



# **Sunshine Coast Regional District**



## **Groundwater Investigation Phase 2, Part 2 and Groundwater Investigation Phase 3 – Gray Creek**

### **Final Report**

**March 25, 2021**



**Kalwij Water Dynamics Inc.**

## **Sunshine Coast Regional District**

### **Groundwater Investigation Phase 2, Part 2 and Groundwater Investigation Phase 3 – Gray Creek**

#### **Prepared for:**

##### **Sunshine Coast Regional District**

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Sechelt, BC V0N 3A1

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KWD would like to thank the SCRD for the opportunity to lead and conduct Groundwater Investigation Phase 2, Part 2 and Groundwater Investigation Phase 3 – Gray Creek and staff for their collaboration throughout the project.

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## Sunshine Coast Regional District

### Groundwater Investigation Phase 2, Part 2 and Groundwater Investigation Phase 3 – Gray Creek

Respectfully submitted,

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 *March 25, 2021*

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## Summary

The Sunshine Coast Regional District (SCRD) commenced a **Groundwater Investigation Program** in 2017 to determine the feasibility of groundwater development to meet the identified water supply deficit for the Chapman Water System (i.e.: 2 million m<sup>3</sup> of additional supply / storage by 2025) and account for increasing water demand in the future. The development of the Church Road Well Field, scheduled for completion in late 2021, is expected to address approximately 45% of the projected 2025 water deficit. Additional supply sources are therefore required to make up for the remaining shortfall, and groundwater sources are explored in **Groundwater Investigation Phase 2, Part 2 and Groundwater Investigation Phase 3 – Gray Creek explored additional groundwater**. The results are presented in this report.

In July 2020, Kalwij Water Dynamics Inc (KWD) finalized test well drilling locations in collaboration with SCRD staff, and following approval from the Sechelt First Nations (shíshálh Nation) and the Squamish Nation (Sḵwxwú7mesh Úxwumixw) for each of the sites, the test well drilling program proceeded at the following locations:

1. Maryanne West Park - 1224 Chaster Road (adjacent to Cedar Grove Elementary School): **Test Well No. 1.**
2. Langdale – BC Ferries Terminal property: **Test Well No. 2.**
3. Gray Creek - District of Sechelt Road Dedication: **Test Well No 3.**
4. Harman Road, Ministry of Transportation and Infrastructure (MOTI) road-right-of-way: **Test Well No 4.**

The field work program commenced on September 23, 2020, with the drilling of **Test Well No. 1 (Maryanne West Park)** and was concluded on December 18, 2020 (**Test Well No. 4 on Harman Road**). Broadly speaking, the field program included drilling, construction, and development of the test wells, completing 48-hour continuous pumping tests at each location (except for **Test Well no. 4**), in addition to hydrogeological field investigations (i.e.: recording borehole lithology based on drill cuttings retrieved during drilling; a grain size analysis was completed on selected aquifer soil samples in support of well screen selection). The table below summarizes selected information:

Description	Test Well No. 1 Maryanne West Park	Test Well No. 2 Langdale	Test Well No. 3 Gray Creek	Test Well No. 4 Harman Road
Civic Address	1224 Chaster Road	BC Ferries Terminal	District of Sechelt Road Dedication	Harman Road Right-of-Way
Construction / testing (2020)	Sep 23 - Oct 23	Oct 28 - Nov 13	Nov 26 - Dec 11	Dec 10 - Dec 18
Well ID No.	23761	23762	23763	23764
Aquifer material	sand and gravel	sand and gravel	sand and gravel	bedrock*
Depth to aquifer (m-bgs)	79	11	9.1	Water-bearing fractures @ 171 & 238 m-bgs
Aquifer thickness (m)	35	56	15	
Test well depth (m-bgs)	108	64	24	244
Well screen interval (m-bgs)	104-108	60 - 64	18 - 24	-
Screen length (m)	3.66	3.66	5.49	-
Static water level (m-bgs)	80	3.6	5.4	44
Pumping rate - test (L/s)	17.5	22.0	6.3	Est. 1-2 L/s
* The encountered water-bearing sand and gravel aquifer was only 1.5 m in thickness, producing about 1.6 L/s.				

Based on the results of drilling and construction of **Test Well No 4**, it was concluded that the site is unsuitable for further groundwater development as a potential SCRD production well site. Therefore, the test well site was excluded from any further testing and analysis.

### **Calculated Potential Pumping Rates**

All three sites were successfully tested at pumping rates of 17.5 L/s, 22.0 L/s, and 6.3 L/s for Maryanne West Park, Langdale, and Gray Creek sites, respectively. Although Gray Creek site's pumping rate is lower, it is considered suitable for supplying water to the local communities. Higher well yields are anticipated, especially for Langdale site, given the proposed larger diameter of the proposed production wells, larger screen length potential, and room for optimizing well development. Theoretical potential pumping rates of future production wells of 19.3 L/s (Maryanne West Park), 24 L/s (Langdale), and 6.3 L/s (Gray Creek) can be assumed in further discussions. The safe yield of future 300-mm diameter production wells can be determined once the production wells have been drilled and tested.

### **Water Quality**

Results of the preliminary raw water quality analysis completed for water samples collected from **Test Wells Nos. 1, 2 and 3** suggest that the water quality meets Canadian Drinking Water Guidelines for maximum acceptable concentrations of the analyzed constituents. Only **Test Well No. 2 (Langdale)** presented concentrations that exceeded aesthetic objectives, i.e.: for iron and manganese. These are not considered health concerns; if these elevated concentrations persist with pumping, water treatment may be required. Blending with the existing water system supply is also a possibility by authorization of the health authority. Note that although the manganese concentration exceeded the aesthetic objective, the concentration was well below the set maximum acceptable concentration guideline limit (*manganese is one of the few constituents for which Health Canada has defined aesthetic objective as well as maximum acceptable concentration guidelines*). **Test Well No. 3 (Gray Creek)** reported a pH value of 6.76, which is low. Source waters with pH values consistently less than 7.0 may require treatment in order to raise the pH and enhance the effectiveness of chlorination.

### **Source Protection**

Results of the preliminary assessment suggest that all three groundwater sources should be assumed to be at risk of containing pathogens until proven otherwise. This risk may be mitigated with standard chlorination procedure as is currently the practice with all SCRD water sources. A water quality monitoring program should be in place to determine the effectiveness of the chlorination procedure.

### **Stream-Aquifer Hydraulic Connection**

A preliminary assessment of the likelihood of hydraulic connection of the aquifers to nearby streams suggests that:

- **Maryanne West Park Site:** the aquifer is unlikely hydraulically connected to Chaster Creek.
- **Langdale Site:** the aquifer is unlikely directly hydraulically connected to Langdale Creek.
- **Gray Creek Site:** the aquifer is likely hydraulically connected to Gray Creek.



## Multi-Criteria Analysis Workshop

The workshop, held virtually on January 6, 2021, was attended by SCRD staff and KWD's project team members. Criteria and corresponding sub-criteria were developed to determine the feasibility of future groundwater development at each site. All three sites received over 70 percent of the total score available and thus are considered suitable for advancing future groundwater development at this time. Some observations:

- Although Gray Creek site has a lower well productivity potential compared to the other two sites, it was found that this site would be adequate for local supply.
- Possible additional treatment requirements, if elevated iron and manganese concentrations persists at Langdale site, and if low pH persists at Gray Creek site.
- No immediate concerns regarding groundwater source protection at all three sites.
- Groundwater development costs for Langdale site are considerably higher due to water system tie-in requirements to the Chapman Water System.
- Groundwater development costs per unit of anticipated water supply are forecast to be the highest for Gray Creek site and the lowest for Maryanne West Park.
- Energy costs are forecast to be highest for Maryanne West Park site and lowest for Gray Creek site
- Meeting environmental flow need requirements is unlikely to be an issue.
- Maryanne West Park site screens the same aquifer as the Town of Gibsons production wells.
- Maryanne West Park is likely to be the most challenging permitting-wise (i.e.: obtaining groundwater use authorization).
- Gray Creek site was rated highest in resiliency based on the fact that the aquifer is a local aquifer, and a (future) supply source could act as emergency supply should damage occur to the main water system.

## Conclusions

Based on the results of the groundwater investigation program at **Maryanne West Park**, **Langdale**, and **Gray Creek** test well sites in conjunction with the outcome of the multiple-criteria analysis, the following is concluded regarding the viability of groundwater development potential at the explored locations:

- ✓ Maryanne West Park, Langdale, and Gray Creek sites are suitable for production well development.
- ✓ All three sites are suitable for developing a well field with two or more production wells.
- ✓ All three sites presented water quality at the time of testing that meets the drinking water health parameters (i.e.: all tested water quality parameters are below maximum acceptable concentration).
- ✓ For all three sites pathogen risk may be mitigated with chlorination.

## Recommendations

Based on the foregoing we recommend the following for future groundwater development and further steps:

1. Proceed with development of a well field of two production wells at each test well site: **Maryanne West Park, Langdale, and Gray Creek**. A second production well not only increases well field production potential and is more cost efficient, it also provides a mechanical backup in the event of primary well failure, and thus ensures well field resiliency.
2. Consider the implementation of a long-term water quality and groundwater monitoring program as part of future aquifer and watershed management initiatives.
3. Implement a groundwater quality monitoring program for **Test Well No. 2 (Langdale)** in order to provide better insight in the trending of iron and manganese concentrations and determine if water treatment is required.
4. Undertake all technical analyses and monitoring (also including water level / flow monitoring for Gray Creek and Langdale Creek if required) in support of the water licence applications.
5. Begin concurrent water licence applications for each of the well site locations.

## Units and Abbreviations

### Units

Centimetre	cm
Cubic metre per day	m <sup>3</sup> /d
Kilometre	km
Litres per second	L/s
Litres per second per metre	L/s/m
Nephelometric Turbidity Units	NTU
Metres	m
Metres per day	m/d
Micro Siemens per centimetre	μS/cm
Milligrams per litre	mg/L
Millimetres	mm
Million cubic metres	Mm <sup>3</sup>
Percentage	%
Square metre per day	m <sup>2</sup> /d
Years	yrs

### Abbreviations

Aesthetic Objective	AO
Below ground surface	bgs
Hydraulic Conductivity	K
Maximum Acceptable Concentration	MAC
Operational Guideline for Water	
Treatment Plants	OG
Storativity	S
Transmissivity	T



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# 1 Introduction

## 1.1 Background

The Sunshine Coast Regional District (SCRD) owns, operates, and maintains several water supply systems between Earl's Cove and Langdale, including a water system on Keats Island. About 70% of the water supply comes from the **Chapman Water System** which has Chapman Lake and Edwards Lake as supply sources. In addition, the SCRD supplies drinking water to communities through small water systems which rely on groundwater as the primary supply source: *Langdale*, *Soames* and *Grantham's Landing* water systems<sup>1</sup>. SCRD's Chaster Well on Kings Road (Elphinstone – Electoral Area E) is typically placed in operation during the summer months, supplying the Chapman Water system at those times when lake levels are low. Chapman water system and Langdale, Soames and Grantham's Landing water systems supply water to an estimated population of 20,000 people.

SCRD has been undertaking a continued **groundwater investigation program to determine the feasibility of groundwater development to meet the current water supply deficit** (i.e.: 2 million m<sup>3</sup> of additional supply / storage by 2025). This program was a recommendation in the [SCRD 2013 Comprehensive Regional Water Plan](#)<sup>2</sup>, and between 2017 and 2019 the SCRD has completed the following under this program:

- [Phase 1 Groundwater Investigation](#), a desktop study with the objective of identifying potential test well drilling sites.
- [Phase 2 Groundwater Investigation](#), a test well drilling program with the objective of assessing groundwater development potential at the four preferred sites identified in Phase 1. The outcome of Phase 2 resulted in the development of a new well field at Church Road.
- [Phase 3 Groundwater Investigation](#), groundwater development and related work at the Church Road well field and preliminary engineering design (water treatment plant).

The development of the Church Road Well Field, scheduled for completion in late 2021, is expected to address approximately 45% of the water deficit ([Let's Talk Water! - Church Road](#)).

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<sup>1</sup> These three water systems are interconnected and connect to the Chapman Water system via closed or pressure reducing valves, and thus are also functioning as a backup to Chapman Water System and vice versa (based on Opus 2013). Hopkins water system (privately owned) is also interconnected with SCRD water systems. However, the four SCRD water systems North of Secret Cove (Egmont, Cove Cay, North Pender Harbour and South Pender Harbour water systems) do not connect to the Chapman Water system.

<sup>2</sup> The [underlined blue-coloured phrases](#) hyperlink to reports and other information made available by the SCRD on their website.

Additional supply sources are therefore required to make up for the remaining shortfall. As such, the SCRD issued a Request for Proposal on March 30, 2020, to conduct **Groundwater Investigation Phase 2, Part 2 and Groundwater Investigation Phase 3 – Gray Creek**:

- **Phase 2 Part 2** is a continuation of the previous Groundwater Investigation Phase 1 work (2017) and will include exploring additional well site locations not pursued during Phase 2 – Part 1 (2018).
- Gray Creek site was selected in Groundwater Investigation **Phase 1** (2017); test Well Drilling was completed in **Phase 2** (2018); **Phase 3** explores other possible location(s) in the Gray Creek area.

Kalwij Water Dynamics Inc. (KWD) was awarded the project to conduct the groundwater investigation study. KWD engaged Onsite Engineering Ltd. as the Civil/Mechanical Engineering Consultant, and Fyfe Well & Water Services as the Well Drilling Contractor. This report summarizes the results of the Groundwater Investigation Phase 2 Part 2 and Groundwater Investigation Phase 3 – Gray Creek. The report was reviewed by Thierry Carriou, P.Eng. (BC Groundwater Consulting Ltd.).

## 1.2 Project Scope and Timeline

### 1.2.1 Project Scope

The project scope has been divided into the following six (6) key tasks for each of the test well drilling sites:

- Task 1: Test Well Drilling Site Selection
- Task 2: Field Program Implementation: Test Well Drilling and Well Testing
- Task 3: Analysis: Hydrogeology, Groundwater Supply, Water Quality
- Task 4: Cost Estimates and Infrastructure & Operational Requirements
- Task 5: Groundwater Source Risks & Other Considerations
- Task 6: Reporting & Recommendations

**Appendix A** includes project illustrations.

The hydrogeological information presented in this report is based on data collected by KWD during field program implementations. General and supporting information is obtained from reports made available by the SCRD, in addition to online resources such as iMapBC<sup>3</sup>.

### 1.2.2 Timeline

The project commenced in July 2020, with an initialization meeting on July 17, 2020 attended by KWD team and SCRD staff. KWD finalized the test well drilling locations in collaboration with SCRD staff (**Section 1.3**). Following approval from the Sechelt First Nations (shíshálh Nation) and the Squamish Nation (Skwxwú7mesh Úxwumixw), **Task 2 (field program implementation)** was completed between September 23 and December 18, 2020.

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<sup>3</sup> Government of BC online mapping tool (<https://maps.gov.bc.ca/ess/hm/imap4m/>), linked to a well and aquifer database (<https://apps.nrs.gov.bc.ca/gwells/>).

KWD submitted a **project summary report** to the SCRD on January 15, 2021 and presented the results at the SCRD Infrastructure Services Committee on January 20, 2021, and to the Water Supply Advisory Committee on February 1, 2021. In summary, completed milestones are as follows:

July 2020	August 2020	September 2020	October 2020
<u>17</u>   Initialization Meeting		<u>9</u>   Approval received from Sechelt First Nations and Squamish Nation	<u>7</u>   TW-1 drilling & construction completed
<u>24</u>   Test Well Sites Finalized			<u>23</u>   TW-1 well testing completed
			<u>30</u>   TW-2 drilling & construction completed
November 2020	December 2020	January 2021	February 2021
<u>13</u>   TW-2 well testing completed	<u>2</u>   TW-3 drilling & construction completed	<u>6</u>   MCA workshop	<u>1</u>   Presentation to the Water Supply Advisory Committee
	<u>11</u>   TW-3 well testing completed	<u>15</u>   Project Summary Report	
	<u>18</u>   TW-4 drilling & construction completed	<u>20</u>   Presentation to the Infrastructure Service Committee	
			March 2021
			<u>25</u>   Final Report

### 1.3 Test Well Drilling Site Selection

Areas of consideration for potential test well drilling were: (i) Elphinstone; (ii) East Porpoise Bay; (iii) Langdale (iv) DL 1312; and (v) Gray Creek. Consideration was first given to property that was owned by the SCRD and privately owned property for which the landowner or agent granted an initial (verbal) permission to drill a test well. Site visits, in addition to review of available public domain hydrogeological information, were completed to identify candidate test well drilling sites.

Listed below are the finalized test well locations, including references to their locations and a brief explanation of the rationale for each of the selected test well sites:

**Test Well No. 1:** Maryanne West Park, 1224 Chaster Road, Elphinstone.

**Rationale:** available first-hand hydrogeological information from existing domestic water supply wells drilled in the sand and gravel aquifer in this area, in addition to confirmed hydrogeology at Mahan Road (one of SCRD's existing test wells) and SCRD Chaster Well borehole lithology, suggests this could potentially be a good candidate for a test well location. The park is SCRD property.

**Test Well No. 2:** Langdale - BC Ferry Terminal, 1410 Port Mellon Highway.

**Rationale:** based on available information about the sand and gravel aquifer and SCRD's Langdale production well, siting a test well near this production well was considered with an eye toward twinning the existing SCRD production well with a new production well thereby increasing existing well field capacity. Although the existing well supplies the Langdale Water System, a potential future production well could be connected to the Chapman Water System.



The test well was drilled on property owned by Ministry of Transportation and Infrastructure (MOTI), and leased to BC Ferries. Approval to proceed with test well drilling was received from BC Ferries.

**Test Well No. 3: Gray Creek - District of Sechelt Road Dedication.**

Rationale: available information about the high productivity of the production wells at Northern Divine Aquafarm Ltd. suggests that a productive sand and gravel aquifer surrounding the Gray Creek delta area. Drilling at the road dedication, south of the Sechelt Inlet road, places the well further west of the steep relief observed east of the Sechelt Inlet road, and places the test well close to the creek delta presumably outside the Gray Creek flood plain. District of Sechelt approved the drilling of the test well on the road dedication.

**Test Well No. 4: Harman Road – Road Right-of-Way, Roberts Creek.**

Rationale: available first-hand hydrogeological information from existing domestic water supply wells for a bordering subdivision suggests (sand and gravel) aquifer productivity. The test well was drilled on the road right-of-way and approval to proceed was received from MOTI.

**Figure (Fig.) 1-1** shows an overview map of the test well drilling locations. **Appendix B** shows Google Earth imagery for each of the selected test well sites.

Regarding the East Porpoise Bay location, BC Parks indicated that drilling in Porpoise Bay Provincial Park would contravene the BC Parks Act. Hence this site was not pursued further and a test well location on Allen Road was identified. However, based on the relatively close proximity of this candidate test well drilling site to land dedicated for anticipated future expansion of gravel mining operations, the SCRD decided that test well drilling in East Porpoise Bay would be considered as a last resort for exploring potential groundwater development and would be eliminated from the current investigation scope. In September, the finalized test well drilling sites at Gray Creek and DL 1312 were reconsidered and adjusted as a result of changes in land availability.

## 1.4 Organization of this Report

**Section 2** provides a brief overview of the project setting hydrology, geology, and hydrogeology. The report presents the results of the test well drilling program in the order in which the test wells were completed:

- **Section 3** – Test Well No. 1, Maryanne West Park (Elphinstone)
- **Section 4** – Test Well No. 2, Langdale (BC Ferries Terminal)
- **Section 5** – Test Well No. 3, Gray Creek (District of Sechelt Road Right-of-Way)
- **Section 6** – Test Well No. 4, Harman Road (Roberts Creek)

**Section 7** presents preliminary assessments of groundwater source risks, the likelihood of potential hydraulic connection between an aquifer and stream, and discussions on potential salt-water intrusion and climate considerations. **Section 8** presents Class C cost estimates for production well construction, Class D cost estimates for infrastructure, and operational costs estimates. **Section 9** summarizes the results of the multi-criteria analysis workshop. **Section 10** presents the conclusions and recommendations.

## 2 Project Setting (Overview)

### 2.1 Climate & Biogeoclimate

The Sunshine Coast has a temperate coastal climate (mild dry summers and cool wet winters). The climate corresponds with Köppen Climate Classification **Csb**<sup>4</sup>. **Fig. 2-1** shows 30-year climate normals (precipitation and temperature) for Gibsons weather station.

The Coastal Western Hemlock Biogeoclimatic zone is the dominant zone on the Sunshine Coast (as well as for most of BC's Coastal areas, Vancouver Island and Haida Gwaii), and shares territory with the Mountain Hemlock. There are pockets of the Coastal Douglas-fir Biogeoclimatic Zone on the Sechelt Peninsula and selected areas of the Sechelt and Narrows inlets, in addition to areas of Coast Mountain Hemlock<sup>5</sup>.

### 2.2 Hydrology

The Sunshine Coast borders saltwater including the Strait of Georgia, Malaspina Strait, West Howe Sound, and Sechelt Inlet and is characterized by an abundance of creeks (**Fig. 1-1**), with Chapman Creek being the main source of water supply to the SCRD (i.e.: Chapman Creek Water System). KWD identified those creeks closest to the test well drilling sites (creek trajectories are shown on the maps in **Appendix B**):

- **Chaster Creek** is a perennial stream, with its headwaters on Mount Elphinstone, at an elevation of approximately 900 m, which discharges into the Strait of Georgia. Chaster Creek has several tributaries and continues as Lower Chaster Creek below 240 m elevation. Water rights exist on this creek. Chaster Creek is home to various fish species including, among others, *Chum Salmon*, *Coho Salmon*, *Rainbow Trout* and *Steelhead*.
- **Langdale Creek** is a perennial stream, with its headwaters on Mount Elphinstone, at an elevation of approximately 1075 m, and discharges into Howe Sound. Langdale Creek has several documented tributaries and is home to *Pink Salmon*, *Coho Salmon* and *Cutthroat Trout* among other fish species. Water rights exist on this creek<sup>6</sup>.
- **Gray Creek** is a perennial stream, with its headwaters on Tetrahedron Plateau (Tetrahedron Provincial Park), at an elevation greater than 1000 m. Gray Creek, which has many documented tributaries, discharges into the Sechelt Inlet (Porpoise Bay). Gray Creek is home to several fish species including, among others, *Pink Salmon*, *Coho Salmon*, *Chum Salmon*, *Cutthroat Trout*, *Rainbow Trout* and *Steelhead*. The mouth of Gray Creek is just north of Northern Divine Aquafarms Ltd. which farms white sturgeon. Both SCRD and Northern Divine Aquafarms Ltd. have active water licences for diverting water from the creek.

<sup>4</sup> **C**: temperature of warmest month greater than or equal to 10 °C, and temperature of coldest month less than 18 °C but greater than –3 °C; **s**: precipitation in driest month of summer half of the year is less than 30 mm and less than one-third of the wettest month of the winter half; **b**: temperature of each of four warmest months 10 °C or above but warmest month less than 22 °C. (Kottek et al. 2006).

<sup>5</sup> Biogeoclimatic zones: <https://www.sfu.ca/geog/geog351fall07/Group06/webmap.html>.

<sup>6</sup> Based on the Government of BC water rights database: <https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-licences-approvals/water-rights-databases>.

- **Smales Creek** is a perennial stream with its headwaters at an elevation greater than 500 m, and discharges into Strait of Georgia. Smales Creek, which has one tributary documented, is home to fish species (details not available). There are, reportedly, no water rights correlated to this creek.
- **Cornwallis Creek** is a perennial stream with its headwaters at an elevation greater than 600 m, and discharges into Strait of Georgia. The creek, which has reportedly several tributaries, is home to various species (details not available). There are, reportedly, no water rights correlated to this creek.

### **Designated Wetland**

The adjacent area, north of the property on which **Test Well No. 1** (Maryanne West Park) is located, is designated as a “wetland”<sup>7</sup>. The approximate location of the wetland is marked in **Appendix B (Image 1)**.

## **2.3 General Geology**

The Sunshine Coast is situated in the Pacific Range, which is the southern-most subdivision of the Coast Mountains. The Coast Mountains consist of deformed rocks of igneous (intrusive) and metamorphic origin<sup>8</sup>. The Coast Mountains are an uplifted (exhumed) deep magma chamber<sup>9</sup>. During the last glaciation, glacial ice moved over the entire area, southward down Howe Sound and southeast down the main coast (and into Washington State). This glacial ice or Cordilleran Ice Sheet of the Wisconsin Glaciation (~ 85,000 to 11,000 BP<sup>10, 11</sup>) is responsible for the landforms seen today. The ice sheet caused, below 300 m elevation, ground mantled with a variety of unconsolidated materials of glacial, glaciomarine, marine, and fluvial origin (based on McCammon 1977).

**Fig. C-1 in Appendix C** illustrates the area geology (bedrock). Bedrock is exposed and/or underneath Quaternary deposits (**Fig. C-2 in Appendix C**). Sediments from the Quaternary Period (started 2.6 M years ago) of the Cenozoic Era (started about 65 M years ago) are deposits from glacial and interglacial periods in addition to more “recent” deposits (post glacial).

## **2.4 General Hydrogeology**

The area hydrogeology is shaped by (i) bedrock aquifers (consolidated formation): groundwater is primarily stored in (interconnected) fractures; *intrusive as well as sedimentary rock aquifers*<sup>12</sup>, *with intrusive aquifers predominantly granite / diorite / granodiorite saturated fractured rock* (fractured crystalline bedrock); and (ii) sand and gravel aquifers (unconsolidated formation): *groundwater is stored in saturated sand and gravel formations*.

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<sup>7</sup> Sunshine Coast Sensitive Ecosystems Inventory (SEI):  
<http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=3758>

<sup>8</sup> **Intrusive** or igneous (or plutonic) rocks form when magma cools slowly below the Earth's surface; **metamorphic** rocks are transformed rocks because of intense heat or pressure (while being formed).

<sup>9</sup> Personal communications with Diana Allen (on May 31, 2020).

<sup>10</sup> BP stands for “Before Present” and is set to January 1, 1950. The selection of this date is related to the using of radiocarbon dating (started first in the 1940s).

<sup>11</sup> For the geology-minded: we are currently in the **Meghalayan Age** of the Holocene Epoch of the Quaternary Period, and started 4,200 BP.

<sup>12</sup> **Sedimentary rocks** are formed from small grains of mineral and rock eroded from pre-existing rocks and deposited by water, wind or ice in relatively uniform, horizontal layers.

**Fig. C-3 (Appendix C)** shows delineations of known aquifers mapped by the Government of BC. These delineations are approximations, based on available information such as well records, geological records, or any other source detailing subsurface lithology. Similarly, there are aquifers not yet mapped due to limited information and/or lack of any groundwater development.

The **sand and gravel aquifers** were formed in the Quaternary Period (Pleistocene and Holocene Epoch, with the latter being the post glacial period), most of which were formed in the last 60,000 years (BP). Relevant to the Sunshine Coast area, listed from recent to the oldest in time, aquifers and low permeable formations are typically correlated to the following geological units:

- **Salish Formation:** post glacial formation (modern); geomorphic processes that are active today deposit Salish Sediments (Bednarski 2015).
  - Shore, deltaic, fluvial and swamp deposits: gravel, sand, clay, peat (McCammon 1977).
- **Capilano Sediments:** post glacial outwash (glacial retreat); glaciomarine sediments deposited beyond retreating ice margin 10,000 – 13,000 yrs (Clague, 1994).
  - Fluvial, deltaic, fan, and channel deposits: cobbles, gravel, sand, and silt
  - Marine and glaciomarine deposits: varied gravelly, sandy, stoney, clay (McCammon 1977).
- **Vashon Drift:** deposited during the maximum ice advance of the Fraser Glaciation 14,000-18,000 yrs (Clague, 1994), and comprises of massive to stratified poorly sorted sediments (diamictos):
  - Glacio-fluvial deposits: gravel and sand (McCammon 1977)
  - Ground moraine deposits: mainly till (McCammon 1977).
- **Quadra sand** is deposited in front of advancing glaciers during the early stages of the Fraser glaciation; sand and gravel deposits.
- **Pre-Vashon** Sediments: from a non-glacial interval (~30,000 – 60,000 yrs)
  - gravel, sand and silt (McCammon 1977).

For further reading regarding specific aquifers on the Sunshine Coast please refer to aquifer mapping reports available through [iMapBC](#) and corresponding [Groundwater & Aquifer Online Database](#) (with access to other reports), in addition to the [SCRD Phase 1 Groundwater Investigation Report](#).