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DISTRICT OF SQUAMISH – WATER MASTER PLAN
LONG-TERM GROUNDWATER SUPPLY STRATEGY UPDATE

1.0 INTRODUCTION

The objectives of the Long-Term Groundwater Supply Strategy Update were to review the capacity of the Powerhouse Springs Well Field and the Ring Creek Aquifer, assess potential alternative groundwater supply options, and identify considerations for long-term operation and maintenance of the well field. These objectives were established in the context of future demand for the District of Squamish (the District) water supply system and the associated future population estimates. The supply strategy review consisted of the following components:

- Review of prior reports on the Ring Creek Aquifer and its long-term supply capacity
- Assessment of potential alternative groundwater sources
- Identification of considerations for long-term operation and maintenance of the well field
- Development of preliminary cost estimates for long-term supply strategies

The results of the Update are discussed below. For limitations of this study, please refer to Section 8.0.

2.0 RING CREEK AQUIFER SUPPLY

The Powerhouse Springs Well Field is situated at the western limit of Aquifer 397 (Ring Creek Aquifer; see Figure 2 and Attachment 2). The aquifer consists of the saturated portion of permeable glaciofluvial sediments within a paleochannel that was deposited on the granitic basement rock (Piteau 2014a). The aquifer is inferred to extend beneath the footprint of the Ring Creek Lava Flow, and it is understood to be mostly unconfined, with some confinement in deeper portions of the aquifer provided by discontinuous silt horizons (Piteau 2014a). The upstream extent of the aquifer remains uncertain, but it is believed to reach as far east as the confluence of the Mamquam River and Skookum Creek, and potentially further upstream (Piteau 2014a).

Groundwater flows through Aquifer 397 (Ring Creek Aquifer) in a westerly direction, with total flow through the aquifer estimated to be approximately 800 L/s (Piteau 2014a). This value is supported by basic hydrogeological calculations completed by WSP using documented aquifer parameters. The aquifer parameters estimated by Piteau (2014) and supported by KWD (2019a) are as follows:

- transmissivity on the order of $2x10^{-2}$ m^2/s
- hydraulic conductivity on the order of $6x10^{-4}$ m/s
- storativity ranging between $7x10^{-5}$ and $2x10^{-1}$

Aquifer 397 (Ring Creek Aquifer) is located upgradient and east of Aquifer 398 (referred to here as the “Lower Mamquam Aquifer”), with the Lower Mamquam Aquifer also being comprised of surficial sediments.

WSP reviewed pumping data from the District’s SCADA system for 2018 to 2022 and observed data quality issues including missing data for Wells #1 and #2 (all years), transcription issues (i.e., erroneous repeat values) for Well #7 in 2021, and transcription issues for all wells in 2022. Consequently, WSP obtained Maximum Day Demand (MDD) and Average Day Demand (ADD) calculations from an alternative dataset provided by the District. The dataset was developed from a combined flow meter immediately downstream of the Powerhouse Springs Well Field, with the assumption that all water used within the District supply network was accounted for by this combined flow meter. The dataset consisted of total daily volumes of water pumped from the well field for each calendar day, thus representing average daily pumping rates. ADD was calculated for each calendar year by averaging all daily pumping rates. MDD was identified as the highest daily pumping rate for each calendar year. In 2022, MDD and ADD were estimated to be 223 L/s and 150 L/s, respectively. As of the writing of this report in mid-2023, MDD and ADD for 2023 are thus far 238 L/s and 154 L/s, respectively. Although the 2023 MDD represents 93% of the permitted withdrawal rate (255 L/s), the ADD represents only 60% of the permitted withdrawal rate (255 L/s). It is the ADD value (i.e., average day demand) to which the permitted withdrawal limit applies. Figure 1 presents anticipated demand along with projected growth for the District, assuming that the per capita water usage rates will remain similar to the 2013-2021 average. Projected growth rates were assumed to be 3% per year (District of Squamish 2023a). Based on these estimates, the ADD is projected to exceed the permitted withdrawal rate for Aquifer 397 (Ring Creek Aquifer) by 2040. This projection does not account for any additional effects as a function of climate change. Climate projections predict day-to-day weather will become more extreme, with more intense storms in the fall and winter, and warmer temperatures and longer drought periods in the summer. As a result, it is anticipated that there will be less infiltration of precipitation and associated groundwater recharge and higher water demand during summers in the future.

For comparison, the total aquifer yield estimated by Piteau (2014a) is 800 L/s. The total yield cannot be fully utilized because withdrawal rates must consider environmental flow needs of watercourses which are hydraulically connected to the aquifer. It is anticipated that as withdrawal rates increase in line with population growth, the effect of pumping on the aquifer and nearby watercourses will require additional study. To better understand the dynamics between withdrawal rates, aquifer recharge, and nearby watercourses, development of a numerical flow model may be necessary.

As per discussions with District officials as well as their consulting hydrogeologist (KWD 2023), Aquifer 397 (Ring Creek Aquifer) has a relatively high productivity and is expected to be able to support construction and pumping of more wells at the Powerhouse Springs Well Field. This is supported by an investigation on well interference conducted by KWD (2019a), which indicated that limited drawdown was observed in non-operational wells during consistent pumping at active wells, only tens of meters away. If more wells were installed at Powerhouse Springs, a request to increase the licensed withdrawal rate may be required. Installing additional wells at Powerhouse Springs is likely to be the most cost-effective option for increasing water supply capacity, given its high productivity.

Based on discussions with District staff as well as communications received by the District (District of Squamish 2023b), a key consideration for expansion in the well field at Powerhouse Springs is the conveyance infrastructure that links the well field to the supply network. It is WSP’s understanding that the majority of the water from the well field is pumped up to the University Zone (Opus 2015) to facilitate a gravity-feed supply approach to other neighbourhoods. Between Powerhouse Springs and the University Zone, there are three creek crossings; two over the Mamquam River, and one over Ring Creek. In addition to potential hazards posed by flood or seismic events, falling trees pose a hazard to the suspended supply line crossings. It is therefore recommended that expansion at the Powerhouse Springs Well Field consider redundancy (i.e., alternative supply lines) or upgrades in the conveyance infrastructure downstream of the well field.

Further to the above concerns regarding redundancy in conveyance infrastructure, which is understood to be a primary objective for the District, alternative groundwater supply locations may be a prudent consideration from a perspective of redundancy. These considerations are discussed further below.

3.0 ASSESSMENT OF POTENTIAL ALTERNATIVE GROUNDWATER SUPPLY OPTIONS

Although Aquifer 397 (Ring Creek Aquifer) is considered to have a high productivity and is expected to satisfy the District’s growing demand for more than 15 years based on current permits, a seismic event or major storm event may cause damage to the existing conveyance infrastructure; specifically the crossings of the Mamquam River and Ring Creek. To support system redundancy and improve resiliency of the water system, the District could consider alternative groundwater supply which does not originate from Aquifer 397 (Ring Creek Aquifer). Three options for alternative groundwater supply were considered by WSP:

- existing water wells that are owned by the District and completed in other aquifers
- new water wells in other aquifers where groundwater supply is inferred to be available based on review of existing well records and mapped aquifers
- new water wells in prospective aquifers based on available geological information

The alternative groundwater supply options are discussed further below in Sections 3.1 through 3.3.

3.1 New Supply from Existing Water Wells

The District of Squamish owns multiple water wells outside of Aquifer 397 (Ring Creek Aquifer) which are used for irrigation purposes, or were drilled for previous groundwater resource studies (e.g., Piteau 1995). District water wells, in addition to other wells or boreholes of note, are listed below in Table 1. These wells and boreholes are also shown on Figure 2.

Table 1: Wells and Boreholes of Note in the Squamish Area

Well / Borehole Name	Current Usage	Year Installed	License Status	Estimated Well Yield[a] (USgpm)	Notes
Hendrickson Well	Irrigation	2000	Unlicensed	500	Currently in use by District.
Centennial Well	Irrigation	1977	Unlicensed	50	Currently in use by District.
Cemetery Well	Irrigation	1998	Unlicensed	100	Currently in use by District.
Piteau TH-1 Well	None	1994	Unlicensed	220[b]	Main candidate identified for additional groundwater supply outside of Ring Creek Aquifer (Piteau 1995). Located near confluence of Mamquam and Mashiter. Piteau TH-4 borehole located nearby.
Piteau TH-2 Borehole	N/A	1994	N/A	N/A	Tests conducted during drilling with casing bottom left open. No well installed. Use for geological reference only. Located on Government Road near Watershed Grill.
Piteau TH-3 Borehole	N/A	1994	N/A	N/A	Tests conducted during drilling with casing bottom left open. No well installed. Use for geological reference only. Located near 42081 Ross Road.
Newport Ridge Well	Unknown	1994	Unlicensed	902	Identified in cross-section by Piteau (1995). Status unknown. Use for geological reference only.

Notes:
a. Estimated yield is based on driller's preliminary observation and should be considered an approximation.
b. Value obtained from pumping test data (Piteau 1995).

Although the District's operational wells listed in Table 1 (i.e., Hendrickson, Centennial, and Cemetery Wells) are currently being used for irrigation purposes, a preliminary review of their potential use for drinking water was completed by WSP. This preliminary review also included the Piteau TH-1 well. The review was conducted from a hydrogeological perspective and does not consider applicable infrastructure upgrades that may be required to connect the wells to the District's distribution system. Water quality data were obtained from the District for the Hendrickson Well and the Piteau TH-1 Well, while data for the Centennial and Cemetery Wells were retrieved from the Groundwater Wells database (see Section 3.2). For each well, only one sampling date was observed (see Attachment 1). WSP screened the water quality data against the Guidelines for Canadian Drinking Water Quality (GCDWQ) and the BC Contaminated Sites Regulation Drinking Water Standard (CSR-DW), as presented in Attachment 1. Results from the screening indicated that the analytical report for each of the four wells contained one or more parameter at concentrations that were greater than the most conservative water quality criteria. A summary of the results is described below:

- Hendrickson Well:
  - GCDWQ exceedance observed for total manganese based on the maximum allowable concentration (MAC) and the aesthetic objective (AO)
- Centennial Well:
  - GCDWQ exceedance observed for pH (value below recommended range)
  - GCDWQ exceedances observed for total and dissolved iron based on the aesthetic objective (AO)
  - the detection limit for total manganese was above the GCDWQ aesthetic objective
- Cemetery Well:
  - GCDWQ exceedance observed for pH (value below recommended range)
- Piteau TH-1 Well:
  - GCDWQ exceedance observed for pH (value below recommended range)
  - GCDWQ exceedances observed for total aluminum, total iron, and total manganese based on the aesthetic objective (AO)
  - the detection limits for total tungsten and total vanadium were above the CSR-DW guideline

Although data collected from the Hendrickson Well were relatively recent (2018), data for the other wells were reported at the time of drilling and well installation. For the Centennial, Cemetery, and Piteau TH-1 wells, data were collected in 1977, 1998, and 1994, respectively. As long durations have elapsed since these sampling dates, the data for these three wells may no longer be representative. No microbiological testing data are available for any of the wells.

If these wells are to be considered for drinking water supply, an assessment of current groundwater quality and yield should be completed, together with a downhole camera inspection and/or well redevelopment, if required. The assessment should include sampling and analysis for a comprehensive suite of drinking water parameters and a groundwater at risk of containing pathogens (GARP) assessment to identify what treatment, if any, may be required. Although pH is observed to be slightly below the GCDWQ guidelines for three of the locations, the District has noted that on-site pH adjustment is feasible and currently being conducted in other municipalities.

The Cemetery well is estimated to be a minimum of 240 m away from the nearby cemetery. Although this is double the minimum 120 m distance specified in the BC Health Hazards Regulation, further assessment is recommended if the well were to be considered for municipal usage.

3.2 New Supply Based on Aquifer and Well Records

New drilling locations for alternative groundwater supply are commonly proposed using existing data, such as aquifer maps and well records, and later verified by means of intrusive field investigation (i.e., drilling test wells). To assess the potential for new groundwater supply locations in the Squamish area, WSP conducted a review of the Provincial Groundwater Wells and Aquifers (GWELLS) database (BC ENV). The database provides information on the properties and boundaries of known aquifers in British Columbia based on existing data and studies, as well as drilling records for water wells that have been installed and are registered with the Province.

A summary of mapped aquifers in the Squamish area is presented below in Table 2, including descriptions of the aquifer materials and provincial aquifer classifications. The locations of the aquifers are shown on Figure 2 and detailed factsheets for the aquifers are presented in Attachment 2.

Table 2: Mapped Aquifers in the Squamish Area (BC ENV)

Aquifer Number	Year Mapped	Location	Material	Aquifer Classification[(a)]	Vulnerability[(b)]	Productivity	Density of Existing Wells
396	2007	Squamish-Cheakamus Confluence	Sand and Gravel	IIIA	High	High	Low
397	2007	Powerhouse Springs (Ring Creek Aquifer)	Sand and Gravel	IB	Moderate	High	High
398	2007	Lower Mamquam River	Sand and Gravel	IIIA	High	High	High
399	2007	Squamish River - Downtown to Brackendale	Sand and Gravel	IIIA	High	High	Low
400	2007	Cheekye Fan	Sand and Gravel	IIIB	Moderate	Moderate	Low
401	2000	Cheakamus River (Paradise Valley)	Sand and Gravel	IIA	High	High	Moderate
402	2020	Stawamus River Valley (Valleycliffe)	Sand and Gravel	IIIA	High	High	Low

Notes:
a. Aquifer Classifications:
Level of Development: (I) Heavy; (II) Moderate; (III) Light
Vulnerability: (A) High; (B) Moderate; (C) Low
b. Vulnerability to sources of contamination at the ground surface

Information in the GWELLS database is generally considered reliable; however, historic well records can be prone to record-keeping or digitization error, and as such, the review of water wells is most useful at a high-level for identifying drilling areas which could be considered for future development. A summary of well records in the Squamish area, grouped by location, is shown below in Table 3. The well record locations are shown on Figure 2 along with the aquifer boundaries.

Table 3: Summary of Water Well Groupings in the Squamish Area (BC ENV)

Assigned Grouping Name	Corresponding Aquifer Number	Inferred Depositional Environment[(a)]	Number of Records[(b)] Observed	Maximum Drilling Depth Reported (mbgs)[(c)]	Coarse Gravel Units [(d)] Present?
Upper Squamish	N/A	Floodplain	23	146	No
Upper Cheakamus	401	Glaciofluvial, floodplain	9	52	**Yes**
Mid Cheakamus	401	Floodplain	36	46	**Yes**
Lower Cheakamus	401	Floodplain	9	32	**Yes**
Cheekye	400	Fan deposits, floodplain	31	73	**Yes**
Brackendale	399 / 400	Floodplain	15	28	No
Lower Mamquam	398	Glaciofluvial, floodplain	6	44	**Yes**
Finch Drive	398 / 399	Floodplain	6	128	No

Notes:
a. Water quality inferred to be superior in glaciofluvial environments than in floodplain environments, due to lower solute concentrations.
b. Individual water well record accuracy is not confirmed. Confirmation of suitable water supply requires intrusive investigation.
c. mbgs = metres below ground surface
d. Presence of wells-sorted coarse gravel units is preferential for suitable water supply, however, thickness and lateral continuity of the unit must be considered.
e. Data retrieved and analyzed May 2023

To facilitate long-term monitoring of aquifers with significant usage and/or high vulnerability, the Province has developed a network of observation wells with remote data transmission capabilities. Data from these wells are accessible on the Provincial Groundwater Observation Well Network (PGOWN) webpage. Two of these observation wells are located in the Squamish area:

- OW454 – Located in Aquifer 401, or in the Mid Cheakamus well grouping (i.e., Paradise Valley)
- OW483 – Located in Aquifer 397, at the western terminus of the Ring Creek Aquifer (i.e., upgradient of the Powerhouse Springs Well Field)

The well groupings in Table 3 may serve as an indicator for areas where additional groundwater supply may be achievable; however, the potential for additional available supply must also consider the existing aquifer users as well as environmental flow needs in surface water bodies. Furthermore, although many well records are observed in the Squamish area, limited information exists with respect to water quality. It is expected that water quality in Aquifer 397 (Ring Creek Aquifer) is superior to many, if not all, of the locations listed in the Table 3, based on their inferred depositional environments and sources of recharge. Many of the locations in Table 3 are expected to have reducing conditions at depth due to increased content of organic matter in floodplain sediments, which often results in higher concentrations of reduced species of metals and anions that negatively affect water quality.

3.3 New Water Wells based on Geological Information

To support the evaluation of potential new groundwater supply locations beyond existing wells or aquifers currently being utilized, WSP conducted a review of surficial geological mapping for the Squamish area. A map of surficial geology obtained from the Geological Survey of Canada (Blais-Stevens 2008) is attached in Attachment 3.

Surficial geological maps are not necessarily representative of subsurface geology; however, the units identified at the ground surface can provide context for the depositional environment of sediments during recent glacial retreats. For example, as shown on Figure 3, the glaciofluvial formations in and around the Powerhouse Springs Well Field are indicative of a high energy depositional environment which would likely favour the formation of extensive, coarse-grained gravel units. Such hydrostratigraphy is observed in the Powerhouse Springs well records and upgradient at the Province's Ring Creek Aquifer observation well (OW483).

Based on a review of the surficial geology, an Area of Interest was identified which, as outlined on Figure 3, extends west and south from Powerhouse Springs. This area is mapped as containing sedimentary formations which could be favourable for groundwater production. The surficial geological map (Figure 3, Attachment 3) indicates this area is composed of mainly glaciofluvial terrace (Gt) and glaciofluvial blanket (Gb) sediments. Glaciofluvial terrace (Gt) sediments consist of stratified to massive sand and gravel formations, many metres thick, which form horizontal units associated with meltwater channels (Blais-Stevens 2008). Likewise, glaciofluvial blanket (Gb) sediments consist of similar materials in a comparable thickness; however, the morphology is more undulating, as these units are commonly located near the mouth (or terminus) of meltwater channels (Blais-Stevens 2008). If these geological units extend to greater depths such that they are suitably below the water table, they could serve as potential aquifers.

In the Area of Interest on Figure 3, the geology may be similar to that at the Powerhouse Springs Well Field area; however, potential aquifers in the Area of Interest are less likely to have the same recharge characteristics, due to weaker inferred hydraulic connectivity to surface water courses. This is because Aquifer 397 (Ring Creek Aquifer), which is believed to terminate at the well field, is inferred to have a relatively large catchment area with significant inferred recharge from rivers that are hydraulically connected to the aquifer (Piteau 2014a). A consideration for the Area of Interest on Figure 3 is that any new groundwater supply developed in this area would likely make use of existing conveyance infrastructure along the Powerhouse Springs Road corridor. Given the conveyance redundancy considerations discussed in Section 2.0, the northern-most portion of the Area of Interest would likely be most appropriate for development with respect to minimizing the number of river crossings for any new infrastructure. In particular, the area immediately to the north of the Mamquam River, between Piteau TH-1 and Powerhouse Springs, serves as a reasonable target for further hydrogeological investigation (see "Proposed Investigation" in Figure 3). This area rests within the footprint of Aquifer 398 (i.e., Lower Mamquam Aquifer), for which the District's 1999 project approval certificate for groundwater extraction up to 255 L/s may still be applicable. This is in addition to ongoing permitted withdrawal of 255 L/s from Powerhouse Springs.

The portion of the "Proposed Investigation" area which is adjacent to the unpaved section of Mamquam Road between Piteau TH-1 and Ring Creek is located in a strategically viable area which does not subject conveyance infrastructure to a river crossing, assuming groundwater would be pumped to storage locations in the University Zone. Developing groundwater supply options in this area would improve redundancy in the system and decrease susceptibility to damage from seismic, flood, or wind events. Although the inferred depth to water in this area suggests that considerable pumping capacity would be required in addition to new electrical and conveyance infrastructure, the elevated nature of this location and the associated protection from flooding serves as an attractive long-term benefit. Furthermore, a separate well field would mitigate the District’s susceptibility to localized power outages or contamination events at Powerhouse Springs. The properties of the aquifer in this location are uncertain and consequently, subsurface investigation would be required prior to development of a new well field.

Although not presented on Figure 3, the Upper Cheakamus area (i.e., north end of Paradise Valley) is reported to have a higher occurrence of glaciofluvial formations, as opposed to floodplain deposits (see Attachment 3). These glaciofluvial formations may be conducive to the installation of highly productive water wells; however, the distance from this area to the existing supply network is estimated to be on the order of 10 km, and as a result, the Upper Cheakamus is likely not a cost-effective area for groundwater resource development.

Geological maps can support the identification of potential aquifers; however, groundwater resources can only be reliably confirmed with intrusive subsurface investigation. Other techniques, such as geophysical surveys, may be conducted from the ground surface to estimate depth to bedrock or shallow sediment properties, which in turn may help provide guidance for planning the location of intrusive investigations. In some cases, geophysical surveys can be used in conjunction with existing borehole information. In addition to assessing potential production capacity at new locations, groundwater quality is also a key consideration that would be assessed with groundwater sampling programs.

4.0 CONSIDERATIONS FOR LONG-TERM OPERATION AND MAINTENANCE

4.1 Well Field Maintenance

WSP understands that the District conducts well performance assessment and rehabilitation programs at the Powerhouse Springs Well Field on an annual basis (KWD 2019b, 2019d, 2021, 2022). For aging well infrastructure, these types of programs are important, as they provide the technical basis to monitor performance, maintain performance, and provide guidance for decision making related to planning for the installation of new wells. The same considerations should apply to additional well fields, if developed in the future.

Ideal testing conditions generally require well operations to cease for a given duration prior to and following a pumping test. Conversely, these conditions can be prohibitive since continuous water supply is required for a municipality, and as such, the conditions are often not achievable. Well performance data (i.e., specific capacity) can be estimated from pumping data collected during typical operation. This necessitates that only one well (i.e., the well being tested) be operating at any given time, and that the pumping rate of the single well increases rapidly from zero to the established test rate, and then be held constant. Such an approach generally requires high-quality data from an established data collection and transmission system (e.g., SCADA). As such, the District should work towards improving SCADA data quality so that it is free from transcription errors and can be used for assessment of well performance. This can be accomplished by developing a QA/QC program for SCADA data, to be completed on a recurring basis (e.g., quarterly).

Recent rehabilitation programs have been conducted in 2019 (Wells #5 and #6), 2020 (Wells #1 and #7), 2021 (Well #2), and 2022 (Well #4) (KWD 2022). Methodologies have included physical rehabilitation (surge and pump) and chemical rehabilitation (gentle acid treatment). The rehabilitation programs have yielded positive results, and the most recent well performance observations based on specific capacity estimates (KWD 2022, District of Squamish 2023c) are summarized below:

- Wells #1, #3, #4, #5, #6, and #7 are performing at or near baseline conditions (i.e., post-installation conditions)
- Well #2 specific capacity is estimated to be approximately 20% lower than baseline conditions

Despite the improvements observed in many of the wells following rehabilitation, in some cases performance has been observed to decline in the years that follow the rehabilitation programs. This is often common with aging pumping wells, as the longevity of the rehabilitation effects decrease with recurrent application. As the required frequency of well rehabilitation increases, the District may consider alternative experimental rehabilitation methodologies that have not yet been attempted, with the understanding that the alternative methodologies might not improve well performance, or could actually decrease well performance. Alternatively, when pumping well performance continues to decline and no longer responds to rehabilitation, the District should consider drilling and installing new pumping wells.

4.2 Well Protection Plan

WSP reviewed the District's most recent Well Protection Plan (WPP) developed in 2014 (Piteau 2014b) for the Powerhouse Springs Well Field. The WPP summarized groundwater quality hazards, risks, and management strategies, in addition to contingency responses for potential contamination events. The WPP included immediate and long-term recommendations for monitoring and protection of the well field. As new land uses become apparent in the areas surrounding the Powerhouse Springs Well Field, it is recommended that the District periodically review the WPP and consider updating it to allow for adequate protection measures and feedback from the public. A new WPP should be developed for any new well fields installed by the District in the future.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Following a review of recent reports for the Powerhouse Springs Well Field, WSP observed that the well field is productive and is expected to have additional capacity for new wells to satisfy short-term growth in water demand. This is based on the observed limited drawdown interference between wells during regular operation. For short-term water supply needs in the face of growing demand, WSP recommends installation of at least one new supply well at Powerhouse Springs.

Further to the above recommendation, WSP notes that focusing solely on increasing supply from Powerhouse Springs does not resolve existing vulnerabilities in the conveyance infrastructure. The District should consider and develop costing for an alternate pipeline linking Powerhouse Springs to the University Zone which is not subject to a crossing of the Mamquam River. This information can be used as an input for a cost-benefit analysis to support decision making in the short- and long-term. Even if alternative conveyance options are developed for Powerhouse Springs, power outages or contamination events exemplify the potential risk associated with dependence on a single supply location. As such, the District should weigh the costs and benefits of developing a new well field with the cost of improving and/or developing new conveyance infrastructure linking the Powerhouse Springs Well Field to the University Zone.

The District should conduct assessments of existing conveyance infrastructure given its susceptibility to seismic, flood, and wind events. Specifically, the District should complete a conditions assessment on three over-water crossings; (1) Mamquam River at Powerhouse Springs Road bridge deck, (2) Mamquam River at whitewater kayak put-in, and (3) Ring Creek at Carpenter's Son's Bridge. Of these, the crossing at the kayak put-in is considered to be most at-risk, given its lower elevation relative to the river's flood stage and its susceptibility to damage from flood debris. Since only one supply line is available to transmit water from Powerhouse Springs to primary storage reservoirs in the University Zone, issues with the conveyance infrastructure could have major consequences for the District's ability to supply water. Given these conveyance considerations, the following options may be considered for alternative water supply:

- The District can develop protocols for utilization of municipal irrigation wells for water supply. The necessary infrastructure improvements for these lone irrigation wells may be less cost-effective than the development of a new well field, or the pursuit of alternative conveyance options linking Powerhouse Springs to the University Zone. Use of the irrigation wells for municipal water supply would necessitate further water quality analysis, including a GARP assessment, in addition to the required treatment and conveyance infrastructure needed to connect these wells into the distribution system.
- The District can consider installation of new supply wells in aquifers other than Aquifer 397 (Ring Creek Aquifer) based on existing aquifer and well records. Although existing records provide confidence that new installations will be successful in aquifers that are already highly utilized, the District must consider existing users of the aquifer so as to not negatively affect their water supply. As such, the available water supply in these areas may be limited.
- The District can consider installation of new supply wells based on geological information. This approach makes use of surficial geological mapping and conceptual understanding of subsurface geology in an area with limited existing land development, such as the Area of Interest shown in Figure 3. This would necessitate a hydrogeological investigation consisting of a test well drilling program, and if successful, could lead to the development of a new well field. Depending on the final location of the new well field, this option likely adds the most redundancy to the system, and thus serves as a robust long-term solution to water supply needs.

The District should review the status of its 1999 project approval certificate to confirm it still allows for the development of groundwater supply infrastructure in Aquifer 398 (Lower Mamquam Aquifer). Once confirmed, WSP recommends that a test well drilling program be conducted in the Area of Interest, particularly in the area immediately to the north of the Mamquam River, between Piteau TH-1 and Powerhouse Springs (see "Proposed Investigation" in Figure 3). This area is situated within the footprint of Aquifer 398 (Lower Mamquam Aquifer). A hydrogeological investigation would involve a test well drilling program at multiple locations, as well as step-drawdown pumping tests and an analysis of groundwater quality at each location. Favourable results from the hydrogeological investigation may serve as a prompt for the District to consider land access agreements or parcel acquisition to facilitate future development of water supply infrastructure.

The District should continue with well performance monitoring and system maintenance for existing water supply infrastructure. This includes QA/QC of data collected by the SCADA system, scheduled specific capacity testing (i.e., step-drawdown tests) and well rehabilitation when performance tests show it is necessary. The District should review and update its WPP on a periodic basis and a new WPP should be developed for any additional well fields commissioned in the future.

Should the District wish to proceed in assessing irrigation wells for their potential use as municipal supply wells, a number of assessments are recommended. The District should conduct pumping tests (preferably step-pumping tests) to assess specific capacity, and compare the results to baseline conditions, if known. The District should also conduct camera inspections to assess the potential for corrosion and/or casing integrity issues, as well as the extent of sand pumping, if occurring. The District should sample groundwater from the well for an expanded suite of parameters, including:

- Bacteriological tests: total coliforms and *E.coli*
- Physical tests: colour, conductivity, total dissolved solids, pH, temperature, turbidity, and hardness
- Dissolved anions: chloride, fluoride, sulphate, sulphide, speciated alkalinity
- Nutrients: ammonia, nitrate, nitrite and total Kjeldahl nitrogen
- Metals: total and dissolved metals
- Hydrocarbon parameters: volatile organic compounds
- Miscellaneous parameters: total organic carbon and dissolved organic carbon

It is anticipated that as withdrawal rates increase in line with population growth, the effect of pumping on the aquifer and nearby watercourses will require additional study to ensure that environmental flow needs are met. Specifically, the District should establish a flow monitoring program for Powerhouse Creek, which could potentially be affected by increased pumping at the Powerhouse Springs Well Field (Piteau 2014a). In doing so, the District would develop a dataset for baseline conditions in Powerhouse Creek. If pumping at the Powerhouse Springs Well Field is confirmed to strongly affect flows in Powerhouse Creek, additional surveys may be necessary to assess whether critical species are affected by a reduction in these flows. These studies should also incorporate climate change scenarios where extreme precipitation events and extended droughts are simulated. This may involve the expansion of long-term data collection programs and introduction of new monitoring locations. To better understand the dynamics between withdrawal rates, aquifer recharge, and nearby watercourses, as well as the effects of climate change, development of a numerical flow model may be necessary.

6.0 SUMMARY OF COSTS

WSP estimated costs for major scopes of work discussed above and listed below, which include both contractor efforts and consulting supervisory and reporting efforts. These estimates should be considerate approximate, for planning purposes only, and are subject to revision during the formal proposal process.

- Cost of one new pumping well at Powerhouse Springs, including only drilling, well installation, and well testing (assumes 12” well in 18” borehole down to 50 m): $250,000. Total costs including associated infrastructure: $700,000, as per recent costing received by the District.
- Cost of annual rehabilitation program for one well (assumes mechanical rehabilitation only): $40,000, or as per recent costing received by the District
- Cost of hydrogeological investigation, including four test wells (assumes 6” wells in 12” boreholes down to 50 m), step-drawdown pumping tests, and water chemistry analysis: $400,000

7.0 CLOSURE

We trust the information contained in this report is sufficient for your needs at this time. Should you have any questions or concerns, please do not hesitate to contact the undersigned at (604) 685-9381.

Regards,

WSP Canada Inc.

Engineers and Geoscientists BC
Permit to Practice #1000200

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
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57161
31-Aug-23

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Attachments: Figures 1 to 3
Attachment 1 – Summary of Chemistry for Alternate District Wells
Attachment 2 – BC ENV Aquifer Factsheets (#396 - #402)
Attachment 3 – Surficial Geological Map for the Squamish Area

https://wsponlinecan.sharepoint.com/sites/ca-221-11672-00/shared documents/06. deliverables/3.0 issued/221-11672-00-001-l-rev0/221-11672-00-001-l-rev0-wmp gw supply 31aug_23.docx

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If new information is discovered during future work, including excavations, soil boring, or other investigations, WSP should be requested to re-evaluate the conclusions of this report and to provide amendments, as required, prior to any reliance upon the information presented herein.

9.0 REFERENCES

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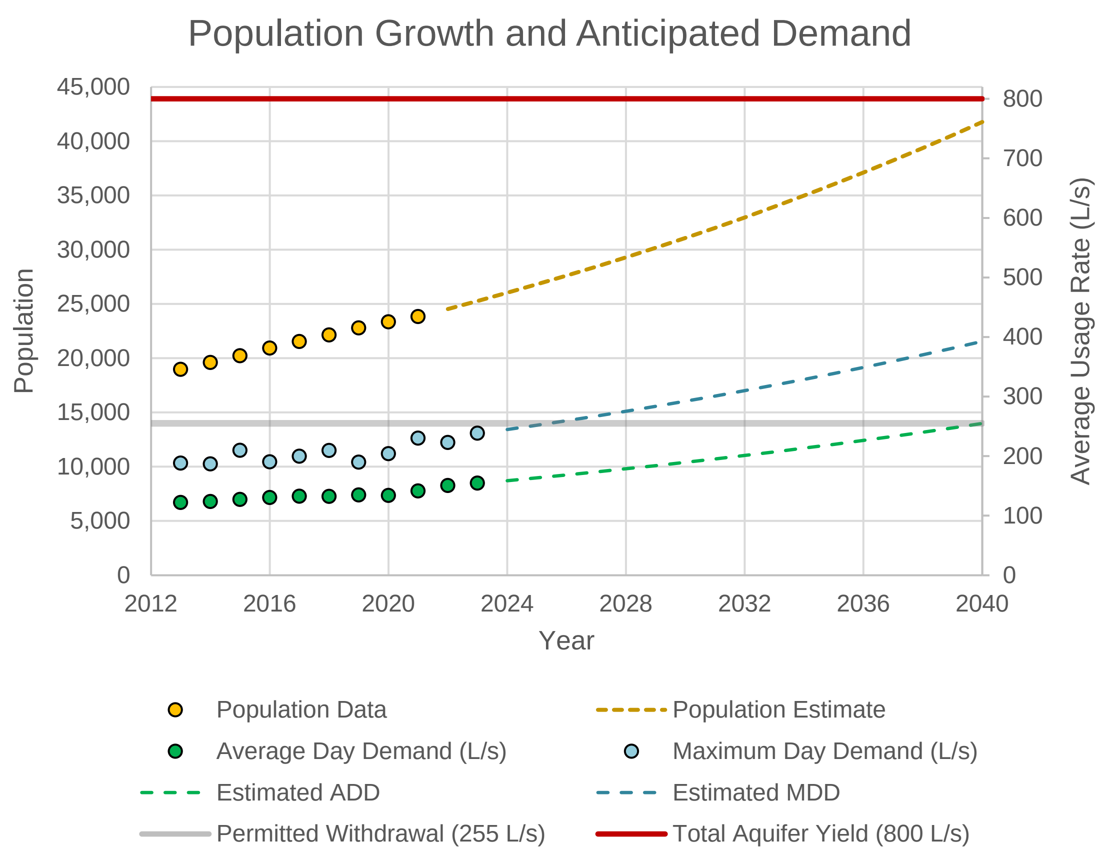
Year	MDD (L/s)	ADD (L/s)	Population	MDD per capita (L/s)	ADD per capita (L/s)
2013	188	122	18,956	0.0099	0.0064
2014	186	124	19,594	0.0095	0.0063
2015	209	127	20,212	0.0104	0.0063
2016	190	130	20,910	0.0091	0.0062
2017	199	132	21,528	0.0093	0.0062
2018	209	132	22,126	0.0094	0.0060
2019	190	135	22,778	0.0083	0.0059
2020	204	134	23,335	0.0087	0.0057
2021	230	141	23,819	0.0096	0.0059
2022	223	150	24,500 (est.)	0.0091 (est.)	0.0061 (est.)
2023	238 (4)	154 (4)	25,300 (est.)	0.0094 (est.)	0.0061 (est.)

NOTES:

1. MDD = MAXIMUM DAY DEMAND (L/s)
2. ADD = AVERAGE DAY DEMAND (L/s)
3. "MDD" AND "ADD" CALCULATED BY DISTRICT OF SQUAMISH USING COMBINED FLOW METER DATA FROM POWERHOUSE SPRINGS WELL FIELD.
4. MDD AND ADD VALUES NOT YET FINALIZED FOR 2023.
5. POPULATION DATA FOR 2013-2021 OBTAINED FROM DISTRICT OF SQUAMISH.
6. POPULATION GROWTH FROM 2021 ONWARD ASSUMES 3% ANNUAL GROWTH RATE (DISTRICT OF SQUAMISH WEBSITE)
7. ESTIMATED MDD PROJECTION ASSUMES 0.0094 L/s/capita AS PER 2013-2021 AVERAGE
8. ESTIMATED ADD PROJECTION ASSUMES 0.0061 L/s/capita AS PER 2013-2021 AVERAGE
9. PERMITTED WITHDRAWAL APPLIES TO RING CREEK AQUIFER ONLY. SECONDARY 255 L/s PERMIT FOR THE MAMQUAM AQUIFER CURRENTLY NOT UTILIZED.
10. TOTAL AQUIFER YIELD ESTIMATED BY PITEAU (2014). TOTAL WITHDRAWAL RATE MUST REMAIN FAR BELOW TOTAL AQUIFER YIELD AS PER ENVIRONMENTAL FLOW NEEDS. INCREASED WITHDRAWAL MAY RESULT IN INCREASED RECHARGE TO THE AQUIFER.



CLIENT
DISTRICT OF SQUAMISH

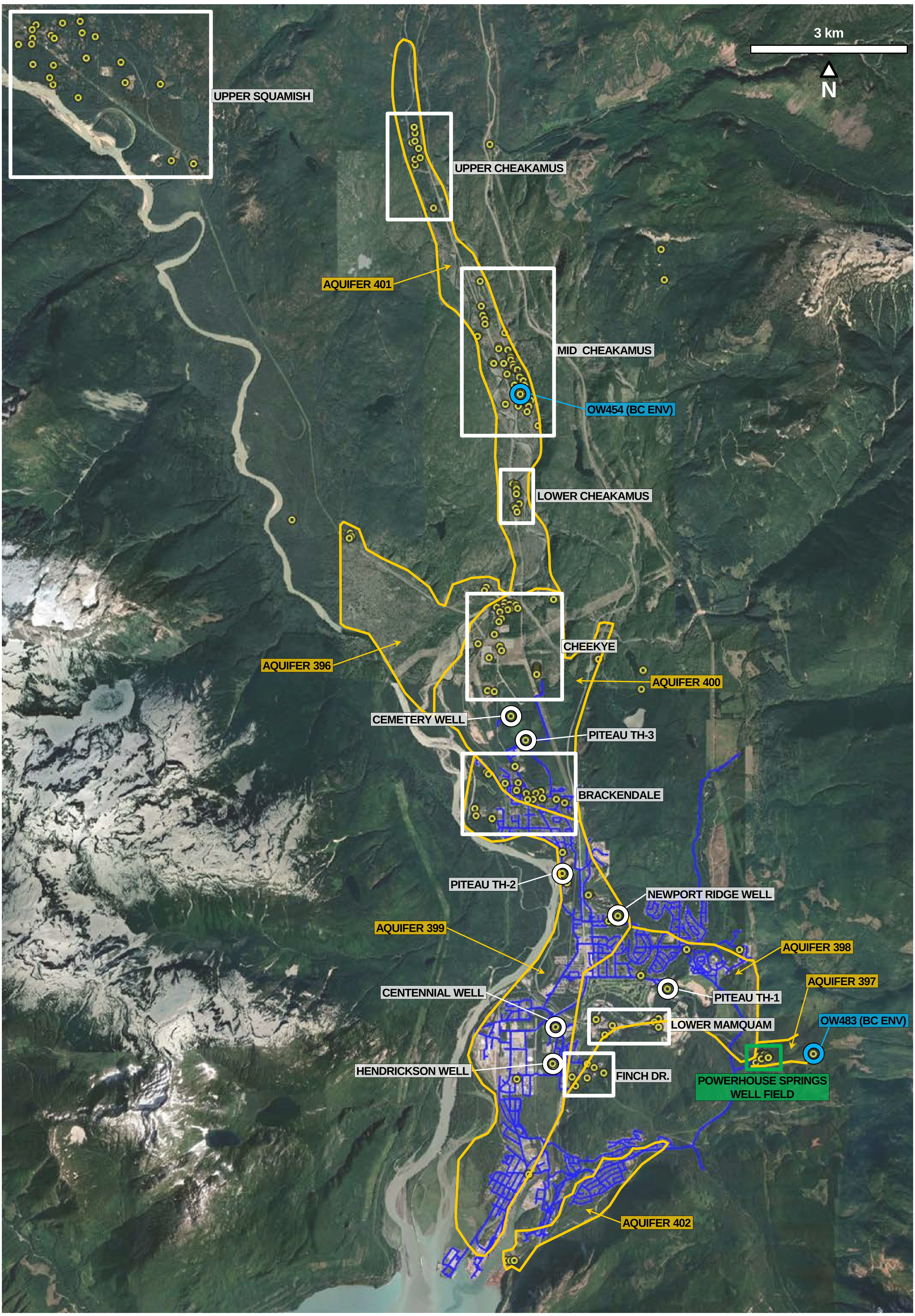
PROJECT
WATER MASTER PLAN
LONG-TERM GROUNDWATER SUPPLY STRATEGY

CONSULTANT
wsp

YYYY-MM-DD	2023-05-15
PREPARED	MZ
DESIGN	MZ
REVIEW	MB
APPROVED	JS

TITLE
PROJECTED GROWTH AND ANTCIPATED WATER DEMAND

PROJECT No.	PHASE	Rev.	FIG
CA-WSP-221-11672-00	**6.6.2**	**0**	**1**



LEGEND:

- DISTRICT WATER SUPPLY LINE
- PROVINCIAL AQUIFER BOUNDARY
- WATER WELL RECORD
- PROVINCIAL OBSERVATION WELL
- WELLS & BOREHOLES OF NOTE

CLIENT
DISTRICT OF SQUAMISH

PROJECT
WATER MASTER PLAN
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YYYY-MM-DD	2023-05-15
PREPARED	MZ
DESIGNED	MZ
REVIEWED	MB
APPROVED	MB

TITLE
PROVINCIAL AQUIFER BOUNDARIES, WELL RECORD GROUPINGS, WELLS OF NOTE, AND EXISTING WATER SUPPLY LINES

PROJECT NO.	REV.	FIGURE
CA-WSP-221-11672-00	0	2

BASE MAP REFERENCE

OPEN FILE 5323

SURFICIAL GEOLOGY AND LANDSLIDE INVENTORY OF THE MIDDLE SEA TO SKY CORRIDOR

BRITISH COLUMBIA

Author: A. Blais-Stevens

Geology by A. Blais-Stevens, 2004–2007

Elevations in metres above mean sea level
Contour interval 20 m

OPEN FILE DOSSIER PUBLIC 5323 GEOLOGICAL SURVEY OF CANADA COMMISSION GÉOLOGIQUE DU CANADA 2008	Open files are products that have not gone through the GSC formal publication process. Les dossiers publics sont des produits qui n'ont pas été soumis au processus officiel de publication de la CGC.

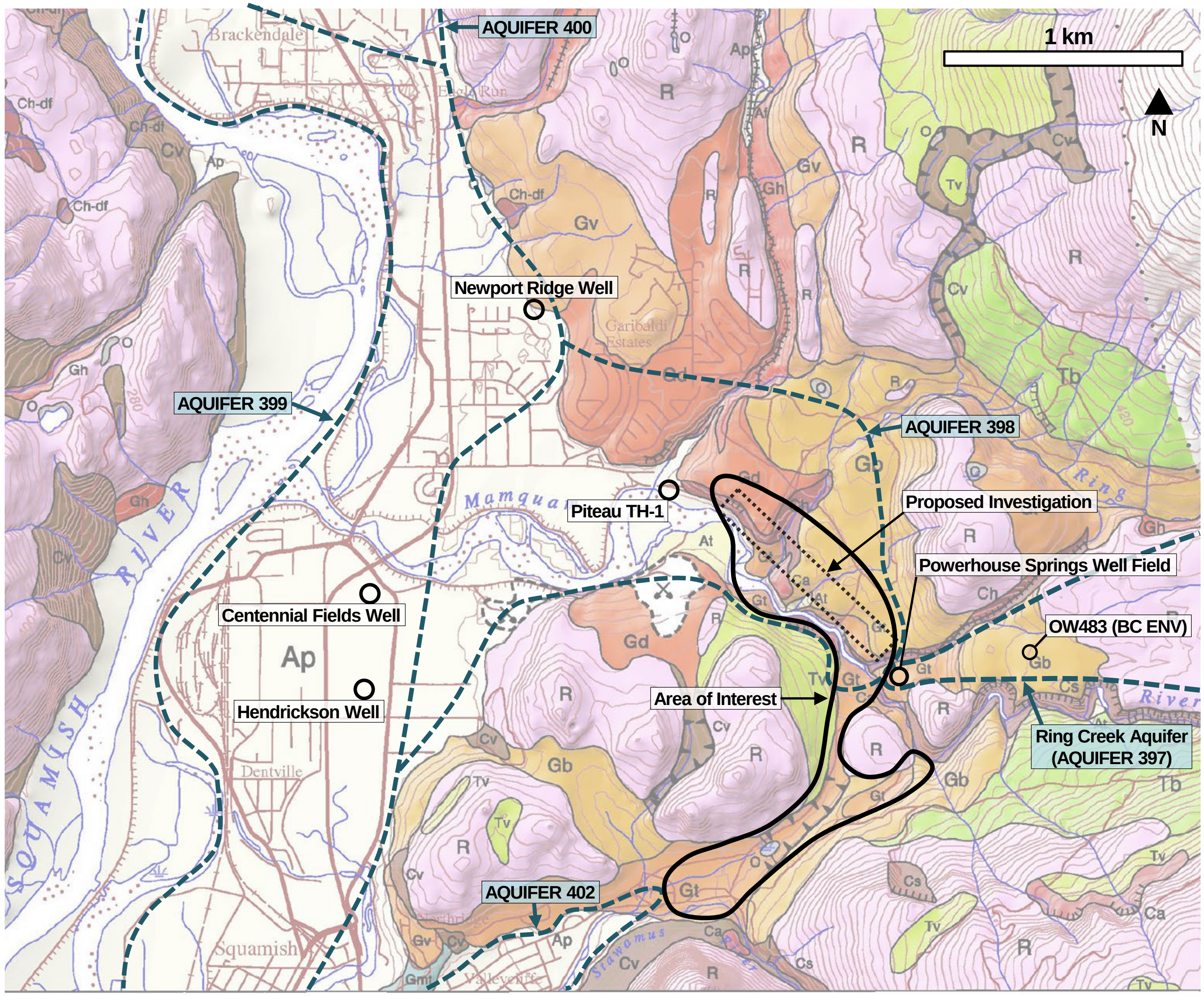
Blais-Stevens, A.
2008: Surficial geology and landslide inventory of the middle Sea to Sky corridor, British Columbia; Geological Survey of Canada, Open File 5323, scale 1:50 000.

BASE MAP LEGEND

- **Ap** – FLOODPLAIN SEDIMENTS
- **At** – TERRACE SEDIMENTS
- **Af** – FAN SEDIMENTS
- **Ch** – LANDSLIDE DEBRIS
- **Cs** – SLOPE COLLUVIUM
- **Ca** – TALUS
- **Cv** – COLLUVIAL VENEER
- **Gh** – ICE-CONTACT DEPOSITS
- **Gt** – GLACIOFLUVIAL TERRACE SEDIMENTS
- **Gb** – GLACIOFLUVIAL BLANKET
- **Gd** – PROGLACIAL DELTAIC SEDIMENTS
- **Gv** – GLACIOFLUVIAL VENEER
- **Tb** – TILL BLANKET
- **Tv** – TILL VENEER
- **R** – BEDROCK (SEDIMENTARY, METAMORPHIC, VOLCANIC, INTRUSIVE)

NOTES:

1. AREA OF INTEREST BASED ON INFERRED GLACIOFLUVIAL ENVIRONMENT AND PROXIMITY TO INFRASTRUCTURE. GROUNDWATER SUPPLY POTENTIAL IN THIS AREA ANTICIPATED TO BE INFERIOR TO RING CREEK AQUIFER.
2. SURFICIAL GEOLOGY, AS PRESENTED ON BASE MAP, IS NOT A RELIABLE INDICATOR OF SUBSURFACE GEOLOGY.
3. GROUNDWATER RESOURCES CAN ONLY BE RELIABLY CONFIRMED WITH INTRUSIVE SUBSURFACE INVESTIGATION.



CLIENT
DISTRICT OF SQUAMISH

PROJECT
WATER MASTER PLAN
LONG-TERM GROUNDWATER SUPPLY STRATEGY

CONSULTANT
wsp

YYYY-MM-DD	2023-05-15
PREPARED	MZ
DESIGN	MZ
REVIEW	MB
APPROVED	MB

TITLE
SURFICIAL GEOLOGY OF THE SQUAMISH REGION, PROVINCIAL AQUIFER BOUNDARIES, AND AREA OF INTEREST FOR SUPPLEMENTARY GROUNDWATER RESOURCES

PROJECT No.	PHASE	Rev.	FIG
CA-WSP-221-11672-00	6.6.2	0	3

ATTACHMENT 1

Summary of Chemistry for Alternate District Wells

Table A1 - Summary of Chemistry for Alternate District Wells

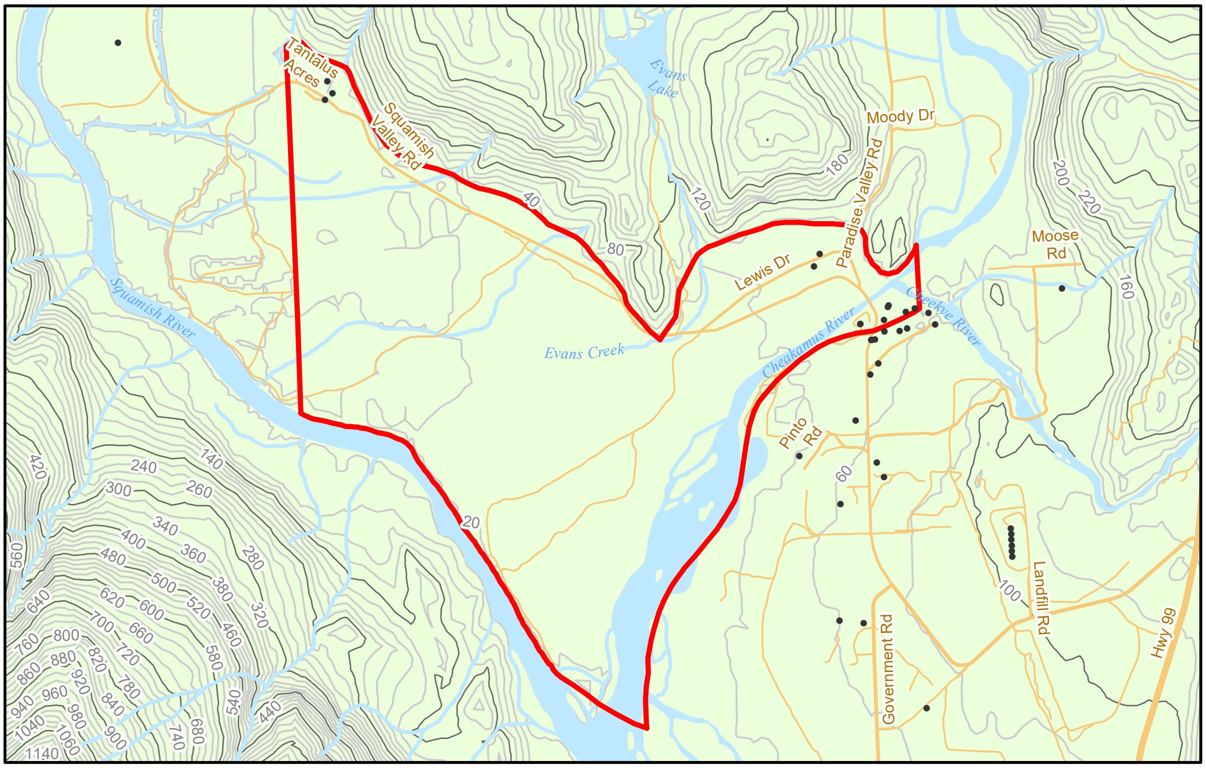
Location	Guidelines for Canadian Drinking Water Quality (GCDWQ)	Contam. Sites Reg. Drinking Water Standard CSR-DW	Hendrickson Well	Centennial Fields Well	Cemetery Well	Piteau TH-1 Well (Mamquam River)
Year Drilled			2000	1977	1998	1994
Date Sampled			23-Aug-2018	25-Mar-1977	17-Dec-1998	20-Dec-1994
Laboratory			ALS Environmental	Can Test Ltd.	Can Test Ltd.	ASL Ltd.
Laboratory Work Order			L2152986	1275C	8122132	E6506
Physical Tests						
Lab Conductivity (uS/cm)			292	80.8	116	63.8
Hardness (mg/L of CaCO3)			99.9	34.7	35	20.2
pH	7.0 - 10.5		8.21	**6.4**	**6.72**	**6.61**
Total Dissolved Solids (mg/L)	500 [AO]		201	70	89	61.5
Total Suspended Solids (mg/L)			-	4.0		196
Turbidity (NTU)			0.66	2.5	0.16	71.7
Anions and Nutrients						
Alkalinity, Bicarbonate (as CaCO3)			-	27.1	43.9	-
Alkalinity, Carbonate (as CaCO3)			-	-	<0.5	-
Alkalinity, Hydroxide (as CaCO3)			-	-	<0.5	-
Alkalinity, Total (as CaCO3)			125	-	-	19.0
Ammonia, Total (as N)			0.378	-	-	-
Bromate (mg/L)	0.01		<0.010	-	-	-
Bromide (Br)			<0.050	-	-	-
Chlorate	1		<0.020	-	-	-
Chloride (Cl)	250 [AO]	250	22.2	32.0	6.1	1.6
Fluoride (mg/L of F)	1.5	1.5	0.129	0.060	<0.05	0.07
Nitrate (as N)	10	10	<0.0050	<0.10	0.28	-
Nitrite (as N)	1	1	<0.0010	-	<0.002	-
Total Nitrogen			-	-	-	0.135
Phosphorus (P)-Total			0.41	-	-	-
Total Phosphates			-	<0.01	-	-
Silicate			-	-	-	39.4
Sulfate (SO4)	500 [AO]	500	<0.30	8.0	10.5	3.9
Sulphide as S	0.05 [AO]		-	-	-	-
Total Metals						
Aluminum (Al)	0.1 [OG], 2.9 [MAC]	9.5	<0.010	-	-	**0.81**
Antimony (Sb)	0.006	0.006	<0.00050	-	-	<0.20
Arsenic (As)	0.010 [ALARA]	0.01	<0.00010	-	<0.001	0.0004
Barium (Ba)	2	1	<0.020	-	0.004	0.015
Beryllium (Be)		0.008	-	-	-	<0.005
Bismuth (Bi)			-	-	-	<0.10
Boron (B)	5	5	<0.10	-	<0.05	<0.10
Cadmium (Cd)	0.007	0.005	<0.00020	-	<0.0002	<0.0002
Calcium (Ca)			25.0	-	-	5.93
Cesium (Cs)			-	-	-	-
Chromium (Cr)	0.05	0.05	<0.0020	-	0.001	<0.015
Cobalt (Co)		0.001	-	-	-	<0.015
Copper (Cu)	1 [AO], 2 [MAC]	1.5	<0.0010	-	0.002	0.014
Iron (Fe)	0.3 [AO]	6.5	0.286	**0.94**	0.09	**0.720**
Lead (Pb)	0.005 [ALARA]	0.01	<0.00050	-	<0.001	0.001
Lithium (Li)		0.008	-	-	-	<0.015
Magnesium (Mg)			9.13	-	1.79	1.30
Manganese (Mn)	0.02 [AO], 0.12 [MAC]	1.5	**0.139**	**<0.05 ***	0.012	**0.027**
Mercury (Hg)	0.001	0.001	<0.00020	-	<0.05	<0.0005
Molybdenum (Mo)		0.25	-	-	-	<0.030
Nickel (Ni)		0.08	-	-	-	<0.020
Phosphorus (P)			-	-	-	<0.30
Potassium (K)			3.12	-	-	2.4
Rubidium (Rb)			-	-	-	-
Selenium (Se)	0.05	0.01	<0.0010	-	<0.002	<0.0005
Silicon (Si)			-	-	-	16.9
Silver (Ag)		0.02	-	-	-	<0.015
Sodium (Na)	200 [AO]	200	18.7	-	-	3.8
Strontium (Sr)	7	2.5	-	-	-	0.064
Sulfur (S)			-	-	-	<0.10
Tellurium (Te)			-	-	-	-
Thallium (Tl)			-	-	-	<0.10
Thorium (Th)			-	-	-	-
Tin (Sn)		2.5	-	-	-	<0.30
Titanium (Ti)			-	-	-	0.034
Tungsten (W)		0.003	-	-	-	**<0.10 ***
Uranium (U)	0.02	0.02	-	-	<0.0005	-
Vanadium (V)		0.02	-	-	-	**<0.030 ***
Zinc (Zn)	5	3	-	-	0.017	0.030
Zirconium (Zr)			-	-	-	-
Dissolved Metals						
Aluminum (Al)	0.1 [OG]	9.5	-	-	-	-
Antimony (Sb)	0.006	0.006	-	-	-	-
Arsenic (As)	0.010 [ALARA]	0.01	-	-	-	-
Barium (Ba)	2	1	-	-	-	-
Beryllium (Be)		0.008	-	-	-	-
Bismuth (Bi)			-	-	-	-
Boron (B)	5	5	-	-	-	-
Cadmium (Cd)	0.007	0.005	-	-	-	-
Calcium (Ca)			-	9.0	11.5	-
Cesium (Cs)			-	-	-	-
Chromium (Cr)	0.05	0.05	-	-	-	-
Cobalt (Co)		0.001	-	-	-	-
Copper (Cu)	1 [AO], 2 [MAC]	1.5	-	-	-	-
Iron (Fe)	0.3 [AO]	6.5	-	**0.45**	<0.05	<0.03
Lead (Pb)	0.005 [ALARA]	0.01	-	-	-	-
Lithium (Li)		0.008	-	-	-	-
Magnesium (Mg)			-	3.0	1.45	-
Manganese (Mn)	0.02 [AO], 0.12 [MAC]	1.5	-	-	0.003	-
Mercury (Hg)	0.001	0.001	-	-	-	-
Molybdenum (Mo)		0.25	-	-	-	-
Nickel (Ni)		0.08	-	-	-	-
Phosphorus (P)			-	-	-	-
Potassium (K)			-	2.5	2.20	-
Rubidium (Rb)			-	-	-	-
Selenium (Se)	0.05	0.01	-	-	-	-
Silicon (Si)			-	-	29.8	-
Silver (Ag)		0.02	-	-	-	-
Sodium (Na)	200 [AO]	200	-	18.5	5.51	-
Strontium (Sr)	7	2.5	-	-	-	-
Sulfur (S)			-	-	-	-
Tellurium (Te)			-	-	-	-
Thallium (Tl)			-	-	-	-
Thorium (Th)			-	-	-	-
Tin (Sn)		2.5	-	-	-	-
Titanium (Ti)			-	-	-	-
Tungsten (W)		0.003	-	-	-	-
Uranium (U)	0.02	0.02	<0.00010	-	-	-
Vanadium (V)		0.02	-	-	-	-
Zinc (Zn)	5	3	<0.050	-	-	-
Zirconium (Zr)			-	-	-	-

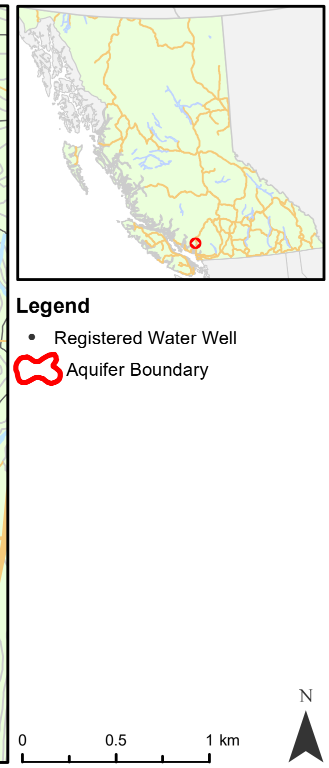
Notes:
Results are expressed in milligrams per litre (mg/L), unless otherwise noted.
AO = aesthetic objective
OG = operational guidance
ALARA = as low as reasonably achievable
MAC = maximum allowable concentrations
Land Use abbreviations: DW (Drinking Water)
- = no data
* - detection limit above guideline

ATTACHMENT 2

BC ENV Aquifer Factsheets (#396 - #402)

BRITISH COLUMBIA



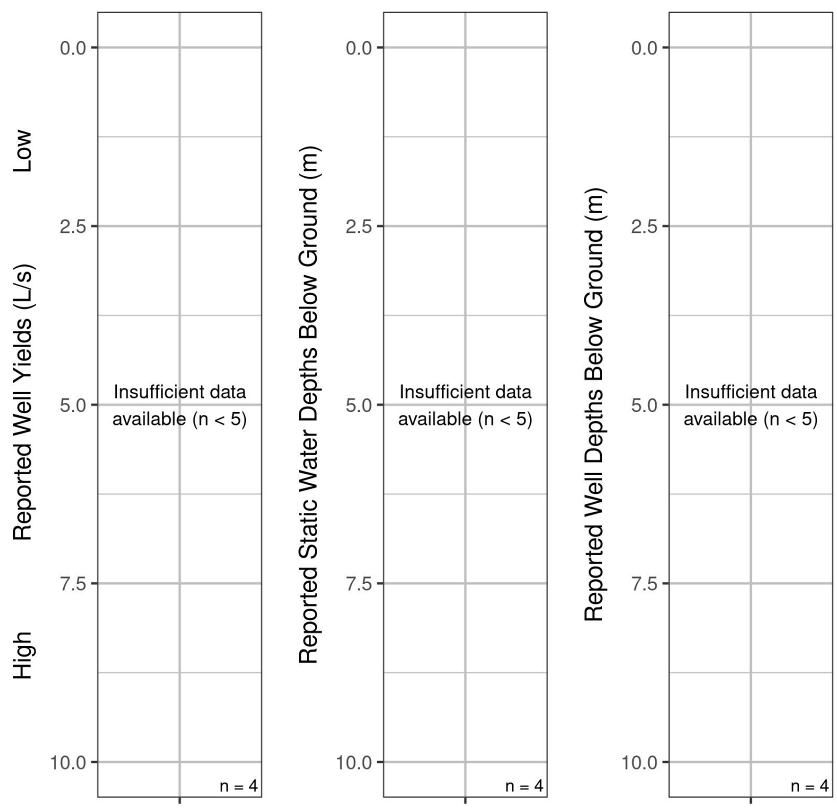


Aquifer Description (Mapping Report - 2007): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	5.1 km^2
No. Wells Correlated	4
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	1
Observation Wells (**Active**, Inactive)	None

* min - max

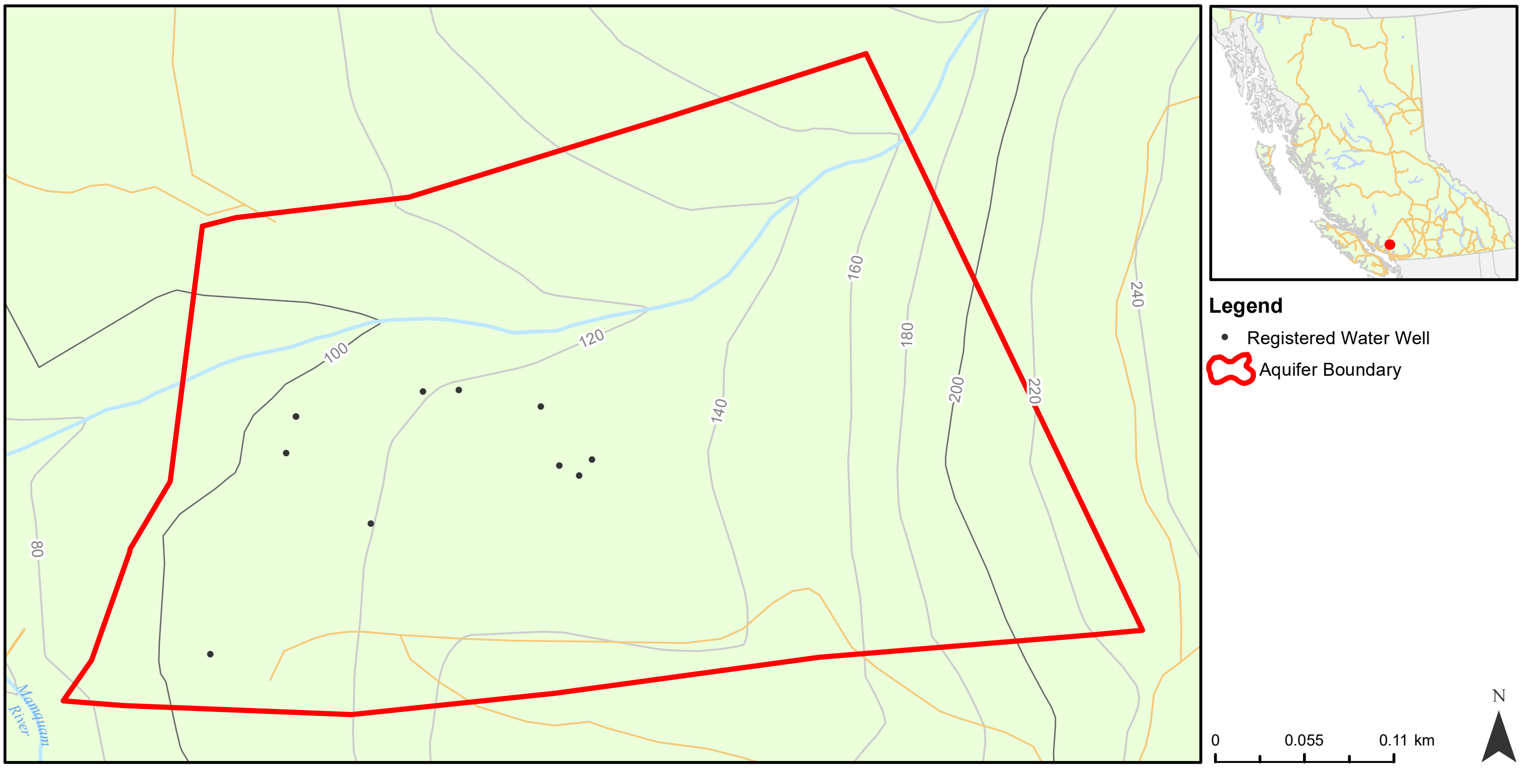
For Hydraulic Connection see guidance document



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

Factsheet generated: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

Aquifer #397

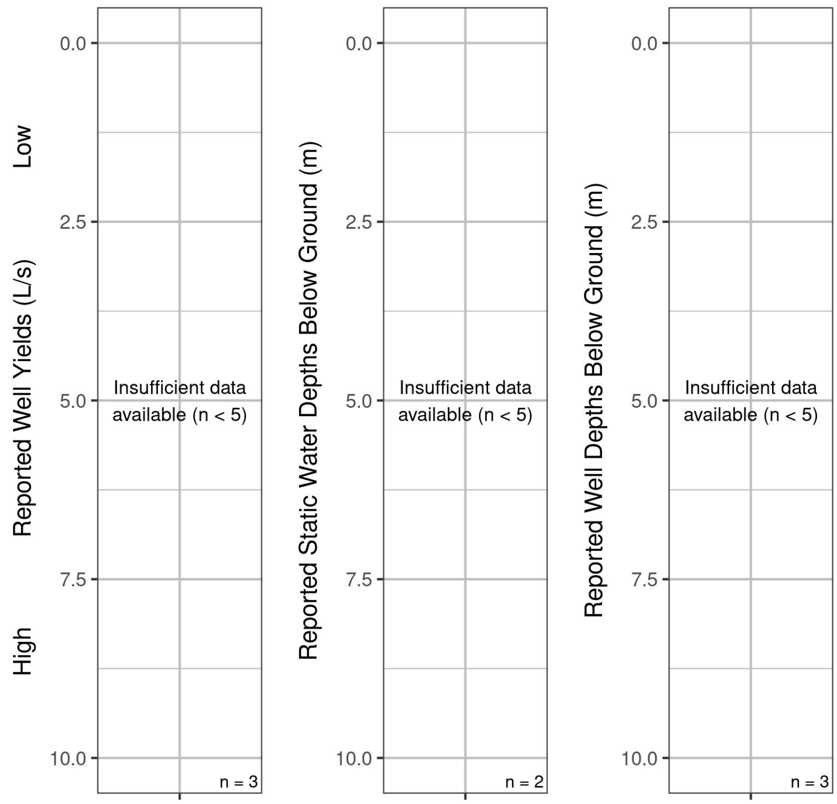


Aquifer Description (Mapping Report - 2007): Confined Glacio-fluvial sand and gravel aquifers underneath till, in between till layers, or underlying glacio-lacustrine deposits (subtype = 4b).

Aquifer Details

Region	South Coast
Water District	Vancouver
Aquifer Area	0.2 km^2
No. Wells Correlated	3
Vulnerability to Contamination	Moderate
Productivity	High
Aquifer Classification	IB
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	**483**

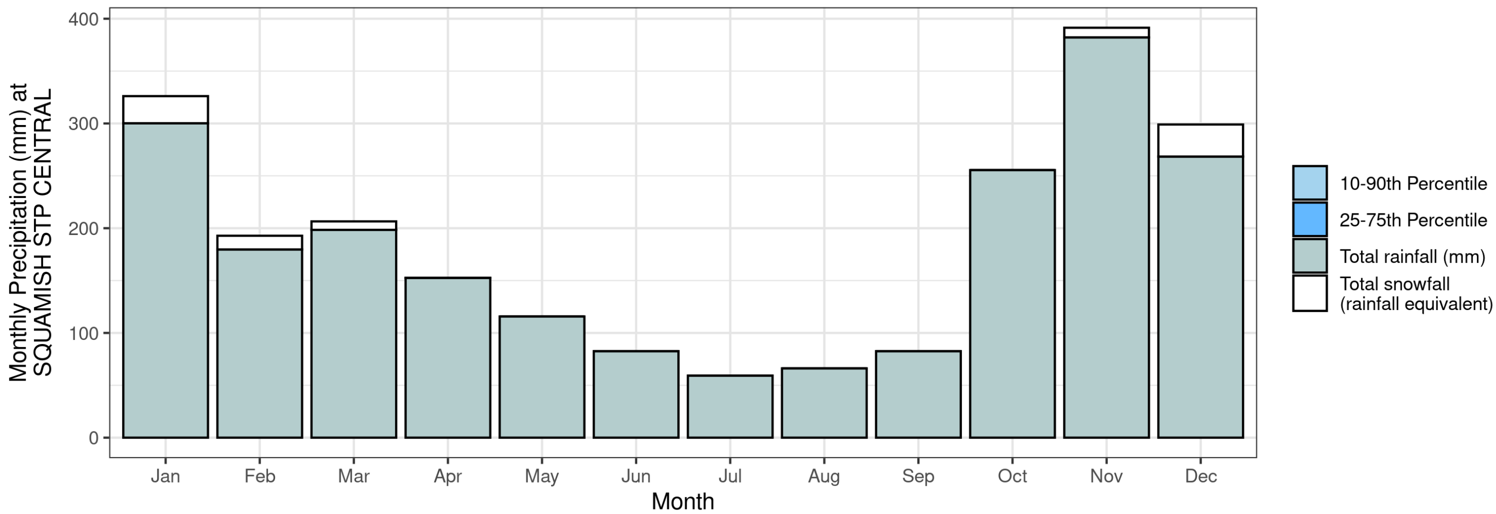
* min - max
For Hydraulic Connection see guidance document



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: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

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

[1] No Monthly Water Level Summary (only 3 years of data; 2019-2022)
[2] Climate Normals Based on SQUAMISH STP CENTRAL Environment Canada Weather Station (1981-2010)



Groundwater Levels and Long-term Trend

Graph not available
(Not enough data)

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

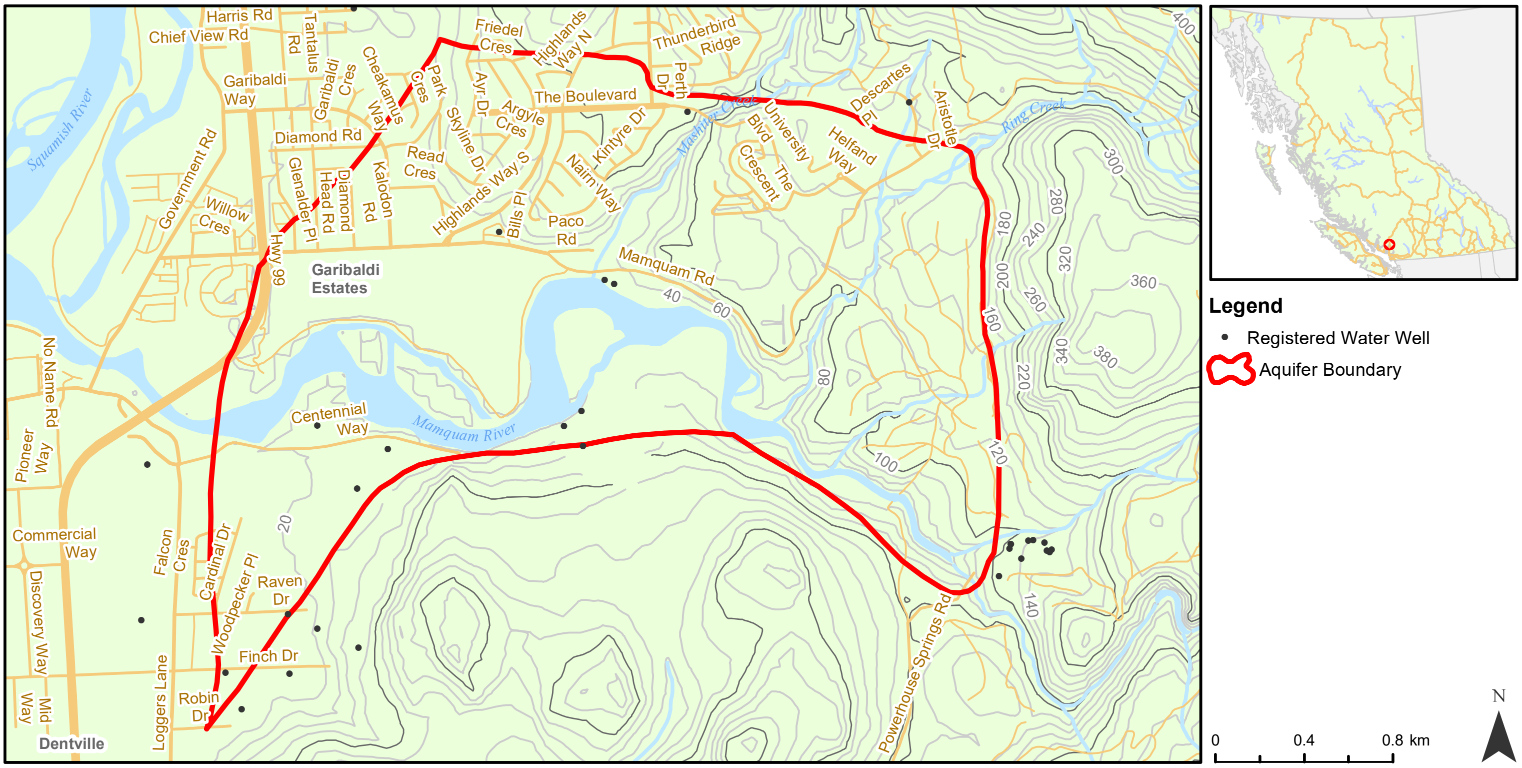
Piper Plot

No summary at this point

Graph not available
(insufficient chemistry data)

BRITISH COLUMBIA

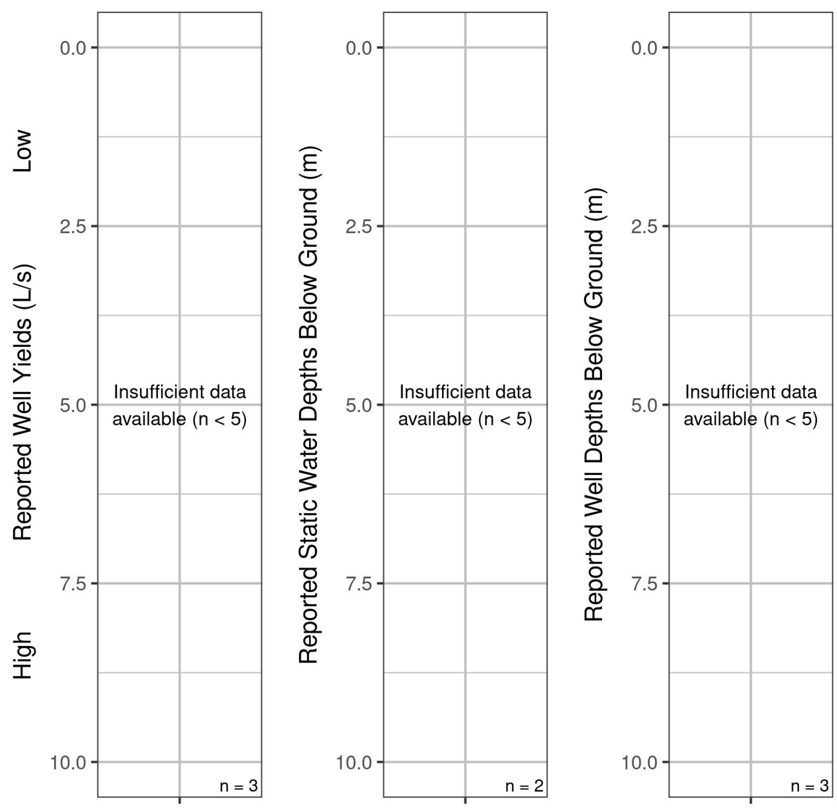
Aquifer #398



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).

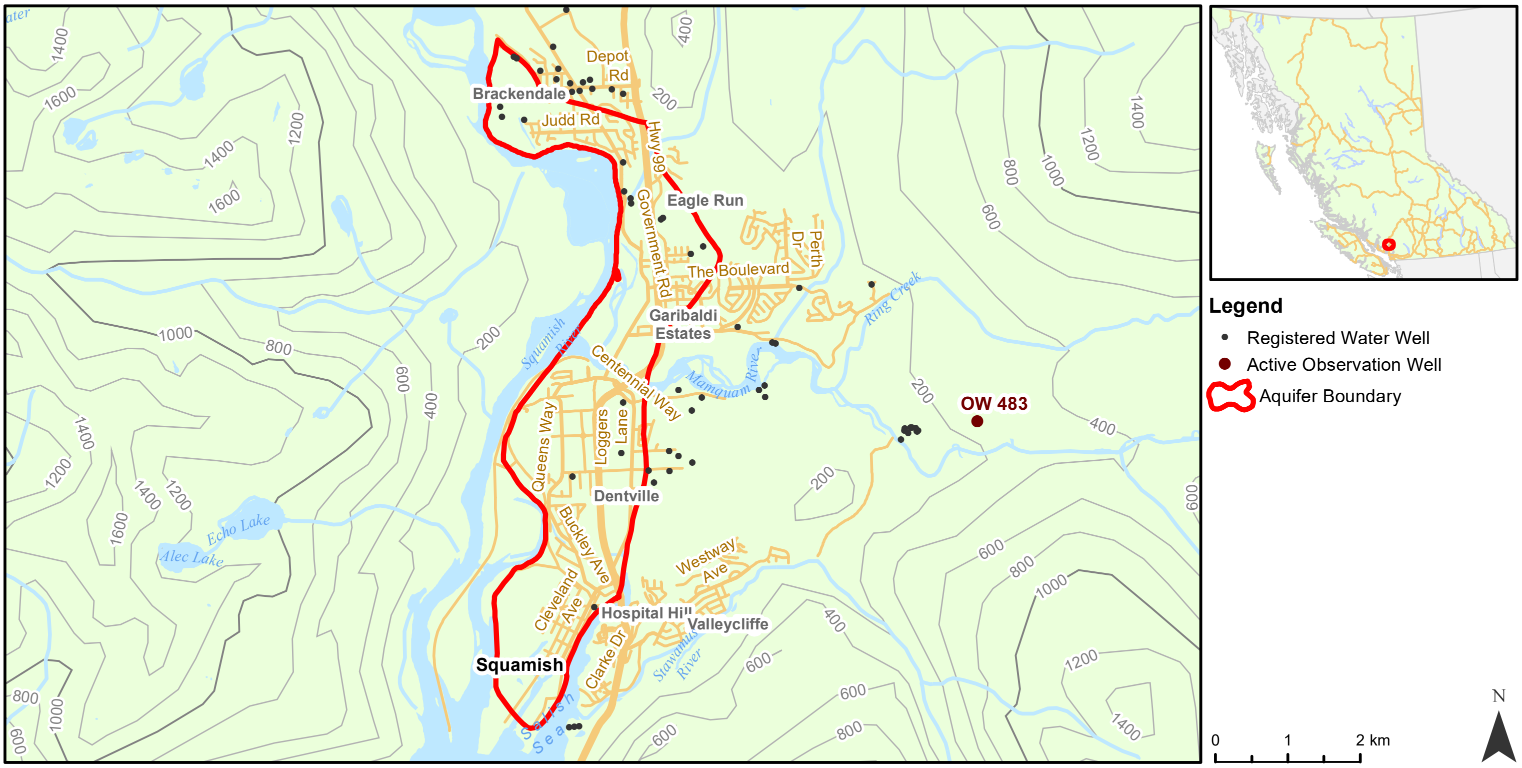
Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	6 km^2
No. Wells Correlated	3
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	None

* min - max
For Hydraulic Connection see guidance document



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

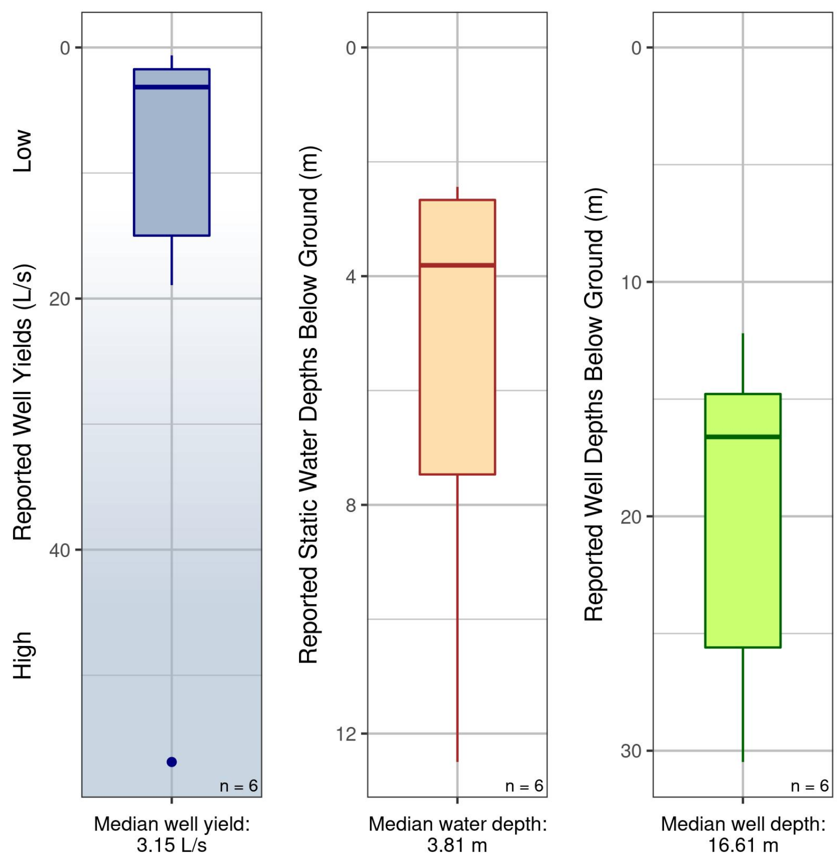
Aquifer #399



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).

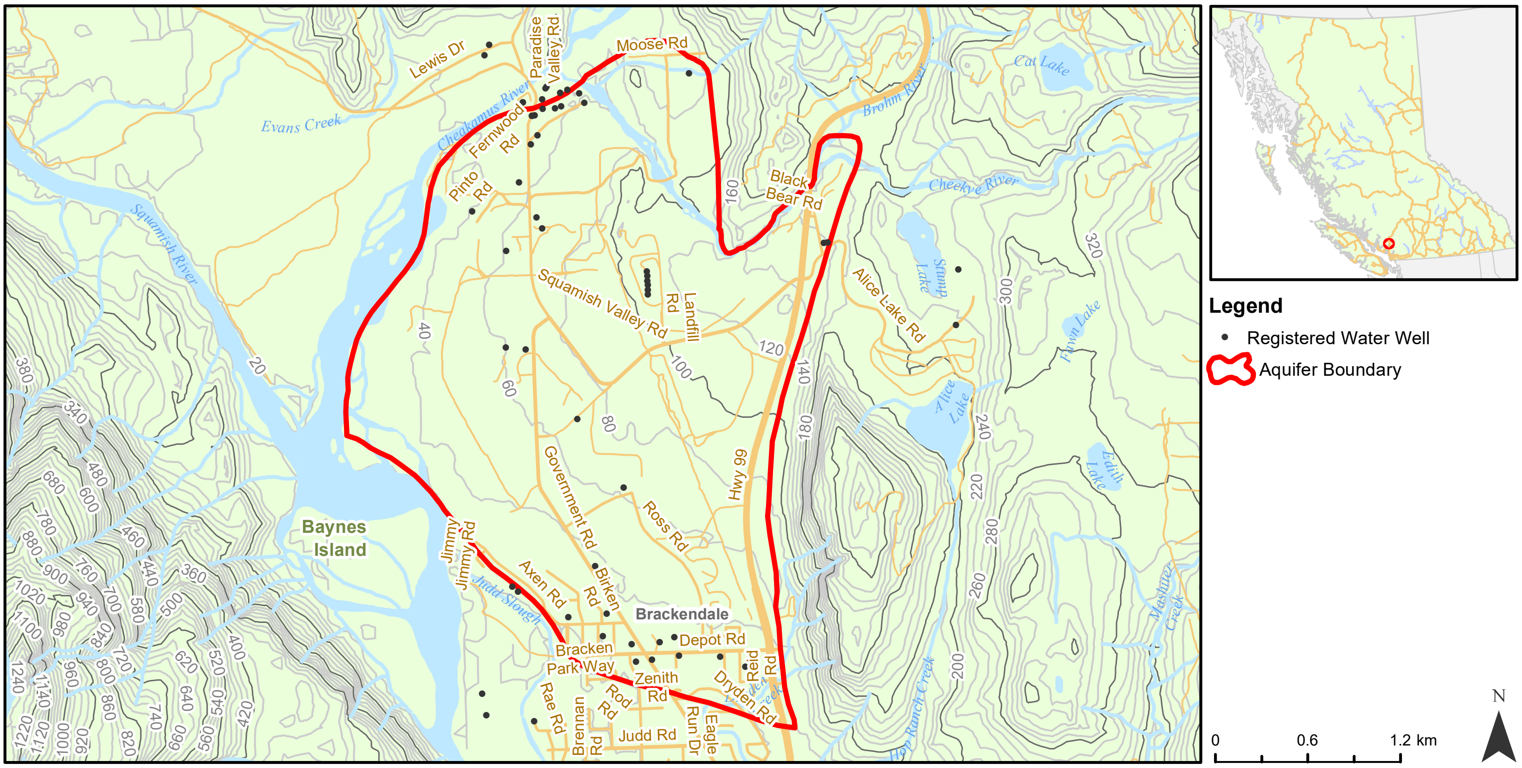
Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	12 km^2
No. Wells Correlated	6
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	1
Observation Wells (**Active**, Inactive)	None

* min - max
For Hydraulic Connection see guidance document



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

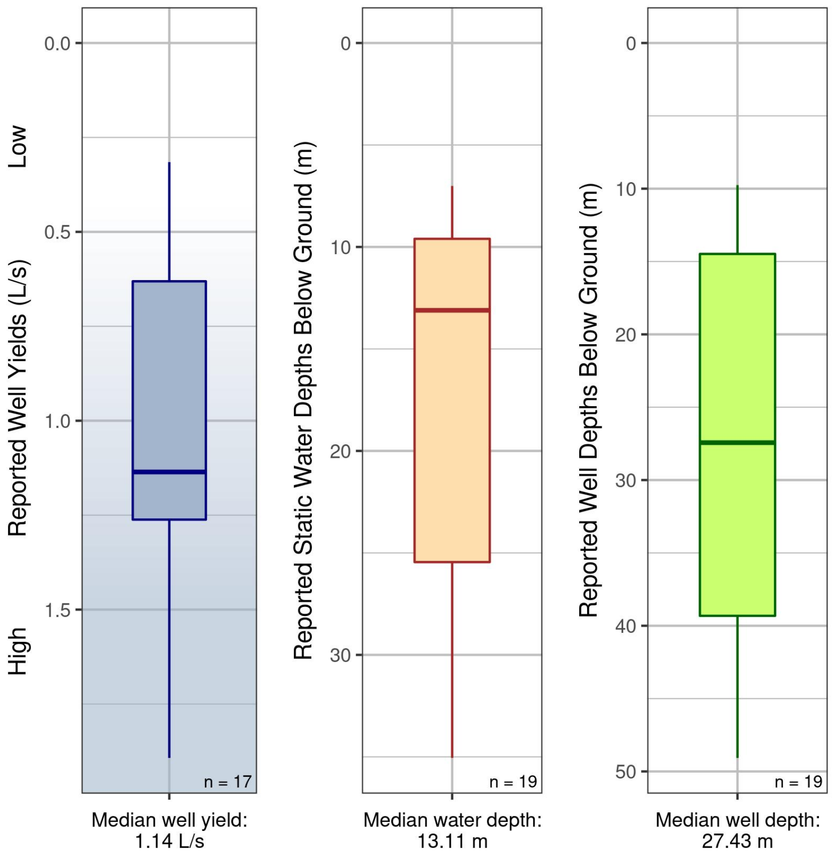
Aquifer #400



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).

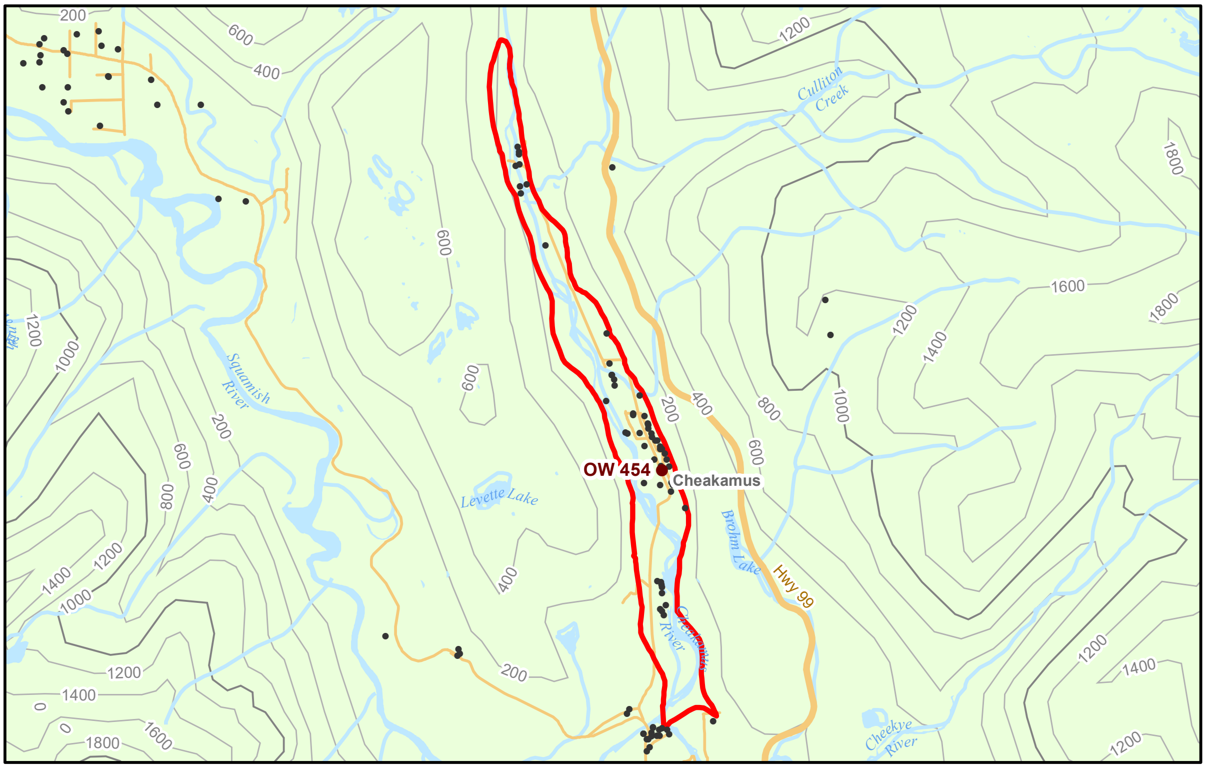
Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	8.7 km^2
No. Wells Correlated	19
Vulnerability to Contamination	Moderate
Productivity	Moderate
Aquifer Classification	IIIB
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	None

* min - max
For Hydraulic Connection see guidance document



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

Aquifer #401

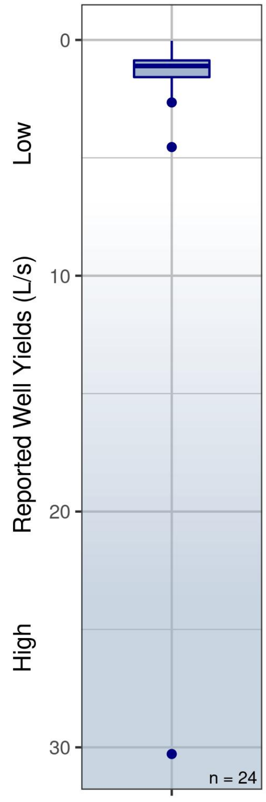


Legend
- Registered Water Well
- Active Observation Well
- Aquifer Boundary

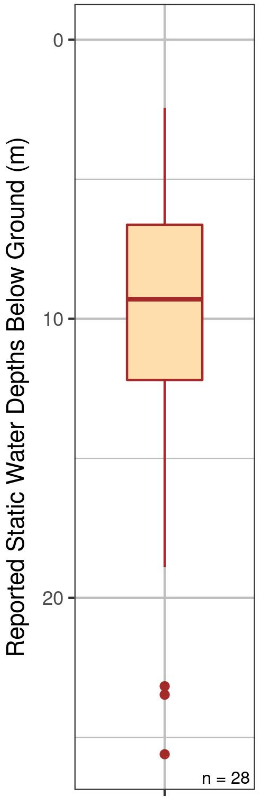
Aquifer Description (Mapping Report - 2000): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	6.4 km^2
No. Wells Correlated	29
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIA
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	**454**

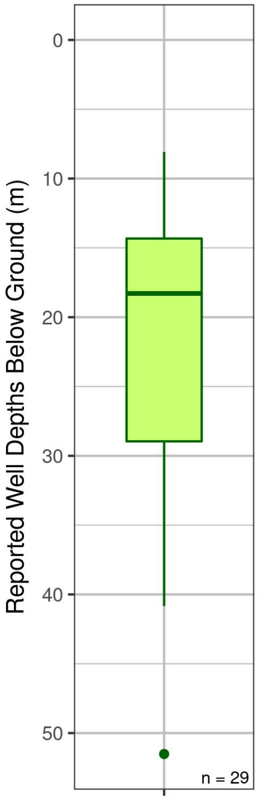
* min - max
For Hydraulic Connection see guidance document



Median well yield: 1.1 L/s



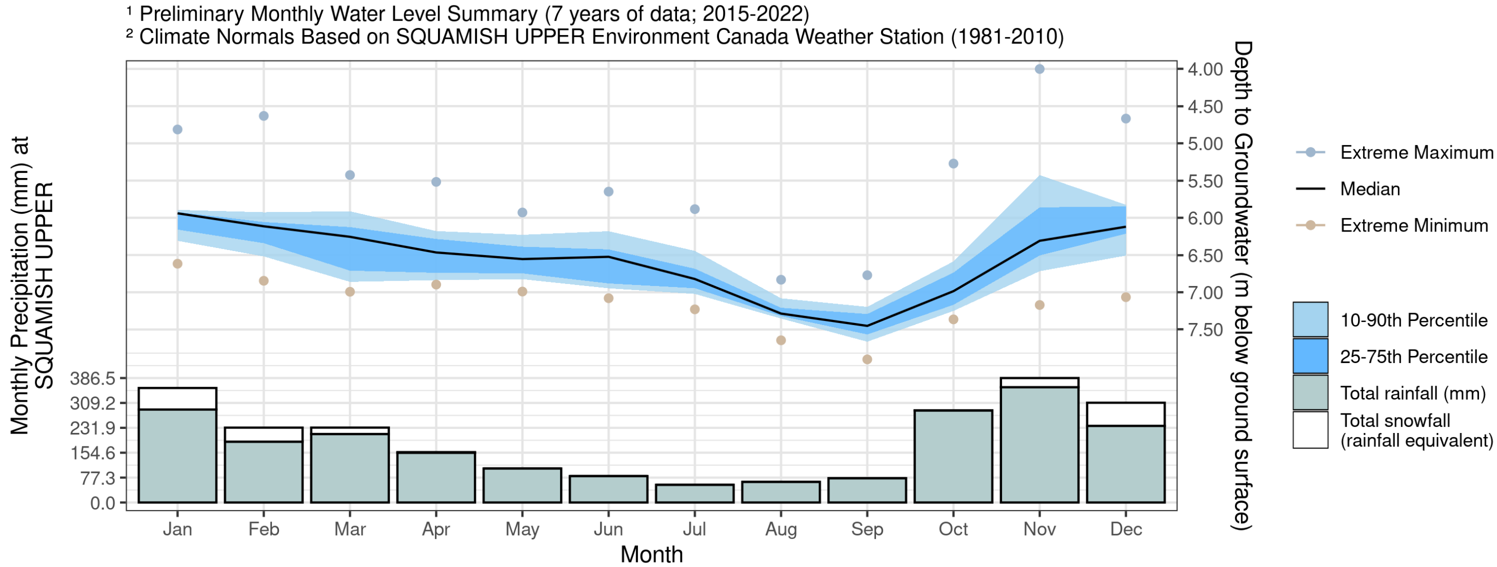
Median water depth: 9.3 m



Median well depth: 18.29 m

Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).
Factsheet generated: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

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

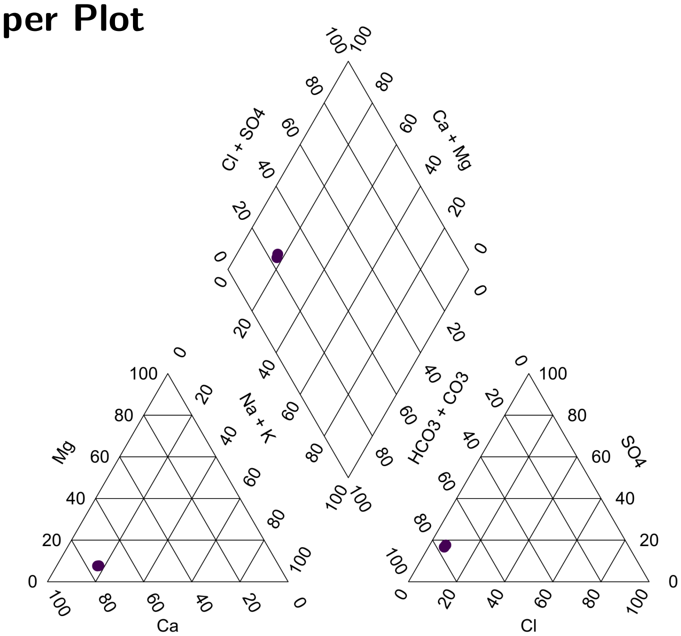


Groundwater Levels and Long-term Trend

Graph not available
(Not enough data)

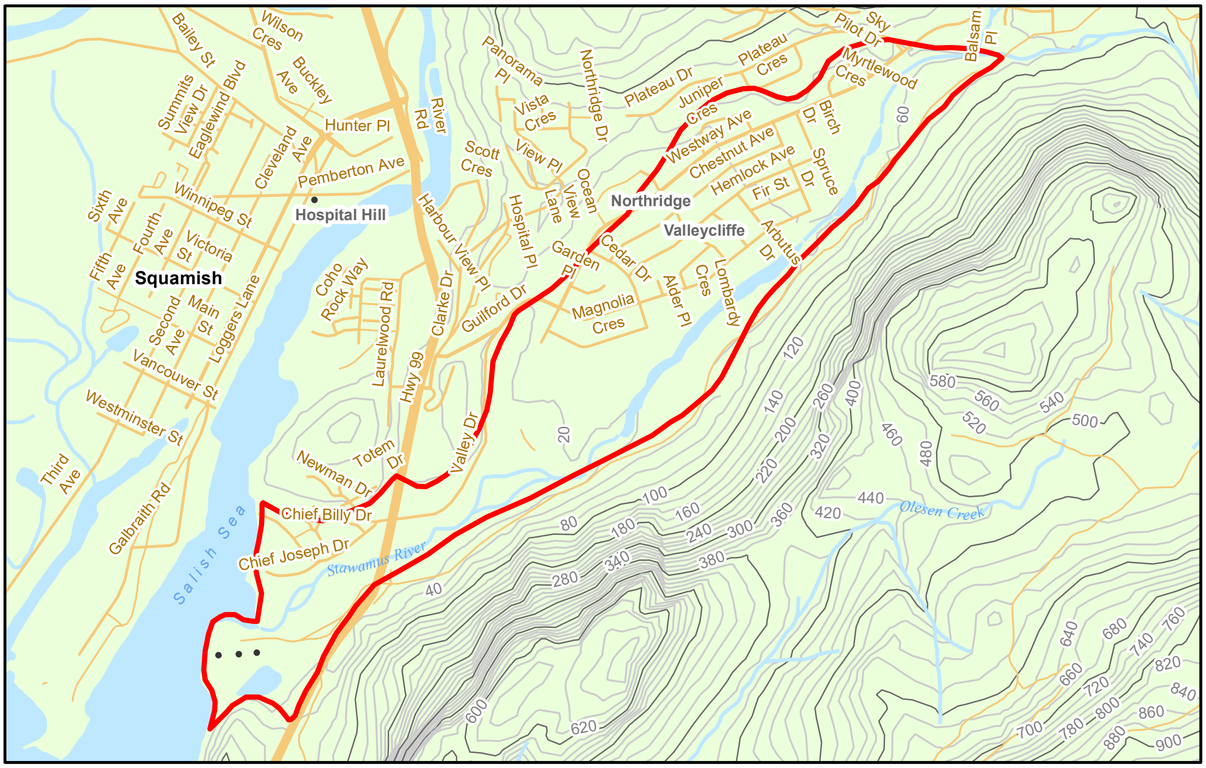
For more information regarding trends in groundwater levels see Environmental Reporting BC

Piper Plot



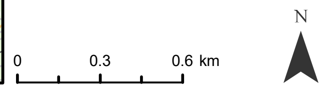
The groundwater samples are typically of the Ca-HCO3 type. Ca is the dominant cations, which indicates a less evolved/short flow path recharge area type of groundwater. The fact that HCO3 is the dominant anion shows the source is primarily recent precipitation in the surficial aquifer #401. For EMS water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

Aquifer #402



Legend

- • Registered Water Well
- Aquifer Boundary

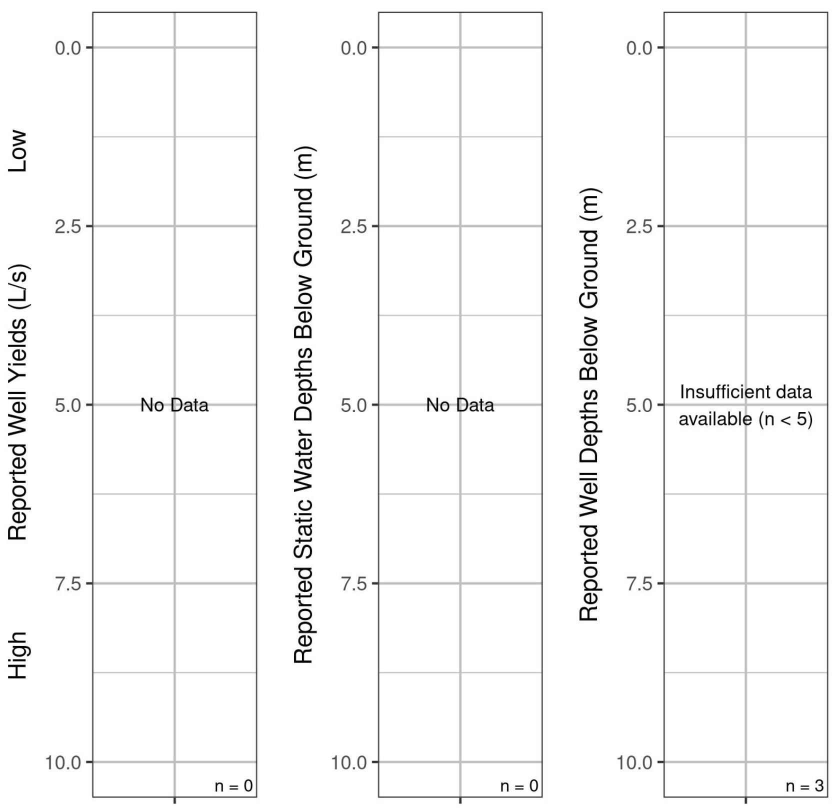


Aquifer Description (Mapping Report - 2020): Predominantly unconfined fluvial or glacio-fluvial sand and gravel Aquifers found along rivers of moderate stream order with the potential to be hydraulically influenced by the river (subtype = 1b).

Aquifer Details	
Region	South Coast
Water District	Vancouver
Aquifer Area	1.6 km^2
No. Wells Correlated	3
Vulnerability to Contamination	High
Productivity	High
Aquifer Classification	IIIA
Hydraulic Conductivity *	Unknown
Transmissivity *	Unknown
Storativity *	Unknown
No. Water Licences Issued to Wells	Unknown
Observation Wells (**Active**, Inactive)	None

* min - max

For Hydraulic Connection see guidance document



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

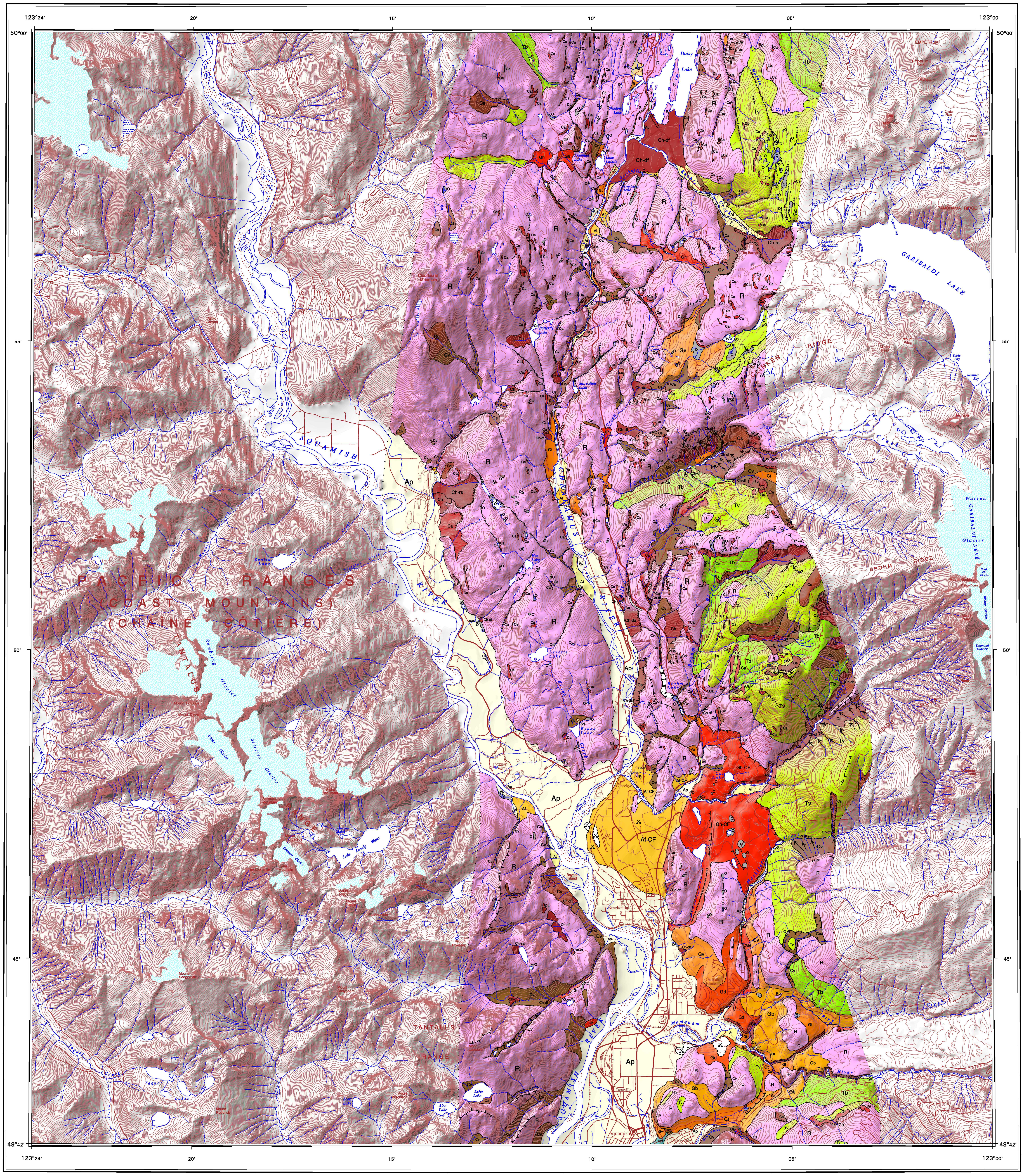
Factsheet generated: 2022-07-27. Aquifers online: https://apps.nrs.gov.bc.ca/gwells/aquifers.

ATTACHMENT 3

Surficial Geological Map for the Squamish Area

Natural Resources Canada   Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA   COMMISSION GÉOLOGIQUE DU CANADA



LEGEND

SURFICIAL GEOLOGY
QUATERNARY

Glacier: *A mass of ice formed from compacted snow in an area where snow accumulation exceeds melting and sublimation.*

POST-FRASER GLACIATION

NONGLACIAL ENVIRONMENT

X — ***ANTHROPOGENIC DEPOSITS:*** *rubble, diamicton, and gravel; 1 to 10 m thick; forming flat and steep surfaces; emplaced by human activity.*

O — ***ORGANIC DEPOSITS:*** *peat and muck; 1 to 10 m thick (typically 2 to 3 m); forming fens and bogs; organic deposits too small to be shown at this scale occur within other units; common within abandoned meltwater channels.*

ALLUVIAL (FLUVIAL) DEPOSITS: *gravel and sand with minor silt and clay, deposited by streams; commonly stratified; generally well sorted except in alluvial fans.*

Ap — ***Floodplain sediments:*** *sand and silt, commonly including organic materials and underlain, in many places, by gravel; 1 to 3 m thick; occurring as flat surfaces close to river level; prone to flooding.*

At — ***Terrace sediments:*** *stratified sand and gravel overlain by a veneer of sand and silt; 2 to 10 m thick; forming terraces well above flood level.*

Ad — ***Deltaic sediments:*** *stratified sand and gravel underlain by silt and clay; generally 2 to 15 m thick; occurring at the mouths of streams entering lakes.*

Af — ***Fan sediments:*** *poorly sorted sand and gravel, with diamicton; generally 2 to 15 m thick; forming fans at the toe of slopes;* Af-Cf *alluvial fan associated with the Cheekye fan differs geomorphologically.*

COLLUVIAL DEPOSITS: *diamicton and rubble deposited by various mass-wasting processes, ranging from slope wash to rock fall; composition dependent on source materials.*

Ch — ***Landslide debris:*** *mostly unconsolidated sediments, with texture dependent on source materials; generally 1 to 10 m thick, but may exceed 10 m near the toe of large landslides; forming hummocky accumulations on lower slopes and valley floor. Where possible, landslides were identified by type:* Ch-df, *debris flow deposit;* Ch-da, *debris avalanche;* Ch-ds, *debris slide;* Ch-rs, *rock slide;* Ch-ra, *rock avalanche;* Ch-sa, *snow avalanche track.*

Cs — ***Slope colluvium:*** *rock fragments in a matrix of, boulders, gravel, sand, silt, and minor clay; 1 to 10 m thick; formed by bedrock weathering or reworking of unconsolidated deposits on steep (>30°) slopes; commonly gullied.*

Ca — ***Talus:*** *rubble and block accumulations at the bottom of steep (>40°) slopes; 1 to 10 m thick; forming aprons and cones.*

Cv — ***Colluvial veneer:*** *rock fragments in a matrix of boulders, gravel, sand, silt; usually <3 m thick; formed by bedrock weathering or reworking of unconsolidated deposits.*

FRASER GLACIATION (LATE WISCONSINAN)

PROGLACIAL AND GLACIAL ENVIRONMENT

GLACIOMARINE DEPOSITS: *sand and gravel, well to poorly sorted, and commonly stratified; deposited by glacial meltwater; bedding disrupted locally due to melt of glacier ice.*

Gmt — ***Glaciomarine terrace sediments:*** *sand and gravel, stratified to massive; 1 to 10 m thick; forming flat surfaces perched well above alluvial deposits or associated with meltwater channels, may be fossiliferous.*

GLACIOFLUVIAL DEPOSITS: *sand and gravel, well to poorly sorted, and commonly stratified; deposited by glacial meltwater; bedding disrupted locally following the melting of supporting ice.*

Gh — ***Ice-contact deposits:*** *sand and gravel, stratified to massive and commonly faulted; generally >3 m thick; forming hummocky surfaces.* Gh-Cf *is an ice-contact debris flow complex associated with the Cheekye fan which differs geomorphologically and compositionally.*

Gt — ***Glaciofluvial terrace sediments:*** *sand and gravel, stratified to massive; 1 to 10 m thick; forming flat surfaces perched well above alluvial deposits or associated with meltwater channels.*

Gb — ***Glaciofluvial blanket:*** *sand and gravel, stratified to massive; generally 1 to 10 m thick; sediment cover is continuous, but the underlying morphology is visible; commonly located near the mouth of meltwater channels.*

Gd — ***Proglacial deltaic sediments:*** *sand and gravel with minor silt and clay; 5 to 10 m thick; commonly overlying glaciolacustrine silt and clay; forming, in part, slightly inclined surfaces.*

Gv — ***Glaciofluvial veneer:*** *sand and gravel, well to poorly sorted, and commonly stratified; deposited by glacial meltwater; bedding disrupted locally following melting of supporting ice, 1 to 3 m thick.*

GLACIAL ENVIRONMENT

TILL: *Poorly sorted diamicton consisting of pebbles, cobbles, and boulders in a sandy to clayey matrix, directly deposited by glaciers; includes colluvium (reworked till) on steep slopes, and small units of glaciofluvial sediments, especially in valley bottoms and near the mouths and banks of meltwater channels; till surface is commonly rilled on steep slopes.*

Tb — ***Till blanket:*** *continuous till cover with few bedrock outcrops; 1 to 3 m thick on average; conforming to and may be locally obscuring morphology of underlying units.*

Tv — ***Till veneer:*** *discontinuous till cover with abundant bedrock outcrops; 1 m thick on average; reflecting topography of underlying bedrock.*

PRE-QUATERNARY

R — ***BEDROCK:*** *sedimentary, low-grade metamorphic, volcanic, and intrusive rocks of Jurassic to Quaternary age; including, in places, till veneer, drift, and colluvium.*

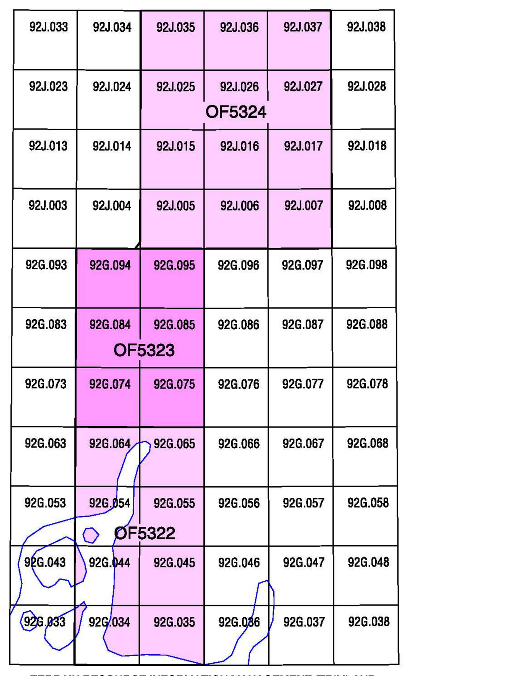
Geological boundary (defined, inferred)
Limit of mapping
Ice-contact scarp
Escarpment
Large meltwater channel
Small meltwater channel
Sand and gravel pit (large, small)
Travel directions of landslides, mainly debris flows and snow avalanches
Crest

ACKNOWLEDGEMENTS

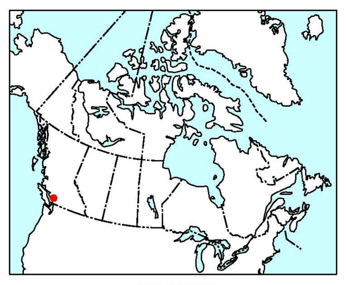
This mapping project was funded by Climate Change Action Fund A769A. The author wishes to thank R. Schwartz and P. Kertland of CCAF for financial and managerial guidance of the project. The author is grateful to T. Millard and M. Geertsema from BC Ministry of Forests and Range for providing digital TRIM data as well as helpful discussions. J. Clague, O. Hungr, and F. Baumann provided invaluable critical reviews. K. Shimamura, S. Denny, M. Ulmi, C. Hickson, N. Jordan, F. Baumann, M. Journeay, R. Hermanns, C. and B. Struik provided field and/or technical assistance. R. Fournier, M. Boutin, F. Créach'cadec, and S. Paradis gave GIS assistance for parts of the map area. M. Méthot and N. Côté are thanked for their assistance in GIS and creating the final map product. Many thanks go to my GSC colleagues for helpful discussions and advice throughout the project.

REFERENCES

Cruden, D.M. and Varnes, D.J.
1996: Landslide types and processes. *In* Special Report 247. Landslide investigation and mitigation. A.K. Turner and R. L. Schuster (eds.) National Research Council, Transportation Research Board, Washington D.C, p. 36–75.



TERRAIN RESOURCE INFORMATION MANAGEMENT (TRIM) AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS


LOCATION MAP

OPEN FILE 5323

SURFICIAL GEOLOGY AND LANDSLIDE INVENTORY OF THE MIDDLE SEA TO SKY CORRIDOR

BRITISH COLUMBIA

Scale 1:50 000/Échelle 1/50 000

kilometres 1 0 1 2 3 4 kilomètres

Universal Transverse Mercator Projection
North American Datum 1983

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1983

Author: A. Blais-Stevens

Geology by A. Blais-Stevens, 2004–2007

Compilation and interpretation was carried out using British Columbia 1994 colour aerial photography series 30BCC94, at 1:15,000 scale.

Digital cartography by M. Méthot and N. Côté, Data Dissemination Division (DDD)

This map was produced from processes that conform to the Scientific and Technical Publishing Services Subdivision (DDD) Quality Management System, registered to the ISO 9001: 2000 standard

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Digital base map from Terrain Resource Information (TRIM), modified by DDD

Shaded relief image prepared by DDD, derived from the digital elevation model, based on TRIM contours elevation data
Illumination: azimuth 315°, altitude 45°, vertical factor 1x

Magnetic declination 2008, 18°08'E, decreasing 12.6' annually.

Elevations in metres above mean sea level
Contour interval 20 m

OPEN FILE
DOSSIER PUBLIC
5323
GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
2008

Recommended citation:
Blais-Stevens, A.
2008: Surficial geology and landslide inventory of the middle Sea to Sky corridor, British Columbia; Geological Survey of Canada, Open File 5323, scale 1:50 000.

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