis Plan has been developed by a QEP and includes testing parameters and sampling frequency for the proposed points of discharge at the Site. The Sampling and Analysis Plan is included in the Waste Discharge Authorization application and has been included in the Water Treatment and Disposal specification as part of the RFP.

8.4 WATER DISCHARGE

FortisBC is conducting feasibility studies, engineering assessments, and biophysical surveys to evaluate three potential options for water discharge locations at the Site listed as follows and shown on Figure 9.

- Option 1: Discharge to the existing stormwater collection and transmission infrastructure at the north end of the Site.
- Option 2: Construct a new temporary discharge line within the existing FortisBC transmission pipeline right-of-way and discharge directly to the Squamish River.
- Option 3: Discharge to the existing stormwater collection and transmission infrastructure at the south end of the Site.

Biophysical surveys will be completed by a QEP to determine potential environmental impacts as well as mitigation measures for all discharge locations under consideration. Options 1 and 2 would involve discharge to the Squamish River within the Skwelwil'em Squamish Estuary Wildlife Management Area (WMA). The WMA was designated with the purpose of maintaining and restoring fish and wildlife habitat productivity (BC MOE 2007). Option 3 would involve water discharge to a wetland area located within the functional Squamish River Estuary but outside of the WMA. The results of a capacity assessment conducted by Urban Systems Ltd. based on the estimated flows produced for the duration of construction, indicate that this wetland currently receives considerable runoff from the Site via a storm sewer and culvert. The relative change in runoff volumes being proposed to the wetland from construction activities would be very small (less than 1 percent of the total runoff volume to the wetland for both 6-month and 2-year storm frequencies) (Urban 2021).

FortisBC will select the preferred discharge location based on a detailed evaluation of potential environmental impacts, infrastructure requirements, engineering effort, as well as consultation with key stakeholders and Indigenous nations. Options 1 and 2 were included as part of the Waste Discharge Authorization submitted to the BC OGC on December 7, 2020 (Application Number 388398). In the event Option 3 is selected as the preferred location, the application documentation will be revised.

Figure 9. Water Discharge Locations at the Site

9. WATER RIGHTS HOLDERS

Existing water licences and use approvals within and downgradient of Aquifer No. 399 were identified by conducting a search of BC Water Rights Databases using iMapBC (accessed May 2021). The search identified 18 water wells in Aquifer No. 399, and available well data are presented in Table 6.

Table 6. Summary of the Contents of the iMapBC Water Wells Database

Well Tag No.	Owner Name	Well Diameter (inches)	Finished Well Depth (feet)	Well Yield (gallons/min)	Licensed Status	Well Class
18707	P J Brennen	6.0	40.00	50	Unlicensed	Unknown
19479	The Corporation of The District of Squamish	12.0	100.00	300	Unlicensed	Domestic Water Supply
36753	Squamish Recreation	8.0	56.00	50	Unlicensed	Unknown
71328	S. M. SLOT	6	47.00	20	Unlicensed	Domestic Water Supply
71326	Erving Reid	6	53.00	10	Unlicensed	Domestic Water Supply
77806	Newport Ridge Golf	8	93.30	902	Unlicensed	Commercial Water Supply
108226	Newport Ridge Golf	8	81.0	Unknown	Unlicensed	Unknown
100903	Precision Service & Pumps	8	80.0	72	Unlicensed	Water Supply
122285	Zen Properties	8	217.0	200	Unlicensed	Commercial and Industrial Water Supply
120619	District of Squamish	Unknown	80.0	Unknown	Unlicensed	Commercial and Industrial Water Supply
108226	Newport Ridge Golf	8	81.0	Unknown	Unlicensed	Unknown
21872	Redline Plumbing	8	88.0	300	Unlicensed	Domestic Water Supply
92096	Redline Plumbing	8	76.00	400	Unlicensed	Recharge
120734	Ingrid Moll Mcdougall	6	55.0	100	Unlicensed	Irrigation Water Supply
110940	Ingrid Mcdougall	8	284.0	35	Unlicensed	Irrigation Water Supply
80265	Province of BC	Unknown	34.8	0	Unlicensed	Unknown
107190	Pat Maloney	6	75.00	60	Unlicensed	Domestic Water Supply
107165	Nicolaas Westiende	6	78.00	60	Unlicensed	Domestic Water Supply

Of the 18 water wells registered in Aquifer No. 399, two wells (Well Tags No. 122285 and 100903) are located downgradient of the Site. Well Tag No. 122285 is located transgradient and downgradient of the Site, and, according to the database is screened at 66 mbgs. Well Tag No. 100903 is located further downgradient and transgradient of the Site and is screen 24 mbgs. Given that both wells are screened much deeper than the area of construction, and that the vertical gradient in this aquifer is upwards, it is unlikely that water quantity or water level will be impacted in either well as a result of dewatering activities occurring at the Site.

In addition to water wells, there are six existing water rights holder applications and licences in Aquifer No. 399. Of the six Water Licence and Use Holders, two are abandoned, three are current, and one is in the active application process. Table 7 presents the available data in the database about the Water Licence and Use approvals.

Table 7. Summary of Existing Water Rights Holders (Applications and Licences)

POD No.	Licence / File Number	Licence Status	Purpose Use	Source Name	Quantity (m^3/d)	Quantity Diversion Max Rate (m^3/s)
PD44571	F020094	Abandoned	01A - Domestic	Drydan Creek	2.27305	N/A
PD44570	C056051	Abandoned	04A- Land Improve: General	Norman Brook	18.18436	N/A
PD44574	C119787	Current	04A-Land Improve: General	Lynn Brook	6.81914	N/A
PD44556	C027696	Current	02I28- Ind'l Waste Mgmt: Sewer Disposal	Michigan Creek	45.4609	N/A
PD183415	C126014	Current	02I33- Vehicle & Eqpt: Truck & Eqp Wash	Lower Lane Creek	2.273	N/A
PW20013	20012295	Active Application	03B – Irrigation: Private	-		N/A

Based on the information included in Tables 6 and 7, the proposed dewatering activities are not anticipated to have adverse effects on water users, as such, consultation with Water Rights Holders was not deemed necessary.

10. INDIGENOUS NATIONS CONSULTATION

The Site is located within the consultation areas of Squamish Nation and Tsleil-Waututh Nation. FortisBC sent consultation packages regarding the proposed dewatering activities on June 15, 2021. In addition, FortisBC provided this East Shaft WMP to Squamish Nation and Tsleil-Waututh Nation for review as part of the consultation package.

11. CONCLUSIONS

While there is a hydraulic connection between Aquifer No. 399 and the Squamish River, the results of the CSM, and conservative calculations of groundwater flux suggest that Aquifer No. 399 contributes less than 0.01 percent to the volume in the Squamish River, near the Site. Given the extremely low volume of water that Aquifer No. 399 contributes to the Squamish River's total volume, diverting up to 200 m^3/d from Aquifer No. 399 during construction activities would not have a negative effect on the quantity or quality of the Squamish River water, nor on the fish and wildlife habitat supported by it.

Dewatering volumes will be monitored by the DB Contractor and verified by FortisBC for the duration of construction activities. Should dewatering volumes approach 200 m^3/d during any phase of construction, the DB Contractor will be required to modify their groundwater diversion activities to meet Permit Conditions. Water produced from construction and operation of the East Shaft as well as Soft Ground Tunnel construction will be treated and discharged in compliance with Permit Conditions.

12. PROFESSIONAL AUTHENTICATION

FortisBC engaged MJA and Jacobs to conduct the required technical studies included in this report. The list of QEPs includes the following:

Jacobs

- Liz van Warmerdam, M.Sc., P. Geo, Senior Hydrogeologist
- Istvan Almasi, Ph.D., P.Geo, Senior Hydrogeologist

MJA

- Stephanie Robillard, M.Sc. P.Eng, Senior Project Engineer- Geotechnical

13. REFERENCES

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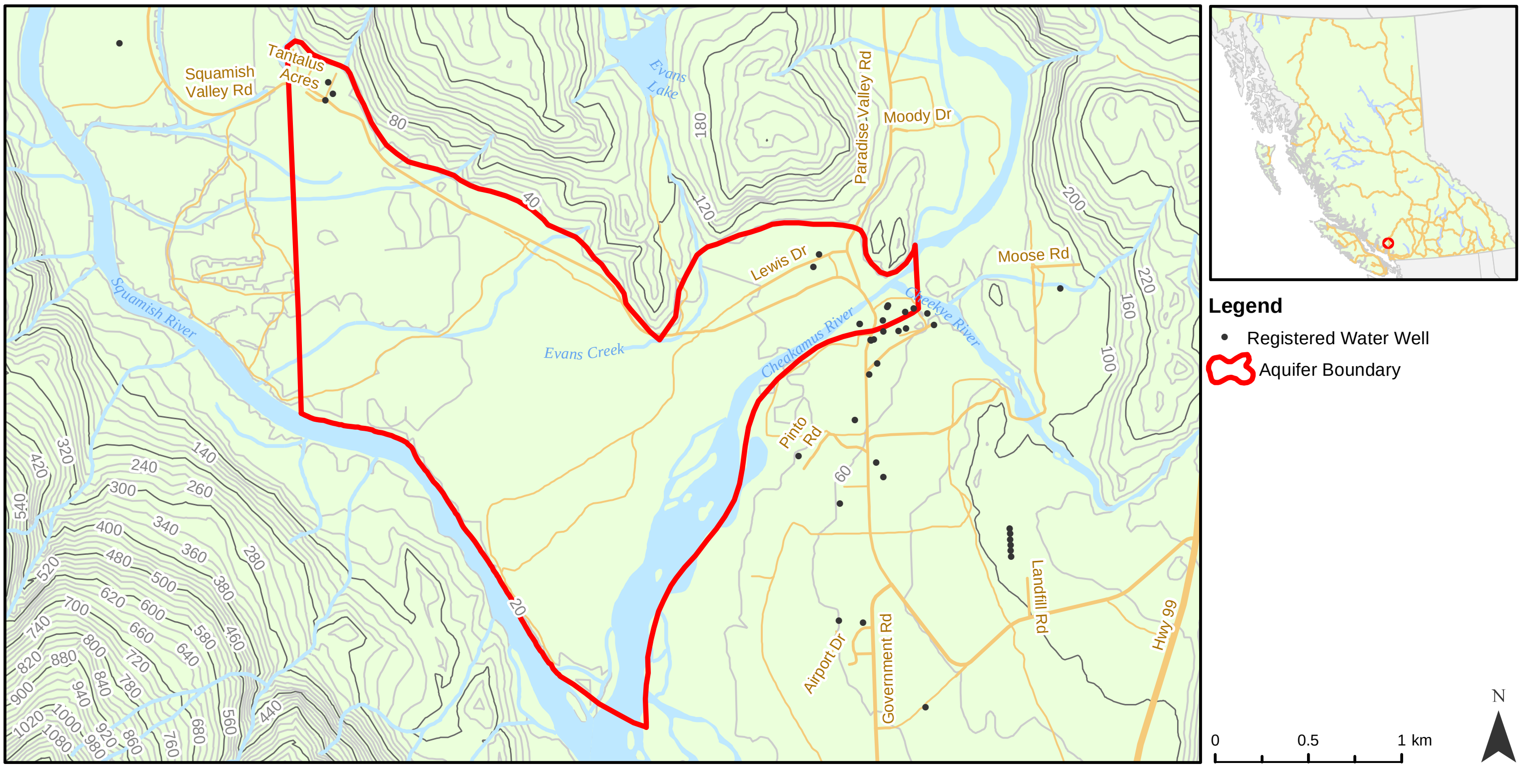
Appendix A
Aquifer Mapping Reports and Aquifer Fact Sheets for Aquifers No. 366, 367, 398, 399, 400, and 401

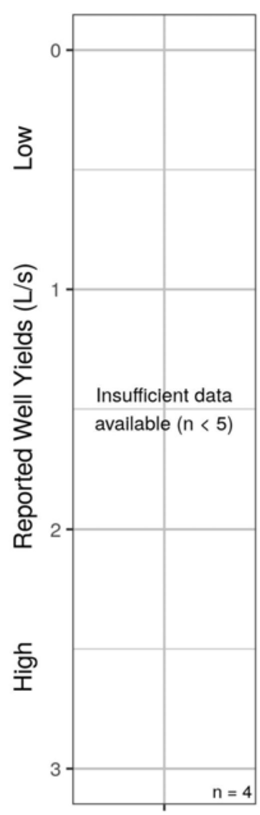
Aquifer #396

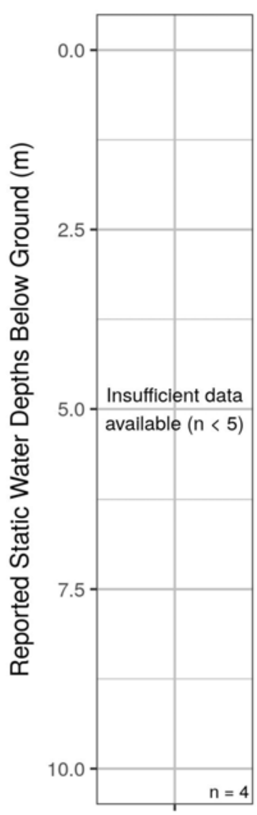


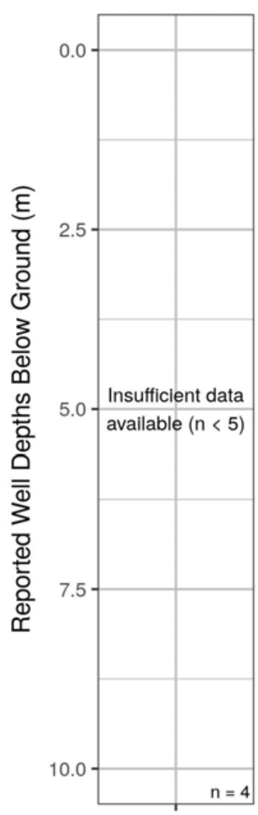
Aquifer Description (Mapping Report - 2007): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	5.1 km^2
No. Wells Correlated to Aquifer	4
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Connectivity[1]	Likely
Aquifer Stress Index	Less stressed
No. Water Licences Issued to Wells	1
Observation Wells (**Active**, Inactive)	None

[1] Based on broad regional assessment







Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).

Factsheet generated: 2020-08-06. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

AQUIFER CLASSIFICATION WORK SHEET

DATE: June 23, 2000

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: 0396

DESCRIPTIVE LOCATION: The main Squamish River Valley, upstream of where the Cheakamus River joins it, at the Cheekye Fan.

NTS MAP SHEET: 092G/14

WELL LOCATION MAPS: New Westminster Land District Sheet 59. BCGS Mapping Areas: 092G.075.3.3.1; 092G.075.3.3.2; 092G.075.3.3.3; 092G.075.3.3.4; 092G.085.1.1.1; 092G.085.1.1.2

CLASSIFICATION: IIIA **RANKING: 9**

Aquifer Size: Approximately 3.5 Km^2. To be planimetered from 1:20,000 Trim mapping.

Aquifer Boundaries: The aquifer is bounded by the Squamish River to the southwest, the Cheakamus River to the southeast, bedrock to the northeast according to geology maps, borehole records and Buchanan (1985). The boundary is undefined to the northwest due to lack of data, but could extend up the valley of the Squamish River.

Geologic Formation (overlying): There is no impermeable protective layer over the aquifer (Pacific Hydrology, 1987).

Geologic Formation (aquifer): The Squamish Valley has been infilled with a mix of glacio-fluvial, fluvial and possibly glacial sediments. From borehole records, these sediments are sand, silty sand and cobbly sand and gravel. Sandy silt and clay layers have also been recorded, which confine deeper granular sediments in areas of the valley. Wood is recorded in a couple of the borehole records (Piteau, 1994).

In the Squamish River Valley, upstream of the confluence of the Squamish River and the Cheakamus River, few water well records are reported. The only known wells, near this confluence are several shallow dug wells which yield water of unsatisfactory quality and a 61m (200 ft) drilled well for the Tantalus Acres Community Water Supply. Two aquifer zones were encountered during drilling. The upper zone extends from 5.2 to 30.5m (17 to 100ft); it consists of sand and gravel interbedded with sand that contains organic debris which is largely wood. The lower aquifer between 43.3 and 46m (142 and 151ft) consists of very fine sand (Pacific Hydrology, 1987). Much further up the Squamish Valley, mile 19.5, Upper Squamish Road, four drilled wells are reported. It appears from checking the assessment rolls these four wells are on district lots 1033 and 988. Two are only 11.3 and 11.6m (37 and 38ft) deep. In both silty sand overlies the sand and gravel aquifer. The other two, also have silty sand at surface, however they are reported to be 95.7 and 146m (314 and 479ft) deep. Both of them report iron in the initial aquifers penetrated. Neither reaches bedrock and one is reported by the driller to produce 7.6L/s (+100 gpm) from an open end pipe bottomed at 146m (479ft) in "water bearing sand and gravel, very little iron".

The sand and gravel sediments which predominate beneath the Squamish Valley floor form a very productive aquifer. The presence of the fine grained sediments may tend to confine some portions of the aquifer, however, with the exception of some localized areas where the fine sediments may be very thick and extensive, an aquifer is interpreted to exist beneath the entire Squamish Valley (Piteau, 1994).

Confined/Unconfined/Bedrock: Unconfined.

Productivity: High.

Vulnerability: High. The aquifer is unconfined and has a relatively shallow water level.

Depth to Water Table: The depth to water table is shallow.

Direction of Flow: The primary groundwater flow would be down gradient, along the Squamish Valley.

Recharge: Likely from surface infiltration over the upland area to the north and east and directly on the aquifer. Also, direct seepage from the Squamish River.

Domestic Well Density: Low.

Users/Level of Use: Low.

Reliance on Source: Conjunctive.

Conflicts Between Users: None documented.

Quantity Concerns (type, source, level of concern): None documented. Piteau (1994) comments there is a potential to develop large quantities of water from wells at most locations within the Squamish Valley. The presence of the fine grained sediments tend to confine some portions of the aquifer, but with the exception of some localized areas where the fine sediments may be very thick and extensive, an aquifer is interpreted to exist beneath the entire Squamish Valley.

Quality Concerns (type, source, level of concern): Piteau (1994) mentions that large quantity wells are quite possible throughout the Squamish valley, however, due to water quality concerns, the potential for developing municipal water supply wells is considered very poor. This refers to elevated concentrations of iron and manganese.

In the Squamish River Valley, upstream of the confluence of the Squamish River and the Cheakamus River, few water well records are reported. The only known wells, near this confluence are several shallow dug wells which yield water of unsatisfactory quality and a 61m (200 ft) drilled well for the Tantalus Acres Community Water Supply. The groundwater from this well is a calcium/bicarbonate type, moderately mineralized and quite soft. With the exception of total iron, total manganese and turbidity, the results of the bacteriological and chemical analyses satisfy all Federal and Provincial drinking water quality guidelines for all parameters tested (Pacific Hydrology, 1987).

Notes: The low gradient of the Squamish Valley, combined with the presence of organic content in the sediments, have apparently resulted in a poorly flushed aquifer and reducing conditions. Elevated iron concentrations are a common problem in this type of hydrogeological environment (Piteau,1994).

References:

Buchanan, R.G. 1991. Geotechnical Investigation Squamish to Whistler Village, Preliminary Planning and Design. Geotechnical and Materials Engineering Branch, Ministry of Transportation and Highways, Province of British Columbia.

Buchanan, R.G. 1985. Sand and Gravel Resource Mapping. Ministry of transportation and Highways, Province of British Columbia.

Camsell, C. 1917. Geology along the Route Traversed by the Pacific Great Eastern Railway between Squamish and Lillooet. Publication No. 1711. Geological Survey of Canada.

Kreye, R. and M. Wei, 1994. A Proposed Aquifer Classification System for Groundwater Management in British Columbia. Groundwater Section, Water Management Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. File No. 00400-20. 68pp.

Pacific Hydrology Consultants Ltd, 1987. Completion Report: Drilling, Construction and Testing of a Community Water Supply at Tantalus Acres, North of Squamish.

Piteau Associates Engineering Ltd., 1994. Groundwater Source Study - Phase 1: Data Compilation and Preliminary Assessment, District of Squamish, B.C. Report prepared for the District of Squamish

Piteau Associates Engineering Ltd., 1995. Groundwater Source Study - Phase 11 and 111, Test Well Program and Final Assessment, District of Squamish, B.C.

AQUIFER CLASSIFICATION AND RANKING

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: **0396**

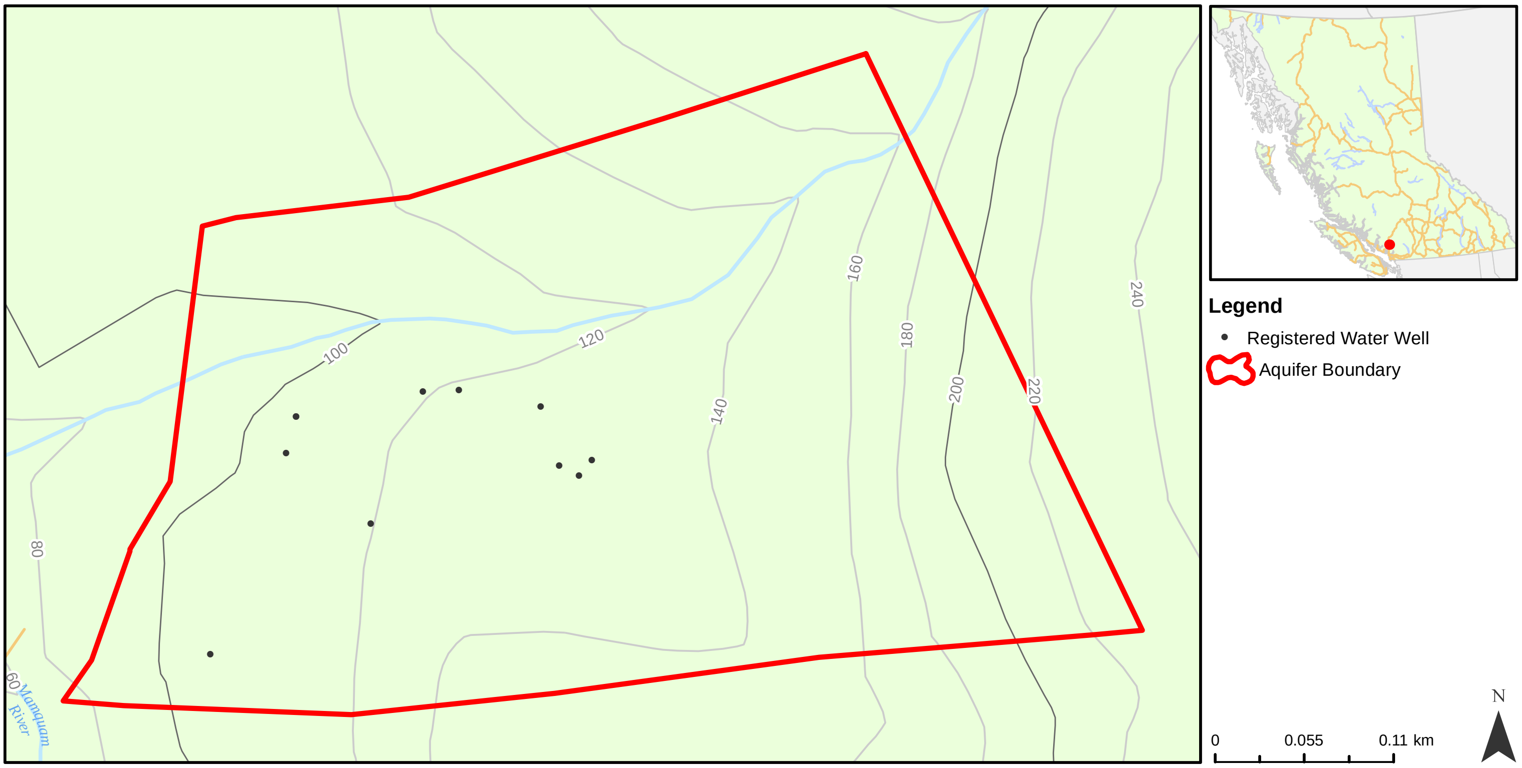
CLASSIFICATION: IIIA **RANKING: 9**

Classification Component: (III) Low level of development. Low demand and high yield.

Vulnerability: (A) High vulnerability to contamination.

Ranking Component:	Value
Productivity:	3
Vulnerability:	3
Size:	1
Demand:	1
Type of Use:	1
Quality Concerns:	0
Quantity Concerns:	0
Total	**9**

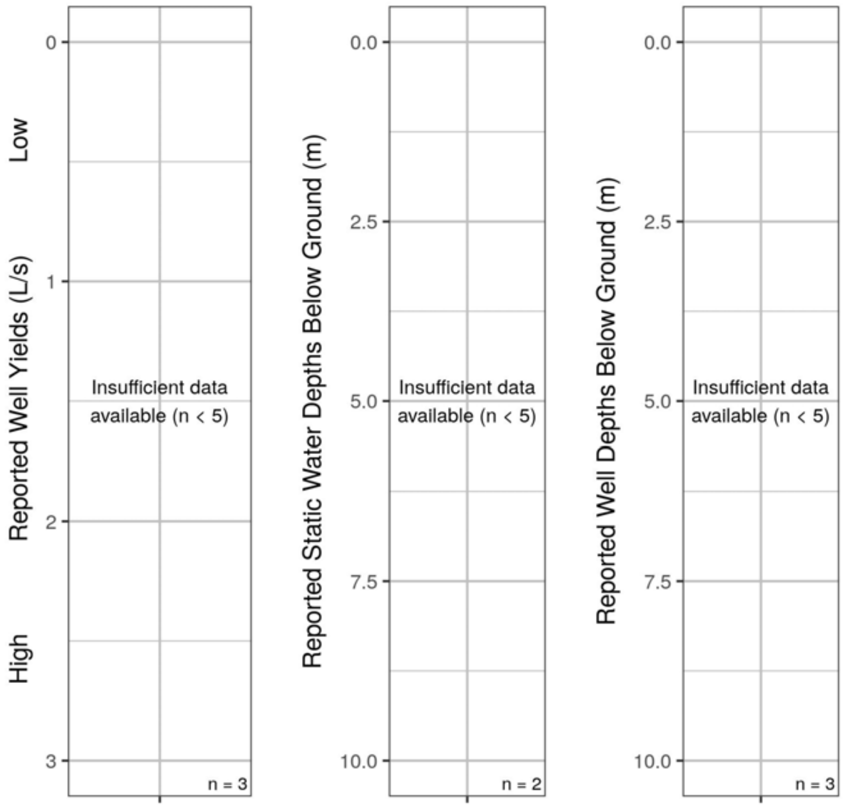
Aquifer #397



Aquifer Description (Mapping Report - 2007): Confined Glacio-fluvial sand and gravel aquifers underneath till, in between till layers, or underlying glacio-lacustrine deposits (subtype = 4b).

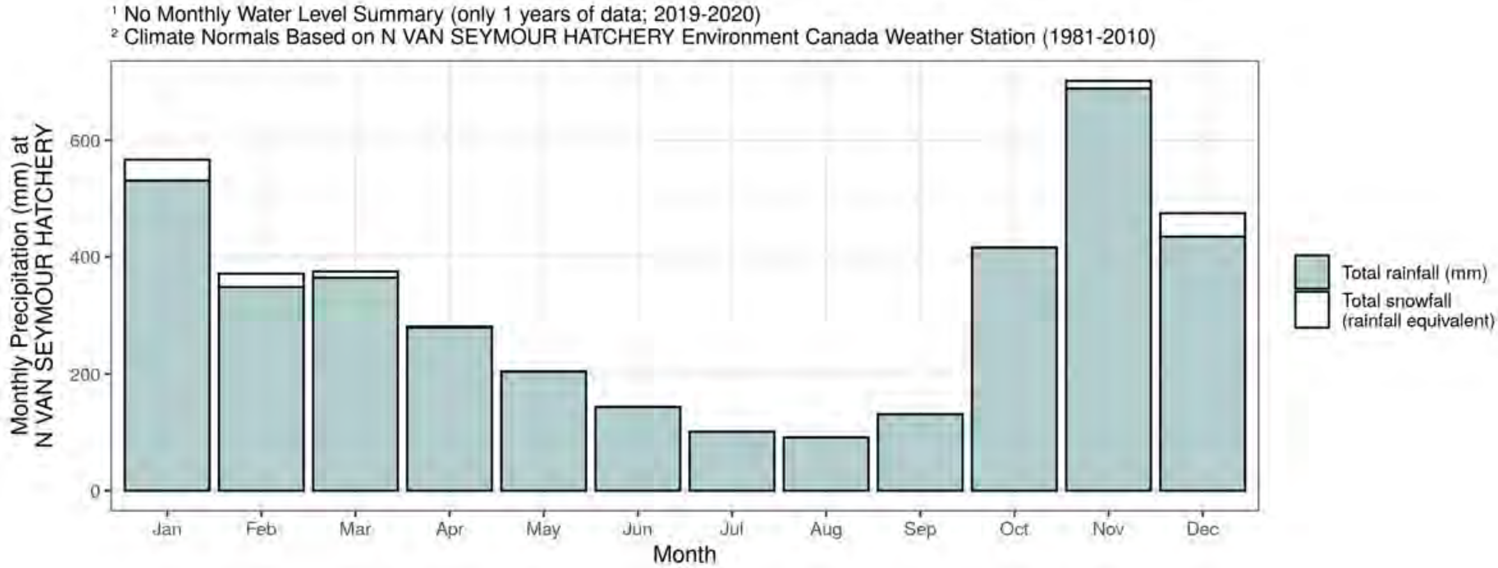
Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	0.2 km^2
No. Wells Correlated to Aquifer	3
Vulnerability to Contamination	Moderate
Productivity	High
Aquifer Classification	IB
Hydraulic Connectivity[1]	Not Likely
Aquifer Stress Index	Method not applicable - confined aquifer
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	**483**

[1] Based on broad regional assessment



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2020-08-06. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

Monthly Groundwater Level[1] with Precipitation from Climate Normals[2]



Groundwater Levels and Long-term Trend

Graph not available
(Not enough data)

For more information regarding trends in groundwater levels see Environmental Reporting BC

Piper Plot

No summary at this point

Graph not available
(insufficient chemistry data)

Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf)

AQUIFER CLASSIFICATION WORK SHEET

DATE: June 23, 2000.

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: 0397

DESCRIPTIVE LOCATION: Powerhouse Springs, adjacent to power generating site on the Mamquam River, east of Squamish..

NTS MAP SHEET: 092G/11

HISTORIC WELL LOCATION MAPS: None - New Westminster Land District

BCGS MAPPING AREA: 092G.075.1.4

CLASSIFICATION: IIIB **RANKING: 11**

Aquifer Size: Less than 0.5 km^2, but may extend much further east. *(To be planimetered from 1:20,000 TRIM mapping.)*

Aquifer Boundaries: The boundaries have been delineated based on geology, borehole data and Piteau (1997 and 1998).

Geologic Formation (overlying): The Ring Creek lava flow overlies the glacial units and is confined by the walls of the basement rock valley (Piteau, 1997). The lava flow extends a distance of about 28 km, from Opal Cone located in Garibaldi Park eastward; the flow terminates roughly 250 metres east of the powerline right-of-way, where it crosses the present day Mamquam River Valley above the powerhouse.

Geologic Formation (aquifer): The extraordinary groundwater flow which discharges from and beneath the Ring Creek lava flow appears to occur primarily within glaciofluvial paleochannel sediments (Piteau, 1997). It is believed that there is an approximately 100 metre wide by 6 metre deep glaciofluvial paleochannel associated with the ancient Mamquam River on the surface of the glaciofluvial outwash sediments (Brooks and Friele, 1992). The entire sequence of glaciofluvial sediments which overlie bedrock are referred to as the paleochannel (Piteau, 1997). Further east, up the lava flow, there may be more groundwater flow within the actual lava. However, at the lower end of the lava flow, Piteau (1998) interprets the majority of groundwater to be flowing within the paleochannel.

Confined/Unconfined/Bedrock: Unconfined. At the area of spring discharge, the aquifer is unconfined; however, east of this location, the lava deposit covers the glaciofluvial channel aquifer to an unknown extent.

Productivity: High. A 400 mm (6”) diameter well drilled for the District of Squamish, near the Power House Springs in 1999 is rated by the driller at 58.7 L/s (930 USgpm). PW97-1 was pump tested at 31.3 L/s (496 USgpm) and stabilized at a drawdown of 3.14 metres (10.3 ft) after about 900 minutes into the test.

Vulnerability: Medium. Unconfined permeable glaciofluvial sediments; some silty sands at surface.

Depth to Water Table: The water level in the wells is 12 to 13 m (39.4 to 42.6 ft) below ground.

Direction of Flow: The direction of flow is east to west, with large spring discharge occurring from and beneath Ring Creek lava at the limit of the lava flow.

Recharge: Recharge to the Powerhouse spring flow regime is interpreted to be from direct infiltration into the top of the lava flow, surface seepage into the lateral margins of the lava flow from Ring and Skookum Creeks, and groundwater discharge directly into the paleochannel from surrounding areas (Piteau, 1998).

Well Density: Low. Only 3 wells, at the spring discharge area above the powerhouse at Powerhouse Creek; recently drilled for District of Squamish.

Users/Level of Use: Not used at this time, however it is being studied and tested as a possible source of water supply for District of Squamish. Soon electrical power will be available and then the District of Squamish will then start using this source.

Reliance on Source: This area is in the early stage of development and not used at this time.

Conflicts Between Users: None documented.

Quantity Concerns (type, source, level of concern): None documented.

Quality Concerns (type, source, level of concern): The quality of the well water from PW97-1 met all objectives of Guidelines for Canadian Drinking Water Quality (GCDWQ Health Canada, 1996), with the exception of pH. At 6.43, pH is just below the minimum recommended 6.5. Surface water samples, and the initial sample of groundwater from PW87-1, all displayed pH measurements above 6.5 (Piteau, 1998).

Notes: The statistics quoted for this aquifer are based on 3 water well records. The range of well depths is from 34.3 to 43 m (112.5 to 141 ft). The three wells are all located very close to one another at Power House Springs. Bedrock was intersected at 42.7 m (140 ft) in the deepest well.

References:

Bostock, H.H. 1963. Geology Squamish (Vancouver West Half) British Columbia. Geological Survey of Canada Map 42-1963. Scale 1:253,440.

Brooks, G.R., and Friele, P.A. 1992. Bracketing Ages for the Formation of the Ring Creek Lava Flow, Mount Garibaldi Volcanic Field. Southwestern British Columbia. Canadian Journal of Earth Sciences, Volume 29, pp. 2425-2428.

Buchanan, R.G. 1985. Sand and Gravel Resource Mapping. B.C. Ministry of Transportation and Highways.

Camsell, C. 1917. Geology along the Route Traversed by the Pacific Great Eastern Railway between Squamish and Lillooet. Geological Survey of Canada Publication No. 1711.

Kreye, R. and M. Wei, 1994. A Proposed Aquifer Classification System for Groundwater Management in British Columbia. Groundwater Section, Water Management Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. File No. 00400-20. 68 pp.

Piteau Associates Engineering Ltd. 1997. Preliminary Assessment of Water Supply of Water Supply Potential-Powerhouse Springs, District of Squamish, B.C. Report prepared for the District of Squamish.

Piteau Associates Engineering Ltd. 1998. District of Squamish. Test Well Program Powerhouse Springs, District of Squamish, B.C., Draft copy.

AQUIFER CLASSIFICATION AND RANKING

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: **0397**

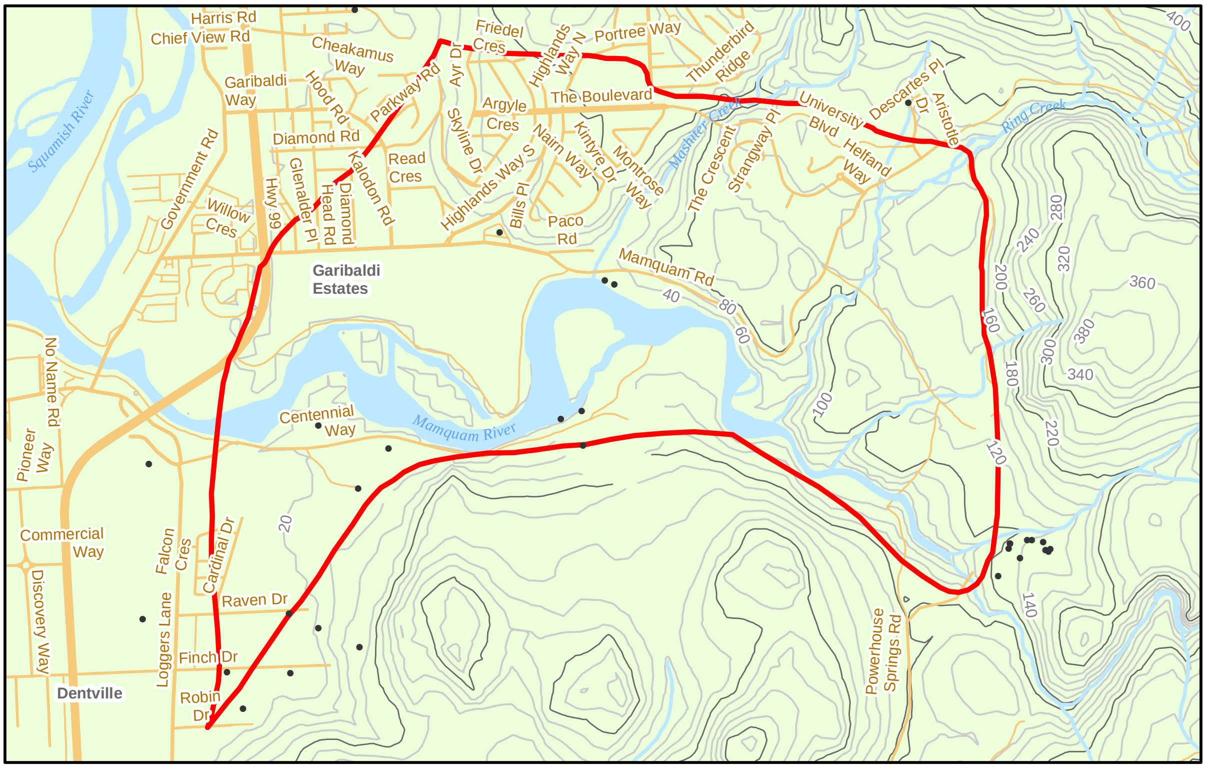
CLASSIFICATION: IIIB **RANKING: 11**

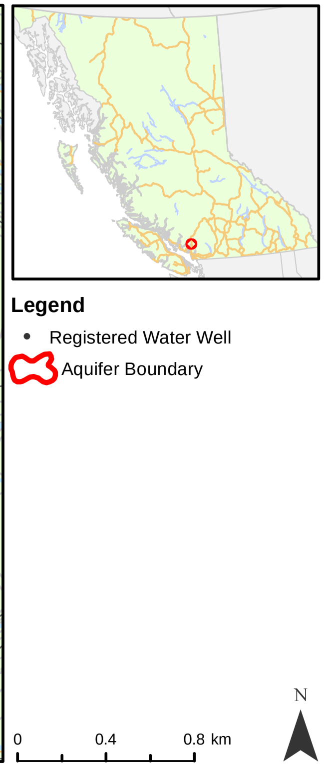
Classification Component: (III) Low level of development. High demand and high yield.

Vulnerability: (B) Moderate vulnerability to contamination.

Ranking Component:	Value
Productivity:	3
Vulnerability:	2
Size:	1
Demand:	3
Type of Use:	2
Quality Concerns:	0
Quantity Concerns:	0
Total	**11**

Aquifer #398

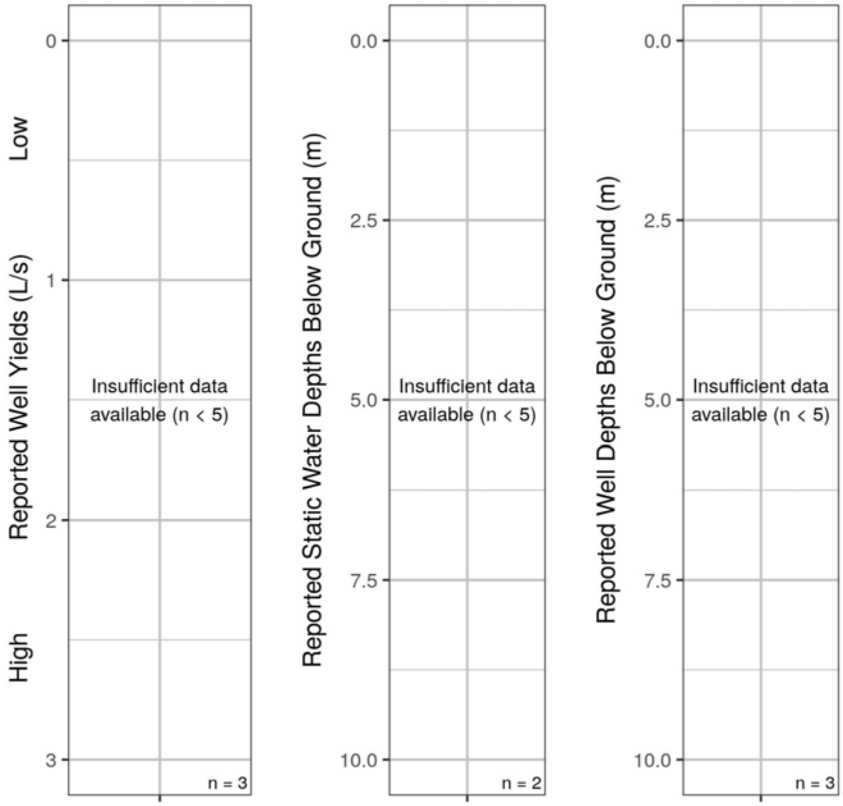




Aquifer Description (Mapping Report - 2007): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	6 km^2
No. Wells Correlated to Aquifer	3
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Connectivity[1]	Likely
Aquifer Stress Index	Less stressed
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	None

[1] Based on broad regional assessment



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2020-08-06. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

AQUIFER CLASSIFICATION WORK SHEET

DATE: June 23, 2000.

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: 0398

DESCRIPTIVE LOCATION: Mamquam Valley: from where the Mamquam River enters the main Squamish Valley to approx. 3.5 km east.

NTS MAP SHEET: 092G/11.

HISTORIC WELL LOCATION MAP: New Westminster Land District Sheet 58.

BCGS MAPPING AREAS: 092G.075.1.2.3, 092G.075.1.4.1

CLASSIFICATION: IIIA **RANKING: 9**

Aquifer Size: Approximately 3 km^2. *(To be planimetered from 1:20,000 TRIM mapping.)*

Aquifer Boundaries: The aquifer is interpreted to be bounded by bedrock to the northeast, east and south, and by Squamish River sediments to the west and northwest. The boundaries have been delineated based on geology maps, borehole records, Buchanan (1985 and 1991) and Piteau (1994 and 1995).

Geologic Formation (overlying): See below.

Geologic Formation (aquifer): Piteau (1995) states that, with completion of their Phase II drilling and test pumping program for District of Squamish, they have verified the presence of at least two aquifers at the site of the Mamquam Test Well. An upper aquifer extends from ground surface to a depth 50.3 m (165 ft), and is comprised primarily of coarse sand, gravel and boulders. A discontinuous layer of clay, sand and gravel underlies the upper aquifer; this layer of clayey sediments is interpreted by Piteau (1995) to represent a low permeability aquitard which hydraulically separates the two aquifers encountered in the test wells at this site. The areal extent of this layer is unknown; however, analysis of the pumping test data indicates that it is relatively continuous, and likely extends on the order of hundreds of metres upstream and downstream of the Piteau Test Well.

The second aquifer in Piteau's Mamquam Test Well, and which is comprised of sand and gravel, extends from 54.9 m (180 ft) to a depth of 63.4 m (208 ft). This second aquifer, which is approximately 8.5 m (27.9 ft) thick, is underlain by clay and gravel. It is interpreted as being a semi-confined (leaky) aquifer, and likely receives most of its recharge through discontinuities in the overlying confining layer (Piteau, 1995).

Piteau (1995) further states the lithology of the sediments below the lower aquifer is unknown. However, Piteau believes that it is likely multiple aquifer/aquitard layers are present below the lower aquifer and above the bedrock.

Confined/Unconfined/Bedrock: Unconfined.

Productivity: High. The Piteau (1995) Mamquam Test Well completed in the upper aquifer was pumped at 13.88 L/s (183 igpm) which resulted in stable drawdown of 6.13 m (20.1 ft) after 150 minutes of pumping; such a drawdown represents only approximately 14% of the total available drawdown. Using 70% of available drawdown, Piteau gave this well a theoretical capacity of 68.2 L/s (900 igpm).

Vulnerability: High. The aquifer is unconfined, has a relatively shallow water level and the sands and gravel extend to surface.

Depth to Water Table: The water table at the Piteau (1995) Mamquam Test Well site is at a depth of about 6 m (19.7 ft) below ground, and is very close in elevation to the Mamquam River at that site. The only other known well in the aquifer is a well located near the south bedrock valley wall, at the Squamish Rod and Gun Club; it has a reported water level of 4.3 m (14 ft).

Direction of Flow: Groundwater flow is westerly to southwesterly, towards the Squamish River (Piteau, 1995).

Recharge: Recharge is interpreted to be primarily leakage from lower reaches of the Mamquam River. Additional recharge is from the valley walls and from the Mashiter and Ring Creek Valleys (Piteau, 1994).

Well Density: Low. Approximately 1.0 wells/km^2.

Users/Level of Use: Minor use.

Reliance on Source: Conjunctive. However, groundwater is little used.

Conflicts Between Users: None documented.

Quantity Concerns (type, source, level of concern): None documented.

Quality Concerns (type, source, level of concern): The chemistry of water samples from two Piteau (1995) test holes generally met the Guidelines for Canadian Drinking Water Quality (GCDWQ), except for total iron and manganese concentrations. Total iron concentrations in reconnaissance samples taken from the confined aquifer and the unconfined aquifer exceeded GCDWQ criteria by more than 3 times. Manganese also exceeded allowable concentrations in most of the samples. However, as the reconnaissance samples were quite turbid, Piteau (1995) attributed the high iron and manganese concentrations as being due to the high level of suspended solids in each sample. Piteau (1995) reported that water samples collected from the lower confined aquifer during the pumping test improved, with both iron and manganese concentrations dropping below GCDWQ levels.

Notes: Only two wells are reported for this aquifer and neither reached bedrock. Piteau (1995) conclude that iron concentrations encountered in groundwater at their Mamquam River site are uncertain. They recommend that development of a groundwater supply at this site should be conducted in a staged manner, so that most of the development costs for a high capacity well field could be deferred until the chemical quality of groundwater from this aquifer quality has been confirmed.

References:

Bostock, H.H. 1963. Geology Squamish (Vancouver West Half) British Columbia. Geological Survey of Canada Map 42-1963. Scale 1:253,440.

Buchanan, R.G. 1991. Geotechnical Investigation Squamish to Whistler Village, Preliminary Planning and Design. Geotechnical and Materials Engineering Branch, B.C. Ministry of Transportation and Highways.

Buchanan, R.G. 1985. Sand and Gravel Resource Mapping. B.C. Ministry of Transportation and Highways.

Camsell, C. 1917. Geology along the Route Traversed by the Pacific Great Eastern Railway between Squamish and Lillooet. Geological Survey of Canada Publication No. 1711.

Kreye, R. and M. Wei 1994. A Proposed Aquifer Classification System for Groundwater Management in British Columbia. Groundwater Section, Water Management Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. File No. 00400-20. 68 pp.

Piteau Associates Engineering Ltd. 1994. Groundwater Source Study - Phase I: Data Compilation and Preliminary Assessment, District of Squamish, B.C. Report prepared for the District of Squamish.

Piteau Associates Engineering Ltd. 1995. Groundwater Source Study - Phase II and III: Test Well Program and Final Assessment, District of Squamish, B.C.

AQUIFER CLASSIFICATION AND RANKING

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: **0398**

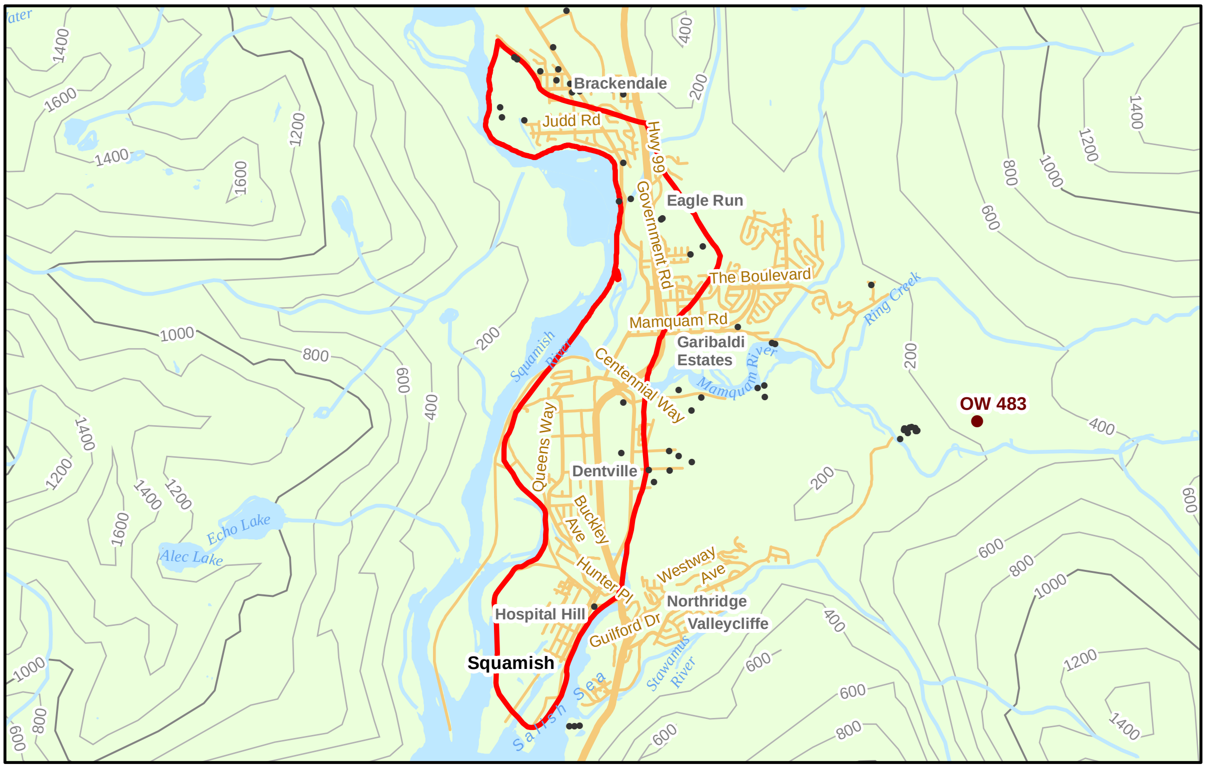
CLASSIFICATION: IIIA **RANKING: 9**

Classification Component: (III) Low level of development. Low demand and high yield.

Vulnerability: (A) High vulnerability to contamination.

Ranking Component:	Value
Productivity:	3
Vulnerability:	3
Size:	1
Demand:	1
Type of Use:	1
Quality Concerns:	0
Quantity Concerns:	0
Total	**9**

Aquifer #399



Legend

- Registered Water Well
- Active Observation Well
- Aquifer Boundary

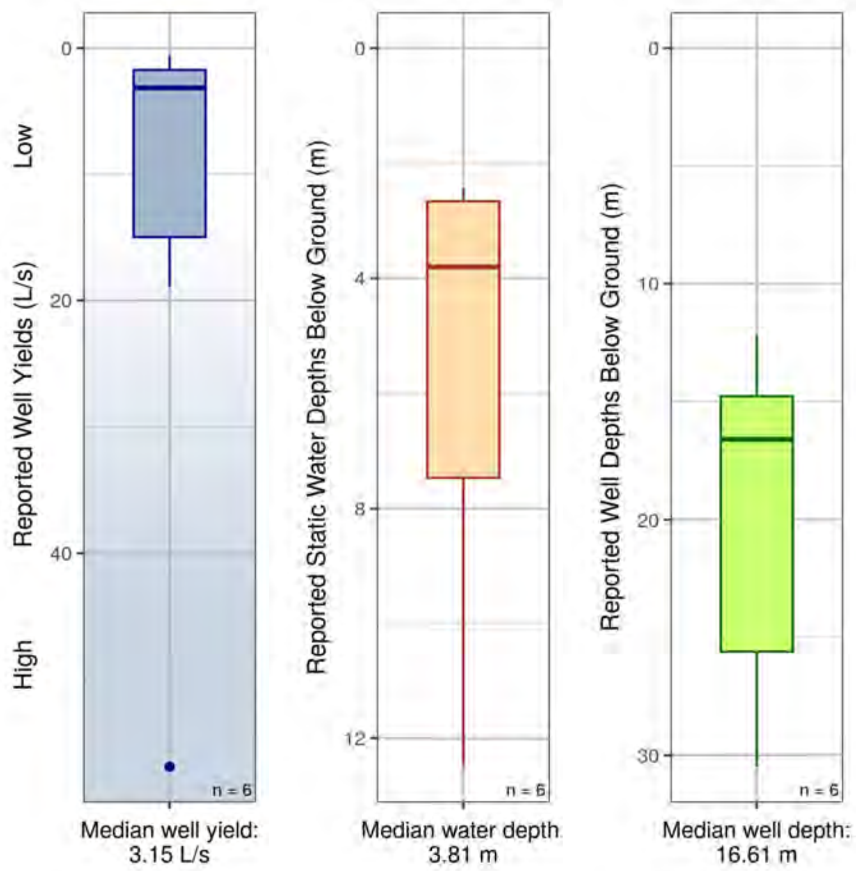
0 1 2 km

N

Aquifer Description (Mapping Report - 2007): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	12 km^2
No. Wells Correlated to Aquifer	6
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Connectivity[1]	Likely
Aquifer Stress Index	Less stressed
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	None

[1] Based on broad regional assessment



Disclaimer: Use of information from Aquifer factsheets (accessed by BC government website) is subject to limitation of liability provisions (further described on that website). That information is provided by the BC government as a public service on an "as is" basis, without warranty of any kind, whether express or implied, and its use is at your own risk. Under no circumstances will the BC government, or its staff, agents and contractors, be responsible or liable to any person or business entity, for any direct, indirect, special, incidental, consequential or any other loss or damages to any person or business entity based on this factsheet or any use of information from it.

Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).

Factsheet generated: 2020-08-06. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

AQUIFER CLASSIFICATION WORK SHEET

DATE: June 23, 2000.

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: 0399

DESCRIPTIVE LOCATION: Squamish River Valley from Squamish to Brackendale.

NTS MAP SHEET: 092G/11 and 092G/14.

HISTORIC WELL LOCATION MAPS: New Westminster Land District Sheets 58 and 59.

BCGS MAPPING AREAS: 092G.065.3.3.2; 092G.065.3.3.4; 092G.075.1.1.2; 092G.0751.1.4; 092G.075.1.2.1; 092G.075.1.2.3; 092G.075.1.3.2; 092G.075.1.3.4; 092G.075.1.4.1; 092G.075.1.4.3; 092G.075.3.1.2; 092G.075.3.1.4; 092G.075.3.2.1; 092G.075.3.2.3

CLASSIFICATION: IIIA **RANKING: 10**

Aquifer Size: Approximately 12 km^2. *(To be planimetered from 1:20,000 TRIM mapping.)*

Aquifer Boundaries: The aquifer is interpreted to be bounded by the Squamish River to the west. Squamish Harbour to the south, the Cheekeye Fan to the north; the east aquifer boundary is defined on the basis of geology, borehole records and information from Buchanan (1985 and 1991) and Piteau (1994 and 1995).

Geologic Formation (overlying): See below.

Geologic Formation (aquifer): The Squamish valley has been infilled with a mix of glaciofluvial, fluvial and possibly glacial sediments. Borehole records show these sediments to consist of sand, silty sand and cobbly sand and gravel. Sandy silt and clay layers, which confine deeper granular sediments in some areas of the valley, have also been recorded. Wood is recorded in a couple of the borehole records (Piteau, 1994).

At the upper end of the valley, the deepest borehole reached 36.6 m (120 ft) and did not encounter bedrock Sediments are likely to extend to much greater depths, based on the steep valley walls (Piteau, 1994). Reports by Brown (1960-1965) concerning a 202.7 m (665 ft) deep rotary testhole on the Squamish tidal flats state that granitic bedrock was probably reached at this depth.

The sand and gravel sediments which predominate beneath the Squamish valley floor, form a very productive aquifer. The presence of the fine-grained sediments may tend to confine some portions of the aquifer; however, with the exception of some localized areas where the fine sediments may be very thick and extensive, an aquifer is interpreted to be present beneath the entire Squamish valley (Piteau, 1994).

Confined/Unconfined/Bedrock: Unconfined.

Productivity: High.

Vulnerability: High. The aquifer is unconfined and has a relatively shallow water level.

Depth to Water Table: The depth to water table in known wells is recorded as 1.22 to 13.4 m (4 to 44 ft) below ground level.

Direction of Flow: Primary groundwater flow is down gradient, along the Squamish Valley.

Recharge: Likely from surface infiltration over the upland area to the north and east and directly on the aquifer. Also, direct seepage from the Squamish River.

Well Density: Low. Approximately 2 wells/km^2; however, many wells are not likely in use as the Squamish water system supplies much of the area.

Users/Level of Use: Low. District of Squamish supplies most of the area mainly from surface water reservoirs.

Reliance on Source: Conjunctive.

Conflicts Between Users: None documented.

Quantity Concerns (type, source, level of concern): None documented. Piteau (1994) comments that there is potential to develop large quantities of water from wells at most locations within the Squamish Valley.

Quality Concerns (type, source, level of concern): Piteau (1994) mentions that high capacity wells are quite possible throughout the Squamish valley; however, due to water quality concerns – in particular, elevated concentrations of iron and manganese - the potential for developing municipal water supply wells is considered very poor. It is reported that a 30 m (100 ft) deep production well on BCGS grid 92G.075.3.2.1 was shut down by District of Squamish due to water quality concerns. Groundwater from the District of Squamish 17.1 m (56 ft) deep well at Centennial Park has a total iron content of 0.94 mg/L and a dissolved iron content of 0.45 mg/L (Badry, 1977); water from this well is only used to water the ball fields, not for drinking (pers. comm., District of Squamish, 2000). Piteau (1994) notes that groundwater from the Newport Ridge Estates well contained 0.24 mg/L iron. However, groundwater from this well satisfies both Provincial and Federal drinking water quality guidelines for all parameters checked (Badry, 1994). The groundwater type is a complex calcium + sodium/bicarbonate + chloride type water.

Reports by Brown (1960-1965) concerning a 202.7m (665 ft) deep rotary testhole on the Squamish River tidal flats state that, from the electro-log and driller report, all aquifers penetrated to the final depth were brackish. Three large production wells, producing brackish water, were constructed for cooling purposes at this site.

Notes: The low gradient of the Squamish Valley, combined with the presence of organic content in the sediments, have apparently resulted in a poorly flushed aquifer and reducing conditions. Elevated iron concentrations are a common problem in this type of hydrogeological environment (Piteau, 1994).

References:

Badry, A. 1977. Squamish Recreational Park, Production Well. E. Livingston Associates letter-report dated April 15, 1977, prepared for District of Squamish. Groundwater Section N.T.S. File 92G/11 #3.

Badry, A. 1993. Feasibility of Developing a Supply of Groundwater for Irrigation of Proposed Newport Ridge Estates Golf Course north of Squamish, B.C. SRK Robinson Inc. letter-report prepared by Ann Badry, Manager of Pacific Hydrology Consultants Ltd. dated October 29, 1993 for R.F. Binnie & Associates Ltd.

Badry, A. 1994. Completion Report: Drilling, Construction and Testing of a Production Well and Installation of a Monitoring Well at Pacific World Management's Newport Ridge Estates Development, North of Squamish, B.C. SRK Robinson Inc. report prepared by Ann Badry, Manager of Pacific Hydrology Consultants Ltd. dated April 11, 1994 for R.F. Binnie & Associates Ltd.

Bostock, H.H. 1963. Geology Squamish (Vancouver West Half) British Columbia. Geological Survey of Canada Map 42-1963. Scale 1:253,440.

Brown, W.L. 1960-1965. Water Supply at Squamish, B.C. Preliminary and Final Report for Pennsalt Chemical Corporation. Groundwater Section N.T.S. File 92G/11 #3.

Buchanan, R.G. 1991. Geotechnical Investigation Squamish to Whistler Village, Preliminary Planning and Design. Geotechnical and Materials Engineering Branch, B.C. Ministry of Transportation and Highways.

Buchanan, R.G. 1985. Sand and Gravel Resource Mapping. B.C. Ministry of Transportation and Highways.

Camsell, C. 1917. Geology along the Route Traversed by the Pacific Great Eastern Railway between Squamish and Lillooet. Geological Survey of Canada Publication No. 1711.

Kreye, R. and M. Wei 1994. A Proposed Aquifer Classification System for Groundwater Management in British Columbia. Groundwater Section, Water Management Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. File No. 00400-20. 68 pp.

Piteau Associates Engineering Ltd. 1994. Groundwater Source Study - Phase I: Data Compilation and Preliminary Assessment, District of Squamish, B.C. Report prepared for the District of Squamish.

Piteau Associates Engineering Ltd., 1995. Groundwater Source Study - Phase II and III: Test Well Program and Final Assessment, District of Squamish, B.C.

AQUIFER CLASSIFICATION AND RANKING

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: **0399**

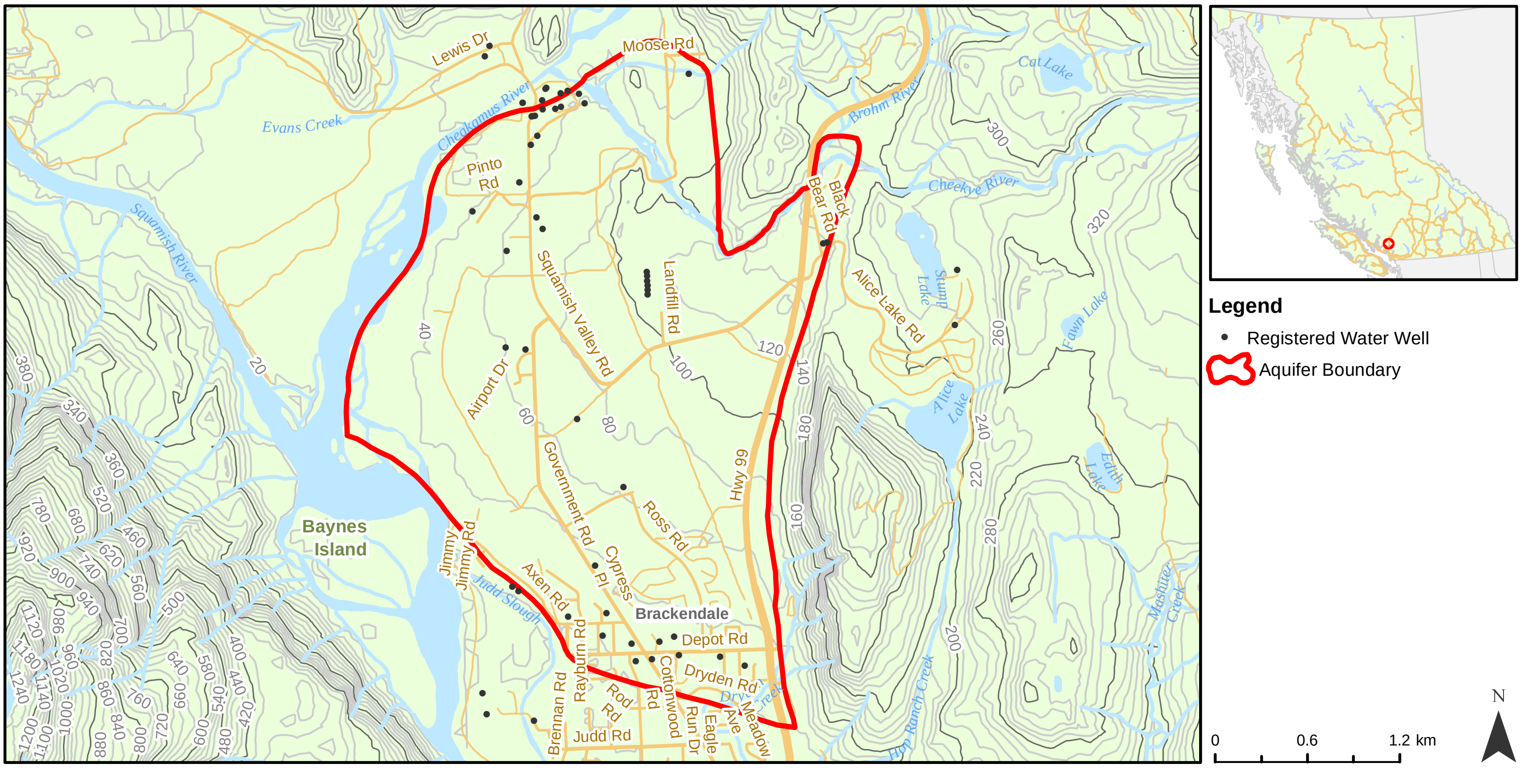
CLASSIFICATION: 111A **RANKING: 10**

Classification Component: (III) Low level of development. Low demand and high yield.

Vulnerability: (A) High vulnerability to contamination.

Ranking Component:	Value
Productivity:	3
Vulnerability:	3
Size:	2
Demand:	1
Type of Use:	1
Quality Concerns:	0
Quantity Concerns:	0
Total	**10**

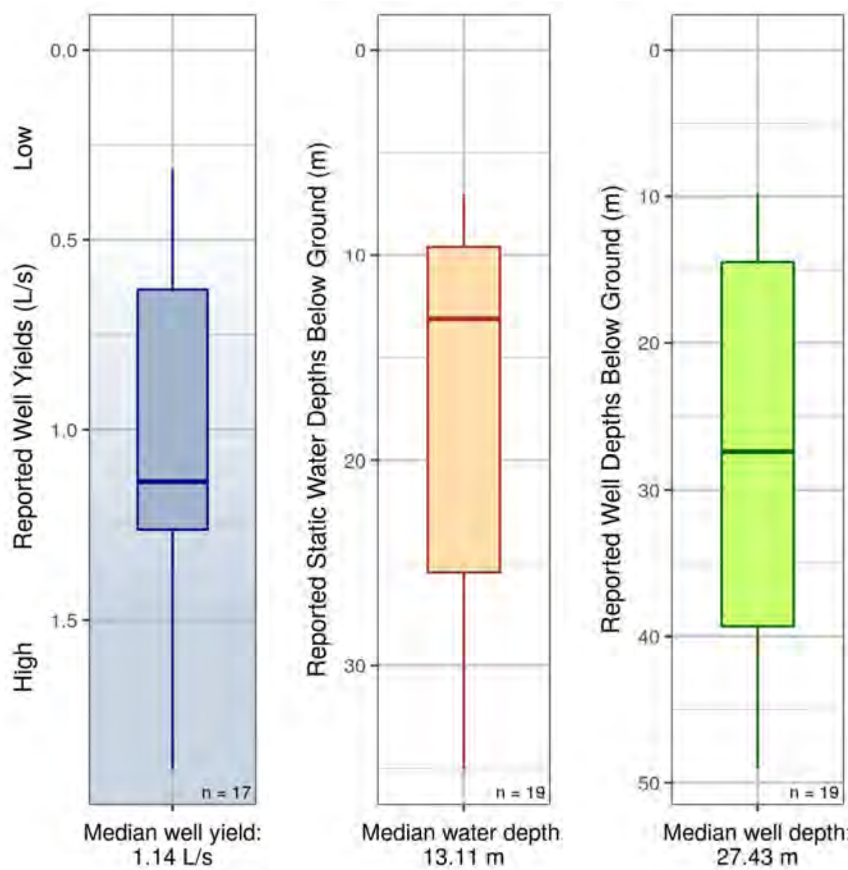
Aquifer #400



Aquifer Description (Mapping Report - 2007): Alluvial or colluvial fan sand and gravel aquifers typically occur at or near the base of mountain slopes, either along the side of valley bottoms, or if formed during the last period of glaciation, raised above the valley bottoms (subtype = 3).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	8.7 km^2
No. Wells Correlated to Aquifer	19
Vulnerability to Contamination	Moderate
Productivity	Moderate
Aquifer Classification	IIIB
Hydraulic Connectivity[1]	Likely
Aquifer Stress Index	Less stressed
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	None

[1] Based on broad regional assessment



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2020-08-06. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

AQUIFER CLASSIFICATION WORK SHEET

DATE: June 23, 2000.

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: 0400

DESCRIPTIVE LOCATION: Confluence of the Squamish, Cheakamus and Cheekye Rivers where the Cheekye River flows into the main Squamish River valley.

NTS MAP SHEET: 092G/14.

HISTORIC WELL LOCATION MAP: New Westminster Land District Sheet 59.

BCGS MAPPING AREAS: 092G.075.3.1.4; 092G.075.3.2.3; 092G.075.3.3.2; 092G.075.3.3.4; 092G.075.3.4.1; 092G.075.3.4.1; 092G.075.3.4.3; 092G.085.1.2.1

CLASSIFICATION: IIIB **RANKING: 12**

Aquifer Size: Approximately 7.5 km^2. *(To be planimetered from 1:20,000 TRIM mapping.)*

Aquifer Boundaries: The aquifers have been defined by geology, borehole records, Buchanan (1985 and 1991) and Piteau (1994 and 1995).

Geologic Formation (overlying): Glaciofluvial sands and gravels (Buchanan, 1991); further, Sand and Gravel Resource Mapping of B.C. Ministry of Transportation and Highways (Buchanan, 1985), denotes the Cheekye fan as an A1 landform with known potential for coarse material, including gravels, gravelly sands and sandy gravels.

Geologic Formation (aquifer): Piteau (1994) described the Cheekye fan aquifer as consisting of sediments of alluvial, debris flow and glacial origin, with the lower fan area described as being underlain by a cobbly diamicton deposited by debris flows. Borehole data shows the diamicton is directly underlain by 5 to 15 m (16.4 to 49.2 ft) of sand, silt and gravel and some boulders and, then, by about 25 to 30 m (82 to 98.4 ft) of compact silt, sand and gravel of glacial origin.

Piteau (1994) further stated that: the above-described sediments will have highly variable hydraulic conductivities, with permeable zones separated by low permeability layers or lenses which may contain many perched flow systems; and, the heterogeneous nature of fan materials often creates a highly compartmentalized type aquifer, in which individual well yields are severely limited by the extent of the individual flow compartments.

Piteau (1995) stated that the Phase II drilling of a test hole verified the above interpretation. Layers of highly permeable coarse sand and gravel sediments, separated by layers of sandy silt, were intersected by the testhole; the sediments were all unsaturated to a depth of 47.2 m (155 ft), where saturated silty sand sediments were encountered. The testhole was terminated at 58 m (190.3 ft). However, no screen was installed and casing was left open ended.

In 1998, Perrys Well Drilling constructed a 71.6 m (235 ft) deep well in the Cheekye fan, for the District of Squamish at a location approximately (0.5 miles) north of the Piteau testhole of 1995. Perry's reports a very tight sand and gravel from 56.7 to 71.6 m (186 to 235 ft) below mostly: cemented gravel and cemented gravel and cobbles. The well, which is completed with a screen set from 68.3 to 71.3 m (224 to 234 ft), was tested for 3 hours at 6.31 L/sec (100 USgpm) by air lift from a pumping water level of 67 m (220 ft); prior to the air-lift pumping, the static water level was 49.7 m (163 ft).

Confined/Unconfined/Bedrock: Unconfined.

Productivity: Moderate.

Vulnerability: Moderate. The aquifer is unconfined; however, the fan materials are heterogeneous, with semi-permeable and cemented layers. Also, the static water levels are relatively deep.

Depth to Water Table: Generally quite deep, ranging from 7.0 to 49.7 m (23 to 163 ft) below ground. The median depth to water is 23.5 m (77 ft); the geometric mean is 32.8 m (107.6 ft).

Direction of Flow: Based on the low water levels in the shallow and deep sediments beneath the toe of the fan, flow within the shallow sediments is interpreted to discharge to the Cheakamus River, whereas flow in the deep sediments is interpreted to discharge to the lower elevation of the Squamish River (Piteau, 1994).

Recharge: Recharge to the fan is interpreted to be from leakage from the Cheekye River and influent groundwater from areas above the fan (Piteau, 1994).

Well Density: Low. Approximately 2 wells/km^2. The native community at the confluence of the Cheekye and Cheakamus Rivers is serviced with individual domestic wells, as is the BC Hydro Substation located west of the landfill, and also the airport located southwest of the landfill. A number of wells have been drilled to supply homes on the south end of the fan, but this area is now serviced by the District of Squamish, so it is likely that most of these wells have been abandoned.

Users/Level of Use: Low. The District of Squamish supplies much of the area.

Reliance on Source: Conjunctive.

Conflicts Between Users: None documented.

Quantity Concerns (type, source, level of concern): None documented.

Quality Concerns (type, source, level of concern): Based on the chemistry data collected in May 1993 by Piteau (1994), groundwater quality in the Cheekye fan meets Guidelines for Canadian Drinking Water Quality (GCDWQ, 1993), with the exception of iron and manganese in groundwater from the airport well, where the concentrations slightly exceeded the acceptable levels.

Leachate from the landfill may be impacting groundwater quality in localized areas of the fan. In 1994 the District of Squamish was monitoring 3 domestic wells for leachate indicator parameters (Piteau, 1994).

Groundwater from Piteau (1995) unscreened testhole on the fan did not meet GCDWQ for total iron and manganese. Dissolved concentrations from non-turbid samples may be much lower.

The 1998 well, Perrys Well Drilling constructed 71.6 m (235 ft) deep in the Cheekye fan, for the District of Squamish at a location approximately (0.5 miles) north of the Piteau testhole was sampled by the District of Squamish and meets Guidelines for Canadian Drinking Water Quality (GCDWQ, 1993), for all parameters tested. The total iron was 0.09 mg/L and manganese 0.012 mg/L.

Notes: There is a difference of opinion about whether the Cheekye fan is a debris fan. Care must be taken in drawing conclusions about the chemical quality of groundwater, specifically iron and manganese in groundwater samples from testholes which are not completed with screens.

Friele (1999) suggests the fan is of late Pleistocene age and not Holocene as has been interpreted by others, and further suggests that the Cheekye fan is largely a product of the geologic past, that is, it is a paraglacial fan. In short, it may be a better aquifer than has been interpreted by others. Further work is required to better understand this aquifer.

References:

Bostock, H.H. 1963. Geology Squamish (Vancouver West Half) British Columbia. Geological Survey of Canada Map 42-1963. Scale 1:253,440.

Buchanan, R.G. 1991. Geotechnical Investigation Squamish to Whistler Village, Preliminary Planning and Design. Geotechnical and Materials Engineering Branch, B.C. Ministry of Transportation and Highways.

Buchanan, R.G. 1985. Sand and Gravel Resource Mapping. B.C. Ministry of Transportation and Highways.

Camsell, C. 1917. Geology along the Route Traversed by the Pacific Great Eastern Railway between Squamish and Lillooet. Geological Survey of Canada Publication No. 1711.

Friele, Pierre A., C. Ekes and E.J. Hickin. 1999. Evolution of Cheekye Fan, Squamish, British Columbia: Holocene Sedimentation and Implications for Hazard Assessment. Canadian Journal of Earth Sciences, Vol. 36, No. 12, pp. 2023-2031.

Kreye, R. and M. Wei, 1994. A Proposed Aquifer Classification System for Groundwater Management in British Columbia. Groundwater Section, Water Management Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. File No. 00400-20. 68 pp.

Piteau Associates Engineering Ltd. 1994. Groundwater Source Study - Phase I: Data Compilation and Preliminary Assessment, District of Squamish, B.C. Report prepared for the District of Squamish.

Piteau Associates Engineering Ltd. 1995. Groundwater Source Study - Phase II and III: Test Well Program and Final Assessment, District of Squamish, B.C.

AQUIFER CLASSIFICATION AND RANKING

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: **0400**

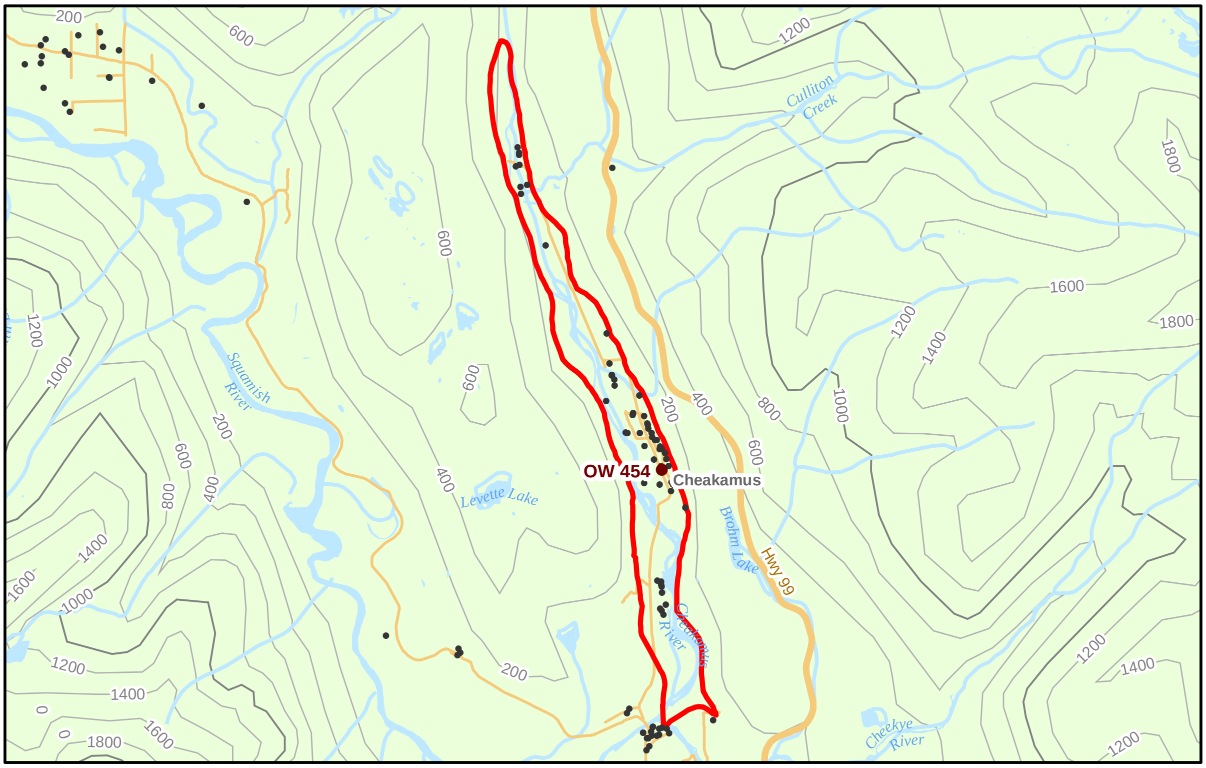
CLASSIFICATION: 111B **RANKING: 12**

Classification Component: (II1) Low level of development. Low demand and moderate yield.

Vulnerability: (B) Moderate vulnerability to contamination.

Ranking Component:	Value
Productivity:	3
Vulnerability:	2
Size:	2
Demand:	2
Type of Use:	3
Quality Concerns:	0
Quantity Concerns:	0
Total	**12**

Aquifer #401



Legend

- Registered Water Well
- Active Observation Well
- Aquifer Boundary

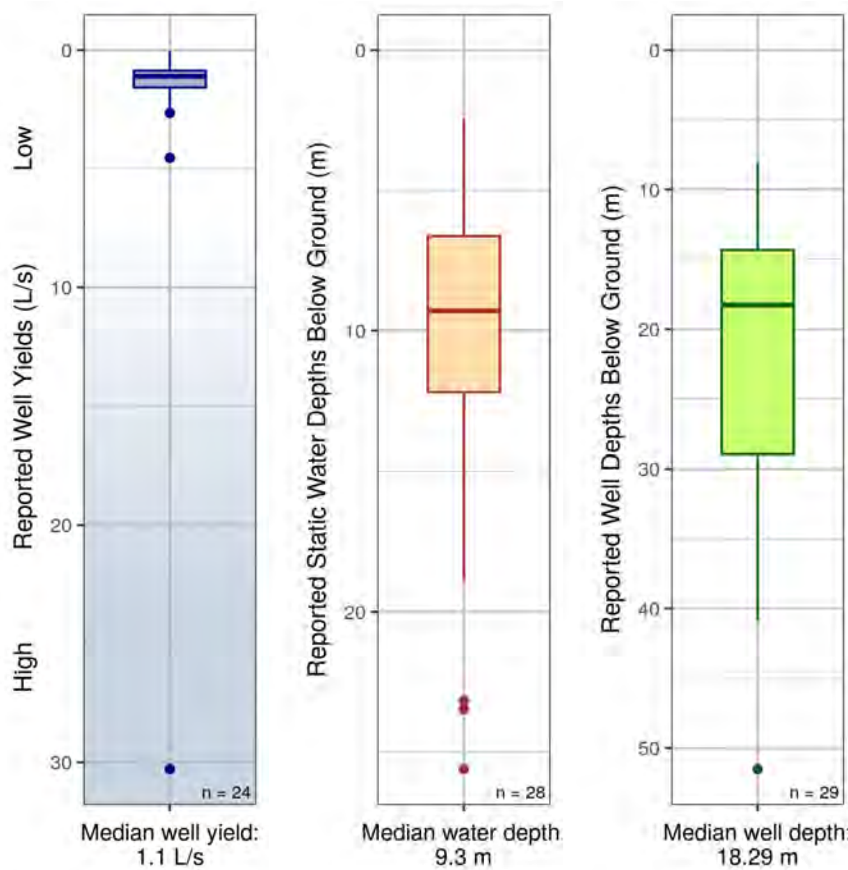
0 1 2 km

N

Aquifer Description (Mapping Report - 2007): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	6.4 km^2
No. Wells Correlated to Aquifer	29
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIA
Hydraulic Connectivity[1]	Likely
Aquifer Stress Index	More stressed (high certainty)
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	**454**

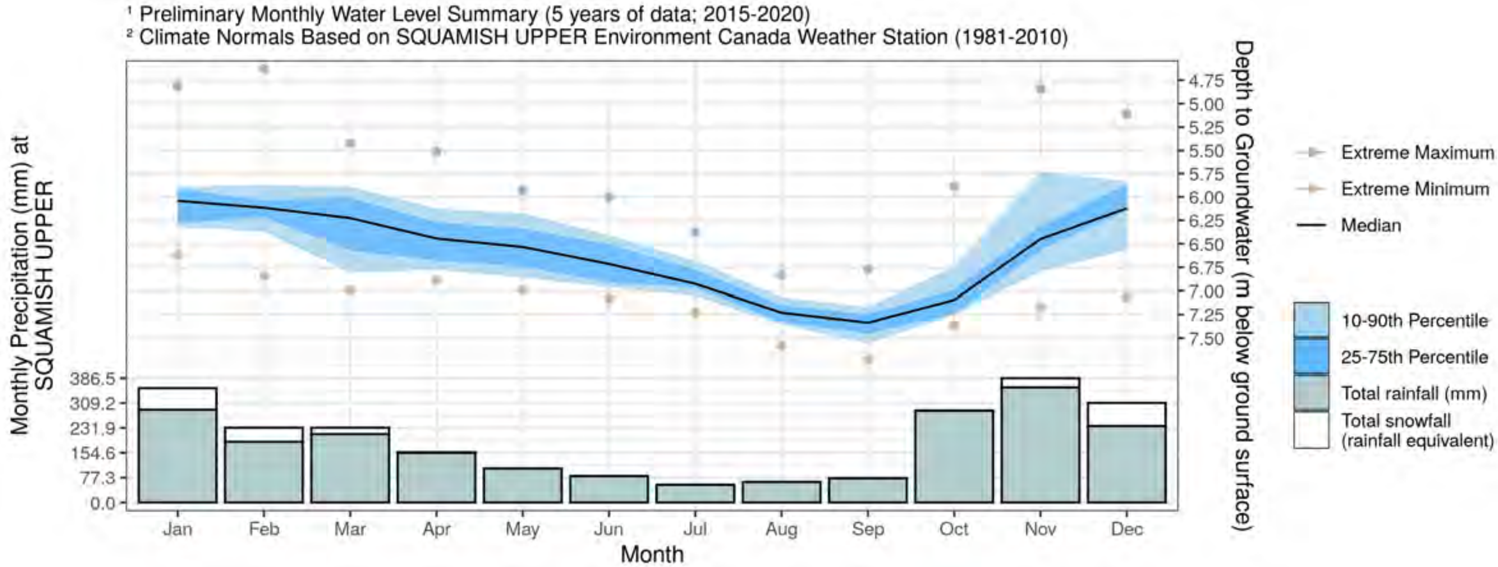
[1] Based on broad regional assessment



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).

Factsheet generated: 2020-08-06. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

Monthly Groundwater Level[1] with Precipitation from Climate Normals[2]

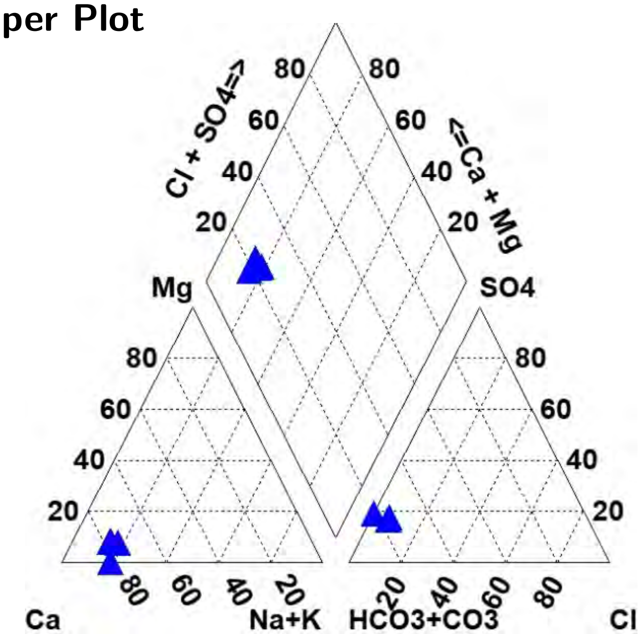


Groundwater Levels and Long-term Trend

Graph not available
(Not enough data)

For more information regarding trends in groundwater levels see Environmental Reporting BC

Piper Plot



The groundwater samples are typically of the Ca-HCO3 type. Ca is the dominant cations, which indicates a less evolved/short flow path recharge area type of groundwater. The fact that HCO3 is the dominant anion shows the source is primarily recent precipitation in the surficial aquifer #401. For EMS water chemistry data, EMSID E303130.

AQUIFER CLASSIFICATION WORK SHEET

DATE: June 23, 2000.

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: 0401

DESCRIPTIVE LOCATION: Approximately 22 km north along the Cheakamus River valley, from the fan formed where the Cheekye River flows into the main Squamish River valley to just north of Culliton Creek.

NTS MAP SHEET: 092G/14.

HISTORIC WELL LOCATION MAPS: New Westminster Land District Sheets 59 and 60.

BCGS MAPPING AREAS: 092G.085.1.1.2; 092G.085.1.1.4; 092G.085.1.2.1; 092G.085.1.2.3; 092G.085.1.3.2; 092G.085.1.3.4; 092G.085.1.4.1; 092G.085.1.4.3; 092G.085.3.1.2; 092G.085.3.1.3; 092G.085.3.1.4; 092G.085.3.3.1

CLASSIFICATION: IIA **RANKING: 13**

Aquifer Size: Approximately 16.5 km^2. *(To be planimetered from 1:20,000 TRIM mapping.)*

Aquifer Boundaries: The aquifer has been defined by use of geology maps, borehole records and Buchanan (1985 and 1991).

Geologic Formation (overlying): Alluvial floodplain (Buchanan, 1991). Also, the Sand and Gravel Resource Mapping of the B.C. Ministry of Transportation and Highways (Buchanan, R.G. 1985), denotes the southern portion as C-w and the northern portion as B1-w. The "B" denotes the landform unit as having probable potential for coarse material, including gravels, gravelly sands and sandy gravels. The "C" denotes the landform unit as having possible potential for granular material. The "w" denotes the landform as a meltwater channel).

Geologic Formation (aquifer): The aquifer is comprised of coarse glacio-fluvial, glacial, and post-glacial fluvial sediments. Coarse sand and gravel sediments appear to be predominant from a depth of about 20 m (65.6 ft) to greater than 45 m (147.6 ft), indicating that a very permeable, unconfined aquifer is present to this depth (Piteau, 1994).

Confined/Unconfined/Bedrock: Unconfined.

Productivity: High. The median well yield is 1.5 L/s (20 gpm) and the geometric well mean is 3.3 L/s (44 gpm). The coarse gravels have made it possible to complete 15, of the total of 22 known wells, as an open-end pipe. Indications are that high capacity production wells could be constructed throughout most of this aquifer. One well for Federal Fisheries was tested at 30 L/s (480 USgpm) with 0.33 m (1.08 ft) of drawdown. Another well, installed for Steamhorse Golf Course in the northwest corner of D.L. 1250, has an assigned yield of 31.5 L/s (500 USgpm) from a coarse gravel aquifer (Pacific Hydrology, 1993). Four wells, drilled to depths of between 30 and 46 m (100 and 150 ft), supply the Tenderfoot Creek Fish Hatchery, located approximately 3 km south of the Steamhorse well. Two of the four hatchery wells each yield about 31.5 L/s (500 USgpm) and two each yield about 60 L/s (1000 USgpm) (Piteau,1994).

Vulnerability: High. The aquifer is unconfined and in some areas the coarse aquifer gravels extend to surface; however, in other areas, natural protection is provided by silty sediments (Arengi and Livingston, 1993). The average depth to water below ground is 9.4 m (31 ft).

Depth to Water Table: Generally moderate depth, ranging from 2.4 to 25.6 m (8.0 to 84.0 ft) below ground level. Median depth to water is 10.7 m (35 ft); geometric mean is 9.4 m (31 ft).

Direction of Flow: Groundwater flow is south, down Cheakamus River valley.

Recharge: Upstream recharge to the gravels from the Cheakamus River, and the numerous creeks and their associated fans that flow into the Cheakamus River valley.

Well Density: Low. Approximately 1.0 wells/km^2.

Users/Level of Use: Multiple. Groundwater is used for domestic, golf course irrigation and fish hatcheries from this aquifer.

Reliance on Source: Conjunctive. Water rights exist on many creeks.

Conflicts Between Users: None documented.

Quantity Concerns (type, source, level of concern): None documented.

Quality Concerns (type, source, level of concern): Groundwater in the Cheakamus River aquifer is very soft, with a hardness of less than 35 mg/L $CaCO_3$/L. Iron and manganese concentrations are very low, indicating that the aquifer is well flushed and not subject to stagnant flow conditions. Nitrate and chloride concentrations are also very low (Piteau, 1994).

Notes: Piteau, 1994 considers the groundwater potential in the Cheakamus Valley very high. Piteau in this 1994 report to the District of Squamish states a well field capable of providing 230 L/s (3646 USgpm) of good quality water, should be possible.

References:

Arengi, J.T. and Ed Livingston. 1993. Completion Report Construction and Testing of a Water Well for Steamhorse Golf and Recreation Resort North of Brackendale, B.C. Pacific Hydrology Consultants Ltd. Report dated October 25, 1993, prepared for Steamhorse Land Developments Ltd.

Arengi, J.T. and Ed Livingston. 1994. Hydrogeological Evaluation Concerning Stormwater and Wastewater Disposal and Fertilizer/Pesticide Application at Steamhorse Golf and Recreation Resort North of Brackendale, B.C. Pacific Hydrology Consultants Ltd. Report dated May 30, 1994, prepared for Eagle Horse Properties Ltd.

Arengi, J.T. and Ann Badry. 1994. Steamhorse Golf and Recreation Resort – Response to Comments from Coast Garibaldi Health Unit Regarding Pacific Hydrology Consultants Ltd. Report of October 25, 1993. Pacific Hydrology Consultants Ltd. letter-report dated May 30, 1994, prepared for Eagle Horse Properties Ltd.

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Brown, W.L. 1972. Groundwater Development Proposed Cheakamus River Hatchery for Fishery Services, Canadian Department of the Environment. Groundwater Section N.T.S. File 92G/14 #4

Buchanan, R.G. 1991. Geotechnical Investigation Squamish to Whistler Village, Preliminary Planning and Design. Geotechnical and Materials Engineering Branch, B.C. Ministry of Transportation and Highways.

Buchanan, R.G. 1985. Sand and Gravel Resource Mapping. B.C. Ministry of Transportation and Highways.

Camsell, C. 1917. Geology along the Route Traversed by the Pacific Great Eastern Railway between Squamish and Lillooet. Geological Survey of Canada Publication No. 1711.

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Piteau Associates Engineering Ltd. 1995. Groundwater Source Study - Phase II and III, Test Well Program and Final Assessment, District of Squamish, B.C.

AQUIFER CLASSIFICATION AND RANKING

AQUIFER LOCATION: Squamish, B.C.

REFERENCE NUMBER: **0401**

CLASSIFICATION: IIA **RANKING: 13**

Classification Component: (II) Moderate level of development. Moderate demand and high yield.
Vulnerability: (A) High vulnerability to contamination.

Ranking Component:	Value
Productivity:	3
Vulnerability:	3
Size:	2
Demand:	2
Type of Use:	3
Quality Concerns:	0
Quantity Concerns:	0
Total	**13**

Appendix B
Analytical Results of Organic and Inorganic Analyses From Groundwater Samples

Table 1. Groundwater Analytical Results - Organic Parameters

Hydrogeological Assessment at BC Rail Site for the FortisBC EGP Project

Chemical Name	s	Long-term Chronic WQG[b]	Short-term Acute WQG[c]	20MW-04D		20MW-04S		20MW-05		20MW-06		20MW-07		20MW-08		20MW-09		20MW-10D		RPD
Sample ID		BC WQG Freshwater Aquatic Life[a]		20MW-04D_121620	20MW-04D_031521	20MW-04S_121620	20MW-04S_031521	20MW-05_121220	20MW-05_031521	20MW-06_121220	20MW-06_031521	20MW-07_121620	20MW-07_031521	20MW-08_121720	20MW-08_031521	20MW-09_121720	20MW-09_031521	20MW-10D_121720	QA2_121720	
Sample Date				16-Dec-20	15-Mar-21	16-Dec-20	15-Mar-21	12 Dec 2020	15-Mar-21	12-Dec-20	15-Mar-21	16-Dec-20	15-Mar-21	17-Dec-20	15-Mar-21	17-Dec-20	15-Mar-21	17-Dec-20	17-Dec-20	
Laboratory Certificate Sample #				VA20C3660-004	VA21A4849-004	VA20C3660-005	VA21A4849-005	VA20C3657-001	VA21A4849-006	VA20C3657-002	VA21A4849-007	VA20C3659-001	VA21A4849-008	VA20C3659-002	VA21A4849-009	VA20C3660-003	VA21A4849-010	VA20C3659-003	VA20C3659-005	
BTEX / VPH																				
Benzene	µg/L	40	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Ethylbenzene	µg/L	0.2	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Toluene	µg/L	0.5	NS	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	NC
VH	µg/L	NS	NS	< 100	NT	< 100	NT	NT	NT	NT	NT	< 100	NT	< 100	NT	< 100	NT	< 100	< 100	NC
VPH	µg/L	NS	NS	< 100	NT	< 100	NT	NT	NT	NT	NT	< 100	NT	< 100	NT	< 100	NT	< 100	< 100	NC
Xylenes, Total	µg/L	NS	NS	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.75	NC
Extractable Petroleum Hydrocarbons																				
EPH C10-C19	µg/L	NS	NS	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	NC
EPH C19-C32	µg/L	NS	NS	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	NC
HEPH C19-C32	µg/L	NS	NS	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	NC
LEPH C10-C19	µg/L	NS	NS	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	< 250	NC
Polycyclic Aromatic Hydrocarbons																				
1-Methylnaphthalene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.021	0.030	NC
2-Methylnaphthalene	µg/L	NS	NS	0.019	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.013	< 0.010	< 0.010	NC
Acenaphthene	µg/L	6	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.013	< 0.010	< 0.010	< 0.020	< 0.030	NC
Acridine	µg/L	3	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.020	< 0.010	NC
Anthracene	µg/L	4	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC
Benzo(a)anthracene	µg/L	0.1	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC
Benzo(a)pyrene	µg/L	0.01	NS	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	NC
Benzo(b&j)fluoranthene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.012	< 0.010	< 0.010	NC
Benzo(g,h,i)perylene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC
Benzo(k)fluoranthene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC
Chrysene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.015	< 0.010	< 0.010	NC
Dibenz(a,h)anthracene	µg/L	NS	NS	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	NC
Fluoranthene	µg/L	4	NS	< 0.010	< 0.010	0.012	< 0.010	< 0.010	0.01	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.022	< 0.010	< 0.010	NC
Fluorene	µg/L	12	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.036	0.053	NC
Indeno(1,2,3-cd)pyrene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC
Naphthalene	µg/L	1	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	0.273	0.329	19%
Phenanthrene	µg/L	0.3	NS	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	0.024	NC
Pyrene	µg/L	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.012	< 0.010	0.02	< 0.010	< 0.010	NC
Quinoline	µg/L	3.4	NS	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.075	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	NC
VOCs																				
1,1,1,2-tetrachloroethane	µg/L	110	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,1,1-trichloroethane	µg/L	21	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,1,2,2-tetrachloroethane	µg/L	NS	NS	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	NC
1,1,2-trichloroethane	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,1-dichloroethane	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,1-dichloroethene	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,2-dichlorobenzene	µg/L	0.7	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,2-dichloroethane	µg/L	100	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,2-dichloropropane	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,3-dichlorobenzene	µg/L	150	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
1,4-dichlorobenzene	µg/L	26	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Bromodichloromethane	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Bromoform	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Carbon tetrachloride	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Chlorobenzene	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Chlorodibromomethane	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Chloroform	µg/L	1.8	NS	**3.82**	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
cis-1,2-dichloroethene	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
cis-1,3-dichloropropene	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Dichloromethane	µg/L	NS	NS	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 0.50	NC
Methyl tert-butyl ether (MTBE)	µg/L	NS	3,400	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Styrene	µg/L	72	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Tetrachloroethene	µg/L	110	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
trans-1,2-dichloroethene	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
trans-1,3-dichloropropene	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Trichloroethene	µg/L	20	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Trichlorofluoromethane	µg/L	NS	NS	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC
Vinyl chloride	µg/L	NS	NS	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	NC

Chemical Name	20MW-10D		RPD	20MW-10S		20MW-11		MW19-01		RPD	MW19-01	MW19-03		MW06-34							RPD	MW06-34
Sample ID	20MW-10D_031521	QA3_031521		20MW-10S_121720	20MW-10S_031521	20MW-11_121220	20MW-11_031521	MW19-01_121620	QA1_121620		MW19-01_031521	MW19-03_121620	MW19-03_031521	MW06-34	MW06-34	MW06-34	MW06-34	MW06-34_011421	MW06-34_031521	QA4_031521		MW06-34-TOP_031521
Sample Date	15-Mar-21	15-Mar-21		17-Dec-20	15-Mar-21	12-Dec-20	15-Mar-21	16-Dec-20	17-Dec-20		15-Mar-21	16-Dec-20	15-Mar-21	06-Jan-11	25-Jul-13	25-Jul-13	06-Feb-14	14-Jan-21	15-Mar-21	15-Mar-21		15-Mar-21
Laboratory Certificate Sample #	VA21A4849-011	VA21A4849-014		VA20C3659-004	VA21A4849-012	VA20C3657-003	VA21A4849-013	VA20C3660-001	VA20C3660-006		VA21A4849-002	VA20C3660-002	VA21A4849-003	W475	W890	W891	W1033	VA21A0730-001	VA21A4849-001	VA21A4849-015		VA21A4849-016
BTEX / VPH																						
Benzene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50
Ethylbenzene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	**3.32**	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50
Toluene	< 0.40	< 0.40	NC	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	NC	< 0.40	< 0.40	< 0.40	**0.11**	< 0.50	< 0.50	< 0.50	**0.60**	< 0.40	< 0.40	NC	< 0.40
VH	NT	NT	NC	< 100	NT	NT	NT	< 100	< 100	NC	NT	< 100	NT	< 100	< 100	< 100	< 100	< 100	NT	NT	NC	NT
VPH	NT	NT	NC	< 100	NT	NT	NT	< 100	< 100	NC	NT	< 100	NT	< 100	< 100	< 100	< 100	< 100	NT	NT	NC	NT
Xylenes, Total	< 0.50	< 0.50	NC	< 0.75	< 0.50	< 0.75	< 0.50	< 0.75	< 0.75	NC	< 0.50	< 0.75	< 0.50	< 0.71	< 0.75	< 0.75	< 0.75	0.51	< 0.50	< 0.50	NC	< 0.50
Extractable Petroleum Hydrocarbons																						
EPH C10-C19	< 250	< 250	NC	< 250	< 250	< 250	< 250	< 250	< 250	NC	< 250	< 250	< 250	NT	NT	NT	NT	510	580	580	0%	NT
EPH C19-C32	< 250	< 250	NC	< 250	< 250	< 250	< 250	< 250	< 250	NC	< 250	< 250	< 250	NT	NT	NT	NT	< 250	< 250	< 250	NC	NT
HEPH C19-C32	< 250	< 250	NC	< 250	< 250	< 250	< 250	< 250	< 250	NC	< 250	< 250	< 250	NT	NT	NT	NT	< 250	< 250	< 250	NC	NT
LEPH C10-C19	< 250	< 250	NC	< 250	< 250	< 250	< 250	< 250	< 250	NC	< 250	< 250	< 250	NT	NT	NT	NT	330	430	420	2%	NT
Polycyclic Aromatic Hydrocarbons																						
1-Methylnaphthalene	0.096	0.108	12%	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	8.73	7.13	6.03	17%	NT
2-Methylnaphthalene	0.019	0.022	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.011	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	10.9	6.84	5.88	15%	NT
Acenaphthene	0.066	0.077	15%	< 0.010	< 0.010	< 0.010	0.012	< 0.010	< 0.010	NC	< 0.010	0.010	< 0.010	NT	NT	NT	NT	**85.5**	**70.5**	**79.4**	12%	NT
Acridine	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	< 2.80	< 2.00	1.91	NC	NT
Anthracene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	**6.15**	**4.58**	**5.14**	12%	NT
Benzo(a)anthracene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	**0.437**	**0.978**	**0.902**	8%	NT
Benzo(a)pyrene	< 0.0050	< 0.0050	NC	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	NC	< 0.0050	< 0.0050	< 0.0050	NT	NT	NT	NT	**0.120**	**0.194**	**0.164**	17%	NT
Benzo(b&j)fluoranthene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	0.176	0.235	0.23	2%	NT
Benzo(g,h,i)perylene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	0.034	0.037	0.04	8%	NT
Benzo(k)fluoranthene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	0.072	0.084	0.098	15%	NT
Chrysene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	0.440	1.09	0.928	16%	NT
Dibenz(a,h)anthracene	< 0.0050	< 0.0050	NC	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	NC	< 0.0050	< 0.0050	< 0.0050	NT	NT	NT	NT	0.0140	0.0199	0.0159	22%	NT
Fluoranthene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	**10.6**	**13**	**13**	0%	NT
Fluorene	0.138	0.16	15%	< 0.010	< 0.010	< 0.010	0.032	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	**37.4**	**32.9**	**32.9**	0%	NT
Indeno(1,2,3-cd)pyrene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	0.024	0.039	0.04	3%	NT
Naphthalene	0.583	0.623	7%	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	NC	< 0.050	< 0.050	< 0.050	NT	NT	NT	NT	**13.6**	**7.03**	**6.21**	12%	NT
Phenanthrene	0.058	0.068	NC	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	NC	< 0.020	< 0.020	< 0.020	NT	NT	NT	NT	**39.4**	**33.4**	**35.7**	7%	NT
Pyrene	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	NC	< 0.010	< 0.010	< 0.010	NT	NT	NT	NT	5.87	7.37	6.92	6%	NT
Quinoline	< 0.050	< 0.050	NC	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	NC	< 0.050	< 0.050	< 0.050	NT	NT	NT	NT	< 0.050	< 0.900	< 0.950	NC	NT
VOCs																						
1,1,1,2-tetrachloroethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,1,1-trichloroethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,1,2,2-tetrachloroethane	< 0.20	< 0.20	NC	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	NC	< 0.20	< 0.20	< 0.20	NT	NT	NT	NT	< 0.20	< 0.20	< 0.20	NC	< 0.20
1,1,2-trichloroethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,1-dichloroethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,1-dichloroethene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,2-dichlorobenzene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,2-dichloroethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,2-dichloropropane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,3-dichlorobenzene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
1,4-dichlorobenzene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Bromodichloromethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Bromoform	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Carbon tetrachloride	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Chlorobenzene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Chlorodibromomethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Chloroform	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
cis-1,2-dichloroethene	< 0.50	< 0.50	NC	< 0.50	< 0.50	1.06	2.21	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
cis-1,3-dichloropropene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Dichloromethane	< 1.0	< 1.0	NC	< 0.50	< 1.0	< 0.50	< 1.0	< 0.50	< 0.50	NC	< 1.0	< 0.50	< 1.0	NT	NT	NT	NT	< 0.50	< 1.0	< 1.0	NC	< 1.0
Methyl tert-butyl ether (MTBE)	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Styrene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Tetrachloroethene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
trans-1,2-dichloroethene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
trans-1,3-dichloropropene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Trichloroethene	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Trichlorofluoromethane	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	NC	< 0.50	< 0.50	< 0.50	NT	NT	NT	NT	< 0.50	< 0.50	< 0.50	NC	< 0.50
Vinyl chloride	< 0.40	< 0.40	NC	< 0.40	0.53	< 0.40	0.75	< 0.40	< 0.40	NC	< 0.40	< 0.40	< 0.40	NT	NT	NT	NT	< 0.40	< 0.40	< 0.40	NC	< 0.40

Notes:

Highlighting and bold indicates value exceeds a BC WQG for Long-Term Chronic Exposure

Highlighting indicates value exceeds BC WQG Short-Term Exposure

% = percent

< = less than

µg/L = microgram per litre

QA = field duplicate sample

DW = drinking water use

ID = identification

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

NC = RPD could not be calculated, as one or more results is less than or equal to 5 times the detection limit

NS = not specified

NT = not tested

RPD = relative percent difference

Parameter Acronyms

BTEX = benzene, toluene, ethylbenzene, xylenes

EPH = extractable petroleum hydrocarbons

HEPH = heavy extractable petroleum hydrocarbons

LEPH = light extractable petroleum hydrocarbons

VH = volatile hydrocarbon

VOC = volatile organic compound

VPH = volatile petroleum hydrocarbon

Table 2. Groundwater Analytical Results - Organic Parameters

Hydrogeological Assessment at BC Rail Site for the FortisBC EGP Project

Chemical Name	20MW-04D		20MW-04S		20MW-05		20MW-06		20MW-07		20MW-08		20MW-09	
	20MW-04D_121620	20MW-04D_031521	20MW-04S_121620	20MW-04S_031521	20MW-05_121220	20MW-05_031521	20MW-06_121220	20MW-06_031521	20MW-07_121620	20MW-07_031521	20MW-08_121720	20MW-08_031521	20MW-09_121720	20MW-09_031521
	16-Dec-20	15-Mar-21	16-Dec-20	15-Mar-21	12-Dec-20	15-Mar-21	12-Dec-20	15-Mar-21	16-Dec-20	15-Mar-21	17-Dec-20	15-Mar-21	17-Dec-20	15-Mar-21
	VA20C3660-004	VA21A4849-004	VA20C3660-005	VA21A4849-005	VA20C3657-001	VA21A4849-006	VA20C3657-002	VA21A4849-007	VA20C3659-001	VA21A4849-008	VA20C3659-002	VA21A4849-009	VA20C3660-003	VA21A4849-010
Dissolved Metals														
Aluminum (Al)	27.9	14.7	69.6	142	11.6	11.8	16.2	13.5	73.8	12.2	18.6	16.3	6.9	6.3
Antimony (Sb)	0.17	< 0.10	0.50	0.37	< 0.10	< 0.10	< 0.10	< 0.10	0.16	< 0.10	< 0.10	< 0.10	0.16	< 0.10
Arsenic (As)	0.47	1.67	0.32	0.47	0.48	0.84	0.66	0.62	1.79	1.01	1.38	1.19	0.99	0.88
Barium (Ba)	21.4	37.1	11.4	16	61.2	42.8	72.7	52.1	39.6	65.3	64.0	55.3	94.4	199
Beryllium (Be)	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Boron (Bo)	12	12	< 10	< 10	14	12	26	25	21	27	39	43	36	40
Cadmium (Cd)	0.0488	< 0.0050	0.0199	< 0.0050	0.0158	< 0.0050	0.0338	0.0066	0.0225	0.007	< 0.0050	< 0.0050	0.0408	0.0979
Calcium (Ca)	22600	28500	12400	20400	30800	25600	38400	28600	33200	31800	17700	18900	73000	94300
Chromium	0.37	0.59	0.68	1.01	0.42	0.59	0.73	0.84	0.65	0.9	1.31	1.2	0.28	0.23
Cobalt (Co)	0.53	0.41	0.54	0.25	2.56	0.29	2.99	0.23	0.80	0.33	0.86	0.33	1.58	2.64
Copper (Cu)	**4.77**	< 0.20	**5.89**	**16**	< 0.20	< 0.20	< 0.20	< 0.20	**1.01**	< 0.20	**0.33**	< 0.20	**0.38**	**0.44**
Iron (Fe)	**4110**	**26700 J**	61	28 J	**12200**	**18400 J**	**6560**	**16500 J**	**2090**	**18800 J**	**41900**	**32600 J**	45	490 J
Lead (Pb)	0.116	< 0.050	0.309	< 0.050	< 0.050	0.054	< 0.050	< 0.050	0.055	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
Lithium (Li)	3.8	4.8	< 1.0	< 1.0	4.0	2.5	2.4	1	< 1.0	< 1.0	< 1.0	< 1.0	1.8	< 1.0
Magnesium (Mg)	3500	3980	564	391	5000	3310	6340	5520	2830	4230	5530	5940	12600	24100
Manganese (Mn)	436	**870**	68.7	2.24	**1020**	482	**1050**	500	342	741	**1060**	**938**	**833**	**1420**
Mercury (Hg)	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Molybdenum (Mo)	5.13	0.292	1.53	1.54	1.12	0.168	1.15	0.117	3.82	0.229	0.993	0.719	0.848	0.297
Nickel (Ni)	1.58	< 0.50	0.61	0.71	2.09	< 0.50	2.71	< 0.50	1.50	< 0.50	0.91	< 0.50	2.90	4.78
Potassium (K)	3920	3550	1310	1400	3770	3140	3290	3030	2410	3060	2940	2940	2880	2340
Selenium (Se)	0.743	< 0.050	0.110	0.12	0.061	< 0.050	0.069	< 0.050	0.252	0.063	0.061	0.083	0.162	< 0.050
Silver (Ag)	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Sodium (Na)	31300	7360	3400	3650	9090	9380	6990	7400	6540	7950	8660	10300	4900	6080
Thallium (Tl)	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.017	< 0.010	0.012	< 0.010	< 0.010	< 0.010	< 0.020	0.015
Titanium (Ti)	0.45	0.7	0.78	< 0.30	0.31	< 0.30	0.42	0.34	1.18	0.34	0.65	0.61	< 0.30	< 0.30
Uranium (U)	0.527	0.037	0.084	0.072	0.094	0.035	0.187	0.06	0.507	0.05	0.050	0.047	0.537	0.127
Vanadium (V)	1.86	1.64	1.30	1.16	1.59	2.66	3.25	5.33	8.90	3.17	6.83	5.71	0.57	< 0.50
Zinc (Zn)	2.4	< 1.0	1.6	< 1.0	2.8	1.4	2.6	2	2.3	1.5	1.9	3.1	1.3	**11.9**
Hardness, Dissolved	70900	87600	33300	52500	97400	77600	122000	94100	94700	96800	67000	71600	234000	335000

Chemical Name	20MW-10D		20MW-10D		20MW-10S		20MW-11		MW19-01		MW19-01	MW19-03		MW06-34		
	20MW-10D_121720	QA2_121720	20MW-10D_031521	QA3_031521	20MW-10S_121720	20MW-10S_031521	20MW-11_121220	20MW-11_031521	MW19-01_121620	QA1_121620	MW19-01_031521	MW19-03_121620	MW19-03_031521	MW06-34_011421	MW06-34_031521	QA4_031521
	17-Dec-20	17-Dec-20	15-Mar-21	15-Mar-21	17-Dec-20	15-Mar-21	12-Dec-20	15-Mar-21	16-Dec-20	17-Dec-20	15-Mar-21	16-Dec-20	15-Mar-21	14-Jan-21	15-Mar-21	15-Mar-21
	VA20C3659-003	VA20C3659-005	VA21A4849-011	VA21A4849-014	VA20C3659-004	VA21A4849-012	VA20C3657-003	VA21A4849-013	VA20C3660-001	VA20C3660-006	VA21A4849-002	VA20C3660-002	VA21A4849-003	VA21A0730-001	VA21A4849-001	VA21A4849-015
Dissolved Metals																
Aluminum (Al)	8	6.2	10.6	9.7	38.3	23.6	22.7	7.6	7	8	6.5	9.5	9.6	451	330	332
Antimony (Sb)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.13	0.1	< 0.10
Arsenic (As)	< 0.10	0.1	0.1	< 0.10	0.75	0.8	0.26	0.24	0.75	0.63	0.35	0.13	< 0.10	**15.6**	**8.27**	**8.71**
Barium (Ba)	28.1	27.2	20.5	20.6	71.9	58.2	49.4	42	42.3	43.3	21.8	34.6	32.5	32.3	30.3	30.5
Beryllium (Be)	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Boron (Bo)	15	14	12	12	35	44	35	22	17	17	18	18	23	< 10	< 10	< 10
Cadmium (Cd)	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0298	0.0057	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0067	< 0.0050	< 0.0050
Calcium (Ca)	20800	19000	13900	14100	31500	42600	23200	28900	18600	18300	25500	19000	18900	12800	11700	12000
Chromium	0.4	0.42	0.95	0.91	2.29	2.05	1.16	0.52	0.35	0.27	0.46	0.53	0.53	6.42	3.9	3.8
Cobalt (Co)	0.24	0.25	< 0.10	< 0.10	2.43	0.5	0.58	1.14	0.29	0.33	0.11	< 0.10	< 0.10	1.89	1.77	1.83
Copper (Cu)	**0.47**	< 0.20	< 0.20	< 0.20	**0.23**	< 0.20	**0.25**	< 0.20	< 0.20	**0.24**	< 0.20	< 0.20	< 0.20	**4.40**	**2.72**	**2.87**
Iron (Fe)	**24100**	**24100**	**27100 J**	**27500 J**	**13000**	**27100 J**	**15700**	**12600 J**	**12700**	**10000**	**20100 J**	**21600**	**20600 J**	**25200**	**12300 J**	**12500 J**
Lead (Pb)	< 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	**0.691**	**0.476**	**0.476**
Lithium (Li)	3.1	3	2	2	1.4	< 1.0	< 1.0	< 1.0	4	3.8	4.3	2.2	2.3	< 1.0	< 1.0	< 1.0
Magnesium (Mg)	6560	6400	6900	6830	7640	11600	6770	8470	2830	2740	4900	4190	4230	1970	1790	1850
Manganese (Mn)	**868**	**830**	476	484	**1140**	**1210**	507	397	475	469	643	627	599	602	504	508
Mercury (Hg)	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0062	0.0056	< 0.0050
Molybdenum (Mo)	0.804	0.809	0.306	0.323	0.383	0.176	0.285	0.284	0.323	0.429	0.098	0.177	0.082	0.063	0.054	0.059
Nickel (Ni)	0.87	0.8	< 0.50	< 0.50	2.51	< 0.50	0.78	0.66	0.52	0.55	< 0.50	< 0.50	< 0.50	1.32	0.94	0.98
Potassium (K)	3410	3510	2760	2840	2970	3310	2720	2710	2910	2970	3630	3660	3460	2180	1850	1900
Selenium (Se)	< 0.050	< 0.050	< 0.050	< 0.050	0.118	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	**3.20**	0.065	0.07
Silver (Ag)	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.012	< 0.010	< 0.010
Sodium (Na)	8240	8260	6820	6990	5530	7270	4710	4020	8030	9020	8640	6020	6130	2310	1870	1920
Thallium (Tl)	< 0.010	< 0.010	< 0.010	< 0.010	0.012	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Titanium (Ti)	< 0.30	< 0.30	< 0.30	0.34	1.62	0.83	0.44	< 0.30	< 0.30	0.34	0.36	0.32	0.37	6.35	3.88	4.07
Uranium (U)	0.023	0.025	< 0.010	< 0.010	0.112	0.049	0.033	0.018	0.063	0.09	0.033	< 0.010	< 0.010	0.121	0.093	0.094
Vanadium (V)	1	0.97	1.83	1.9	9.40	10.1	5.38	2.52	1.1	0.87	1.76	3.60	3.6	2.99	1.94	2.04
Zinc (Zn)	**10.6**	**9.8**	1.5	1.4	**7.5**	4.8	2.6	6.4	2.2	3.7	< 1.0	1.1	< 1.0	< 1.0	1.7	1.6
Hardness, Dissolved	79000	73700	63100	63300	110000	154000	85700	107000	58000	57000	83800	64700	64600	40100	36600	37600

Notes:

Highlighting and bold indicates value exceeds a BC WQG for Long-Term Chronic Exposure

Highlighting indicates value exceeds BC WQG Short-Term Exposure

% = percent

< = less than

µg/L = microgram per litre

AW = aquatic life water use fw=fresh water m=marine e=estuarine

CSR = contaminated sites regulation

QA = field duplicate sample

DW = drinking water use

ID = identification

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

NC = RPD could not be calculated, as one or more results is less than or equal to 5 times the detection limit

NS = not specified

NT = not tested

RPD = relative percent difference

Iron Standard is applicable only to a Site used for the following activities outlined in Schedule 2 of the CSR: A6, A7, A8, A11, C1, C2, C3, C4, C6, D2, D3, D5, D6, E4, or H14. Standard is also applicable for items H11 or H20 if at least one of the aforementioned activities have also occurred onsite.

Manganese standard is applicable only to a Site used for the following activities outlined in Schedule 2 of the CSR: B1, C1, C3, C4, D2, D3, D5, D6, E4, H3, or H14. Standard is also applicable for items H11 or H20 if at least one of the aforementioned activities or purposes have also occurred onsite.

Table 1. Groundwater Analytical Results - Organic Parameters

Hydrogeological Assessment at BC Rail Site for the FortisBC EGP Project

Chemical Name	Units	Highest Concentrations from AECs 13 & 31D CofC Max Concentrations	AW Standards for GW: 2016 BC CSR AW Standards	AW Standards for GW: 2020 BC CSR AW Standards Freshwater	AW Standards for GW: 2020 BC CSR AW Standards Marine	DW Standards for GW: 2016 BC CSR DW Standards	DW Standards for GW: 2020 BC CSR DW Standards	MW06-34
							Sample ID	MW06-34_12220
							Sample Date	22-Dec-20
							Laboratory Certificate Sample #	VA20C4120-001
BTEX / VPH								
Benzene	µg/L	5	4000	400	1000	5	5	< 0.50
Ethylbenzene	µg/L	7.57	2000	2000	2500	2.4	140 [b]	< 0.50
Toluene	µg/L	5	390	5	2000	24	60 [b]	< 0.40
VH	µg/L	NS	NS	15000	15000	15000	15000	< 100
VPH	µg/L	NS	1500	1500	1500	NS	NS	< 100
Xylenes, Total	µg/L	5	NS	300	NS	300	90 [b]	< 0.75
Extractable Petroleum Hydrocarbons								
EPH C10-C19	µg/L	NS	5000	5000	5000	5000	5000	1480
EPH C19-C32	µg/L	NS	NS	NS	NS	NS	NS	1260
HEPH C19-C32	µg/L	NS	NS	NS	NS	NS	NS	1090
LEPH C10-C19	µg/L	1350	500	500	500	NS	NS	**1050**
Polycyclic Aromatic Hydrocarbons								
1-Methylnaphthalene	µg/L	NS	NS	NS	NS	NS	5.5	**7.56**
2-Methylnaphthalene	µg/L	NS	NS	NS	NS	NS	15	6.88
Acenaphthene	µg/L	NS	60	60	60	NS	250	**143**
Acridine	µg/L	NS	0.5	0.5	0.5	NS	NS	≤ 3.50
Anthracene	µg/L	3.93	1	1	1	NS	1000	**30.8**
Benzo(a)anthracene	µg/L	3.39	1	1	1	NS	0.07	**7.37**
Benzo(a)pyrene	µg/L	0.04	0.1	0.1	0.1	0.01	0.01 [b]	**1.29**
Benzo(b&j)fluoranthene	µg/L	NS	NS	NS	NS	NS	0.07	**2.22**
Benzo(g,h,i)perylene	µg/L	NS	NS	NS	NS	NS	NS	0.238
Benzo(k)fluoranthene	µg/L	NS	NS	NS	NS	NS	NS	0.804
Chrysene	µg/L	2.8	1	1	1	NS	7	≤ 10.0
Dibenz(a,h)anthracene	µg/L	NS	NS	NS	NS	NS	0.01	**0.106**
Fluoranthene	µg/L	2.04	2	2	2	NS	150	**89.4**
Fluorene	µg/L	NS	120	120	120	NS	150	79.4
Indeno(1,2,3-cd)pyrene	µg/L	NS	NS	NS	NS	NS	NS	0.219
Naphthalene	µg/L	14.3	10	10	10	NS	80	2.49
Phenanthrene	µg/L	3.36	3	3	3	NS	NS	**171**
Pyrene	µg/L	1.26	0.2	0.2	0.2	NS	100	**74.3**
Quinoline	µg/L	NS	34	34	34	NS	0.05	≤ 1.00
VOCs								
1,1,1,2-tetrachloroethane	µg/L	NS	NS	NS	NS	NS	6	< 0.50
1,1,1-trichloroethane	µg/L	NS	NS	NS	NS	NS	8000	< 0.50
1,1,2,2-tetrachloroethane	µg/L	NS	NS	NS	NS	NS	0.8	< 0.20
1,1,2-trichloroethane	µg/L	NS	NS	NS	NS	12	3	< 0.50
1,1-dichloroethane	µg/L	NS	NS	NS	NS	NS	30	< 0.50
1,1-dichloroethene	µg/L	NS	NS	NS	NS	NS	14 [b]	< 2.25
1,2-dichlorobenzene	µg/L	NS	NS	7	420	NS	200 [b]	< 0.50
1,2-dichloroethane	µg/L	NS	NS	1000	1000	NS	5	< 0.50
1,2-dichloropropane	µg/L	NS	NS	NS	NS	NS	4.5	< 0.50
1,3-dichlorobenzene	µg/L	NS	NS	1500	1500	NS	NS	< 0.50
1,4-dichlorobenzene	µg/L	NS	NS	260	260	NS	5 [b]	< 0.50
Bromodichloromethane	µg/L	NS	NS	NS	NS	NS	100 [b]	< 0.50
Bromoform	µg/L	NS	NS	NS	NS	NS	100 [b]	< 0.50
Carbon tetrachloride	µg/L	NS	NS	130	130	NS	2 [b]	< 0.50
Chlorobenzene	µg/L	NS	NS	13	250	NS	80 [b]	< 0.50
Chlorodibromomethane	µg/L	NS	NS	NS	NS	NS	100 [b]	< 0.50
Chloroform	µg/L	NS	NS	20	20	NS	100 [b]	< 0.50
cis-1,2-dichloroethene	µg/L	NS	NS	NS	NS	370	8	< 0.50
cis-1,3-dichloropropene	µg/L	NS	NS	NS	NS	NS	NS	< 0.50
Dichloromethane	µg/L	NS	NS	980	980	NS	50 [b]	0.63
Methyl tert-butyl ether (MTBE)	µg/L	NS	NS	34000	4400	NS	95	< 0.50
Styrene	µg/L	NS	NS	720	720	NS	800	< 0.50
Tetrachloroethene	µg/L	NS	1100	1100	1100	30	30 [b]	< 0.50
trans-1,2-dichloroethene	µg/L	NS	NS	NS	NS	NS	80	< 0.50
trans-1,3-dichloropropene	µg/L	NS	NS	NS	NS	NS	NS	< 0.50
Trichloroethene	µg/L	32.2	200	200	200	5	5 [b]	< 0.50
Trichlorofluoromethane	µg/L	NS	NS	NS	NS	NS	1000	< 0.50
Vinyl chloride	µg/L	3.7	NS	NS	NS	2	2	< 0.40

[a] BC Environmental Management Act "Contaminated Sites Regulation (CSR)." BC REG 375/96 O.C. 1480/96 includes amendments up to B.C. Reg 13/2019, January 2019

[b] Standard is set to the 2014 Health Canada "Guidelines for Canadian Drinking Water Quality" for the substance

Notes:

Highlighting and bold indicates value exceeds a BC CSR 2020 standard.

Highlighting indicates value exceeds a 2016 BC CSR standard.

Underline indicates value is non-detect and detection limit exceeds one applicable standard.

% = percent

< = less than

µg/L = microgram per litre

AW = aquatic life water use   fw=fresh water m=marine e=estuarine

CSR = contaminated sites regulation

QA = field duplicate sample

DW = drinking water use

ID = identification

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

NC = RPD could not be calculated, as one or more results is less than or equal to 5 times the detection limit

NS = not specified

NT = not tested

RPD = relative percent difference

Parameter Acronyms

LNAPL =

BTEX = benzene, toluene, ethylbenzene, xylenes

EPH = extractable petroleum hydrocarbons

HEPH = heavy extractable petroleum hydrocarbons

LEPH = light extractable petroleum hydrocarbons

VH = volatile hydrocarbon

VOC = volatile organic compound

VPH = volatile petroleum hydrocarbon