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Enterprise Geoscience Services Ltd.

Savary Shores Improvement District
Wellhead Protection Plan
Savary Island, British Columbia

Project No. 1704 August, 2017

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Wellhead Protection Plan
Savary Island, British Columbia

Prepared For
Savary Shores Improvement District
Savary Island, BC

Prepared by
Enterprise Geoscience Services Ltd.
Vancouver, B.C.

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Executive Summary

The Savary Shores Improvement District operates a water system supplied by two groundwater wells. The system supplies about 165 connections with up to 216 at ultimate build out. The wells are alternated during operation and raw well water is supplied directly to the distribution system with no treatment.

The wells draw water from the Main Aquifer on Savary Island. The aquifer comprises a saturated thickness of Quadra Sands consisting of layered sand and minor gravel deposited as glaciofluvial sediments during the Fraser Glaciation. The aquifer consists of a lens of freshwater extending several metres above mean sea level overlain by an unsaturated zone about 25 to 30 m thick. Compact silty layers are present above the Main Aquifer which slow the downward infiltration of precipitation and form discontinuous perched aquifers which manifest as springs in several locations on the island.

The island is used primarily for recreational purposes with the Savary Shores system supplying a summer population of up to 500 and a winter population closer to 100. As such, water demand is high over the summer months and low through the remainder of the year. Peak water usage during August is about 1,500 m^3 equating to about 300 litres per connection per day, which is considered to be relatively low. Water conservation is achieved through individual metering of connections and financial incentives for conservation.

There is no community sewage collection system for the Savary Shores development or elsewhere on the island, and on-site septic systems are used for disposal of domestic wastewater. Owing to the small lots sizes (generally about 0.25 acres), there is a considerable density of septic systems and this has resulted in elevated nitrate concentrations in the aquifer. Chemical analysis of nitrate concentrations are available dating back to 1989 in the original well, Well 1 constructed in 1969, and since 2012 in the newer well, Well 2. Nitrate concentrations have remained relatively stable in Well 1 at about 3.5 mg/L as N since 2001, although the 2017 test was higher at 4.8 mg/L, the highest measurement to date. Nitrate concentrations in Well 2 are somewhat lower, and the record appears to be stable at about 2.0 mg/L. A well serving a restaurant, which is located in close proximity to the SSID wells, has higher nitrate concentrations with the most recent test results nearly 8 mg/L.

While the current situation with the SSID wells is not ideal, nitrate concentrations currently remain acceptable. There is a valid concern that should concentrations increase, the groundwater may become unfit as a drinking water source. Because of these concerns, Vancouver Coastal Health requested the SSID to commission a Well Protection Plan. The goal of this plan is to identify existing or potential future contaminant sources in the capture zone supplying water to the wells, and to the extent practical, influence land use activities within this zone to protect the quality and quantity of groundwater into the future. A secondary goal is preserve groundwater quantity such that pumping is balanced by recharge and declining aquifer groundwater levels or seawater intrusion is avoided.

The SSID system is well run. The pump house and area surrounding the wellheads is neat and clean with no evidence of storage of hazardous materials except diesel fuel for generators that is in vessels with secondary containment. Individual connections are metered with financial incentives to conserve water.

Review of the original pumping test results for Well 1, the water level monitoring data from the provincial observation well, and chloride data from both wells indicates no evidence of saltwater intrusion or declining aquifer water levels suggestive of over pumping.

Using capture zone analysis, setback distances and professional judgment, a groundwater protection zone was identified. The protection zone is based in part on capture zone analysis and also on a radial setback distance from the wells.

Developed and undeveloped lots in the groundwater protection zone were ranked as “higher” or “lower” according to their relative risk based on proximity to the wells and wastewater loading rates. In this case, risk refers to the probability of having caused existing nitrate concentrations or increasing concentrations through future development of currently undeveloped lots. Three methods of mitigating risk were identified which include lot purchase and dedication to parkland, holding tanks, and installation of equipment designed and verified to remove nitrogen from domestic wastewater systems.

Five recommendations were developed which are stated in point form as follows:

1) Specific recommendations for measures to control nitrate loading on higher and lower risk lots are as follows:

    - Purchase lots 126, 127 and 128 and dedicate them to park space in perpetuity;

    - Prescribe refits of existing septic systems on Lots 48 and 125 to install nitrogen removal components. Equipment must be capable of removing a minimum of 50 % of the nitrogen and be verified by an accredited Canadian technology verification program;

    - Development of future septic systems on lots 42, 43, 44, 45, 46, 47 and 118 should require installation of nitrogen removal systems as described above. The septic system on Lot 118 should be constructed as far as practical to the southeast of the lot.

2) The combination of water consumption as currently recorded by SSID monthly by connection, and the ongoing monitoring of aquifer water level by the province is considered completely adequate for monitoring aquifer water quantity and identifying any adverse trends to suggest over pumping of the aquifer. No suggested changes or improvements were identified.

3) The program of annual monitoring of chemical and physical water quality parameters is considered completely appropriate for the SSID water system. Samples should continue to be collected individually from both wells, at or near the wellhead. In the event of a "spike" in concentrations, the wells should be re-sampled as soon as practical. We would consider a deviation of 1 or 1.5 mg/L above or below historical results to be a spike.

4) A geoscientist or engineer qualified in hydrogeology should review the operational data every five years or more frequently if adverse trends are observed. The purpose of the review would be to identify any adverse trends and recommend corrective actions, where warranted, based on the operational data.

5) Display signage on Lot 129, and Lots 126, 127 and 128 if they are purchased for parkland indicating the area is a groundwater recharge area and protection zone.

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1.0 INTRODUCTION

Savary Shores Improvement District (SSID) operates a water system on Savary Island, BC (Figure 1). The system is supplied by two 8 inch diameter wells which currently serve 165 connections, with an upper limit of 216 connections if all subdivided lots are built upon. There is no treatment of the water prior to distribution.

The island is popular as a vacation destination with a summer population in the Savary Shores development of about 500 with a winter population of around 100. Accordingly, the pattern of water consumption rises markedly during summer with the increased population and declines during the autumn to spring period.

There are no community sewage collection and treatment systems on the island, and domestic wastewater is disposed of through on-site septic fields. In part because of the relatively small size and density of building lots, nitrates from septic systems have affected the groundwater aquifers.

Vancouver Coastal Health, who has a mandate to confirm that water systems are safe for use, has raised concerns over the nitrate levels in the SSID system and has requested the SSID to commission a Well Protection Plan (WPP). The primary objective of the WPP is to identify the area of the capture zone supplying water to the wells and identify means of minimizing or eliminating potential sources of aquifer contamination in this area.

This report presents a WPP prepared for the SSID in 2017.

2.0 SCOPE OF WORK

The scope of work involved the following activities:

- Review and analysis of background information on groundwater resources of Savary Island including previous hydrogeological reports, metered water consumption, historical and recent water quality tests, and other sources;
- A visit to Savary Island to inspect the well capture zone and surrounding area to identify potential contaminant sources and to generally become familiarized with the study area; and,
- Preparation of this report.

3.0 HYDROGEOLOGIC SETTING

With the exception of a small area of bedrock outcropping on the eastern margin, Savary Island is composed of sand which is referred to as Quadra Sand. Quadra Sand deposits are glaciofluvial in origin and were deposited during the Fraser Glaciation period. The sands are stratified (layered), are well-sorted and contain only minor amounts of silt and gravel. The Quadra Sands are found in Vancouver, along the eastern margin of Vancouver Island, and on Quadra, Savary, Hernando and Harwood Islands. In a number of locations, the sands serve as an important water supply aquifer.

The sands are exposed on a number of bluffs and cliffs on Savary and where saturated, they are referred to as the “Main Aquifer”. On the western part of the island, there are shallow perched aquifers and springs at four locations along the bluffs. The springs form where water infiltrating from ground surface reaches less permeable silty beds and discharges at the cliff face before reaching the water table. The total thickness of the Quadra Sand has not been determined from drilling, however, a borehole on Hernando Island indicated the sands extend to at least 25 m below sea level (Clague, 1977).

The SSID wells consist of two 8 inch production wells and there is also an MOE observation well, all of which are located on Lot 129. Copies of the well logs are contained in Appendix A. A summary of well depths and yield estimated by the driller are shown in Table 1 and the estimated elevation of the water table and a summary of the stratigraphy encountered are provided in Table 2.

Table 1: WELL LOG SUMMARY

Well ID	Date of Drilling	Total Depth of Well (m below ground surface)	Static Water Level (m below ground surface)	Drillers’ Estimated Yield (gallons per minute)
Well 1	1969	32.0	22.9	38
Well 2	2011	33.4	22.7	35
Observation Well	1970	27.7	n/a	n/a

Table 2: WELL LITHOLOGY AND WATER LEVEL ELEVATION

Well ID	Estimated Elevation of Ground surface[1] (m above mean sea level)	Estimated Elevation of Base of Well (m above mean sea level)	Estimated Groundwater Elevation (m above mean sea level)	Lithology Notes
Well 1	25	-8.8	2.1	See note [2]
Well 2	25.5	-8.4	2.8	Layered fine to medium sand with silt lenses from 10.7 to 28.0 m. Layered fine to medium sand with thin gravel lenses 28.0 to 33.4 m
Observation Well	25	-2.7	n/a	Sand with several compact beds. Slow drilling progress in compact beds from 3.0 to 27.7 m.[3]

[1] Estimated from topographic map

[2] Lithology descriptions from Well 2 and observation well believed to be more accurate

[3] Source: Livingston, 1970

The water table is relatively deep (about 23 m below ground surface) and is estimated to be approximately 2 to 3 m above mean sea level (m asl). The aquifer consists of layered sand and gravel below a depth of about 28 m. Above the aquifer, compact sand and silt layers were identified that slowed drilling progress. It is expected that these compact sand and silt layers would slow or impede the downwards infiltration of precipitation recharge to the aquifer from ground surface. It is noteworthy that the observation well terminates at 27.7 m, just above the sand and gravel aquifer identified from 28.0 to 33.4 m depth in Well 2. It was originally intended that a sand point would be driven into the aquifer from the base of the observation well, but the soils were too dense (Livingston, 1970).

A conceptual hydrogeologic model of Savary Island is presented in Figure 2. Key components of the model are:

- There is a groundwater divide with flow towards the north and south shores of the island;

- The water table is relatively deep, and with the exception of springs, all seepage reports to the foreshore area;
- The island is surrounded by saltwater which forms wedges that slope inland due to seepage of freshwater and the density contrast between freshwater and saltwater;
- Pumping will not induce saltwater intrusion to the aquifer so long as the elevation of the water table remains above the elevation of mean sea level between the well and foreshore.

4.0 WATER CONSUMPTION

4.1 Total System

SSID monitors monthly water consumption from mechanical meters installed on each well, and from meters installed at each house connection. Historical annual usage from 1992 to 2016 is shown in Figure 3 . Water usage shows a general overall increasing trend consistent with a rising population and a cyclic trend that likely represents year to year changes in summer population due to climate or other factors. Note that water consumption during 2016 was skewed by anomalously high usage in April due to a fixture left running.

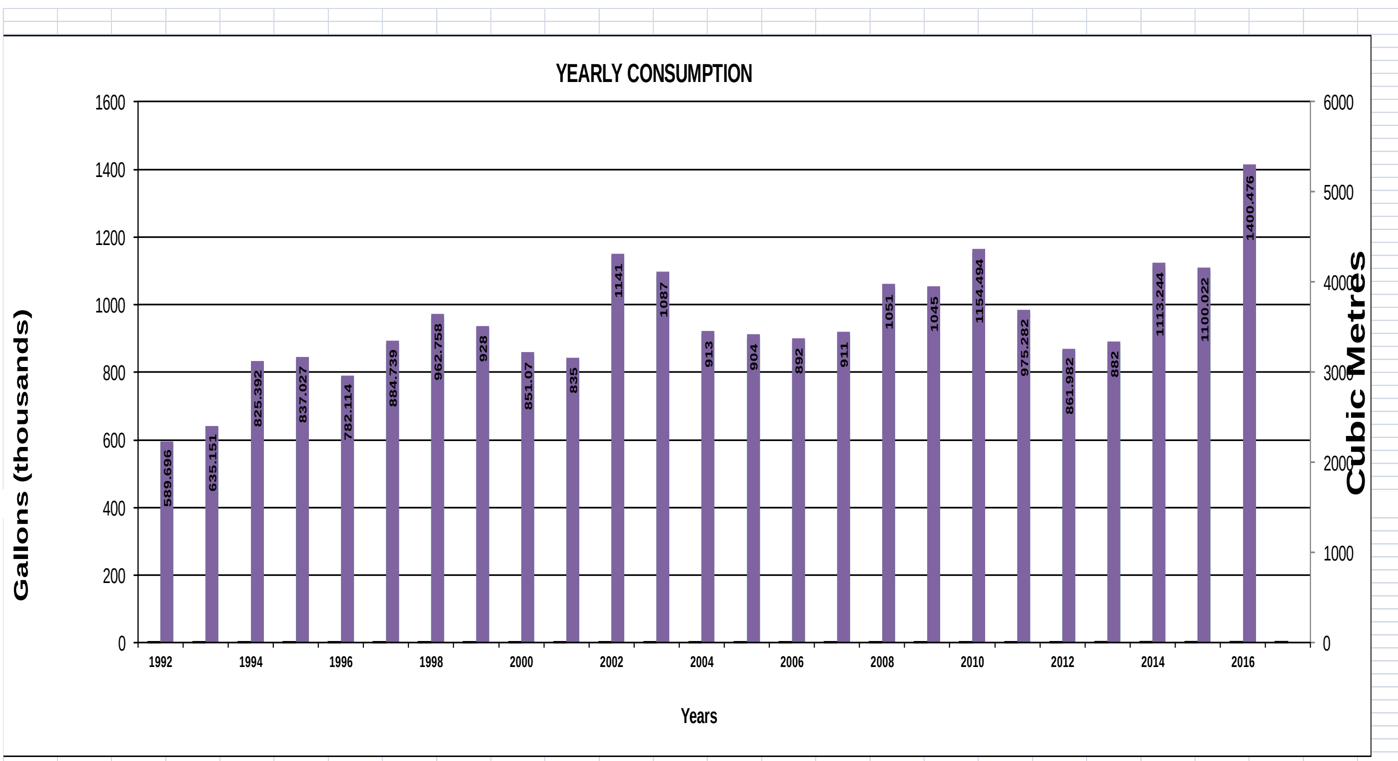


Figure 3: Historical Annual Water Consumption

A typical pattern of water consumption over an annual period is shown for 2015 in Figure 4. As discussed previously, the greater water consumption from June through September reflects the much greater summer population in Savary Shores. For 2015, the total monthly consumption was greatest at 1,266 m^3 and 1,511 m^3 during July and August, respectively. SSID operates both wells on an alternating basis with more pumping from Well 2 in comparison to Well 1.

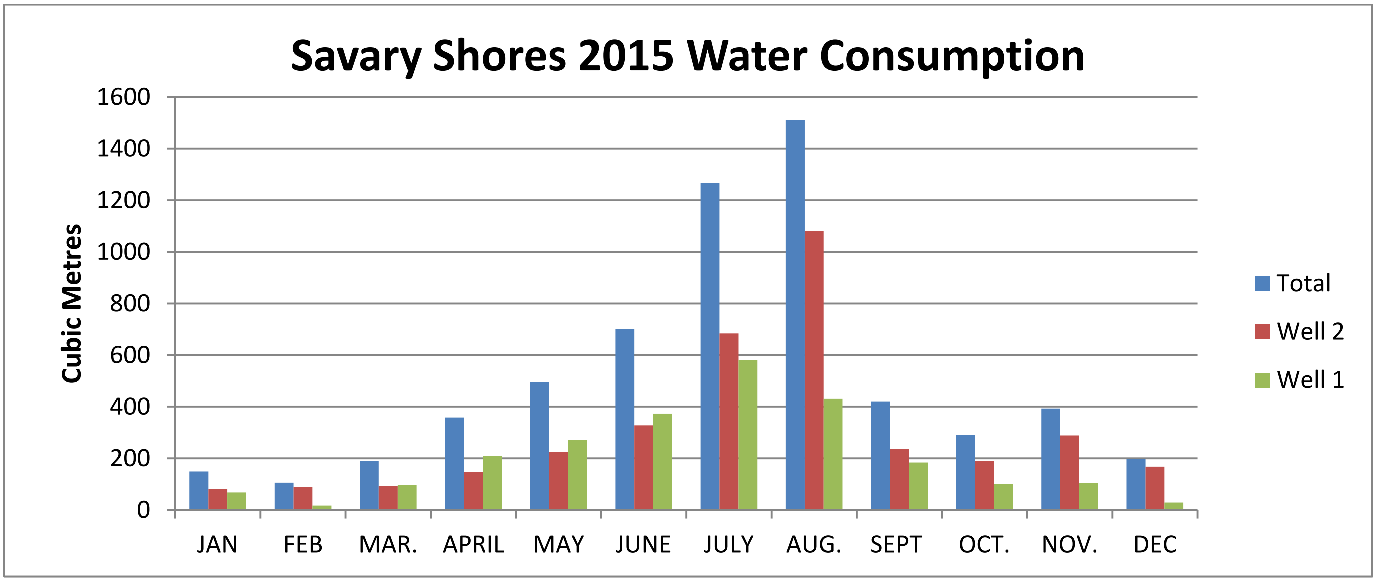


Figure 4: 2015 Annual Water Consumption Pattern

The number of hours each pump is operating per month is presented in Figure 5. During August 2015, Well 1 operated for 54.1 hours, Well 2 operated for 109.1 hours and there was a total of 163.2 hours when pumps were in operation. During the pumping periods, the flow rate is about 2.57 L/s. In other words, if the pumps were operated at 2.57 L/s for a period of 163.2 hours, the total amount of water produced would be the August 2015 consumption of 1,511 m^3.

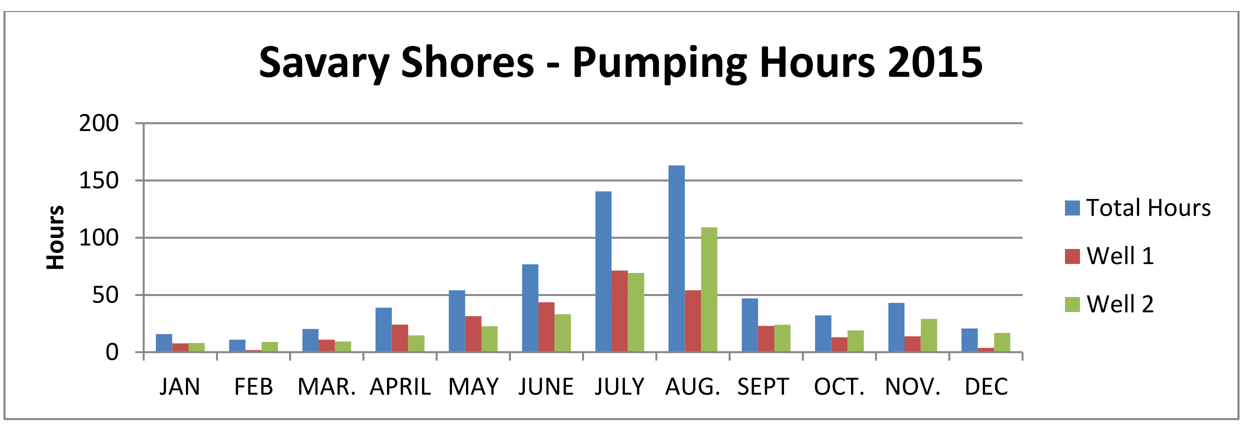


Figure 5: 2015 MONTHLY PUMPING HOURS

For purposes of estimating well capture zones, it is necessary to express the water consumption on the basis of a continuous pumping rate. For example, the continuous pumping rate would be the rate where the August 2015 total of 1,511 m^3 was produced by the pumps operating 24 hours per day, seven days per week. Expressed in this manner, the continuous pumping rate during the peak usage month of August would be 0.56 L/s.

4.2 Per Connection Basis

The Savary Island Official Community Plan (Bylaw 403, 2006) recognizes the importance of stewardship of the groundwater resources on Savary Island, including water conservation and protection of water quality. It is instructive to determine water use on the basis of individual connections as a comparison with other rural areas.

In 2015, the SSID system supplied approximately 162 connections. Taking the peak usage of 1,511 m^3 during August 2015, this works out to about 9.33 m^3/connection. Water consumption is commonly expressed on a daily basis. The average consumption per connection during August 2015 is about 300 L/connection/day. Although the OCP does not specify a maximum usage per connection, a quantity of 2,275 L/connection/day (500 Imperial gallons) is commonly used in rural residential developments in BC.

Water consumption during the peak summer period appears to be relatively low in comparison to typical rural subdivision requirements. This is likely due in part to the metering of individual users and financial incentives for conservation.

4.3 Effect of Pumping on Aquifer Water Level

To assist in stewardship of the main Savary Island aquifer, in 2011, Ministry of Environment installed a water level datalogger in an observation well (number 408) located on Brian's Way about 7 m from Well 1. Long term monitoring of aquifer water levels are important in determining if pumping is balanced by recharge to the aquifer. Where pumping is not balanced by recharge, aquifer water levels may decline leading to problems such as reduced well yields or saltwater intrusion.

The longer-term water level monitoring record from the observation well is presented in Figure 6. The record extends from mid-2011 to present. The record indicates seasonal variations on the order of 0.6 to 0.8 m, with lower aquifer water levels occurring during summer. This is consistent with greater pumping and lower precipitation recharge in the summer months.

Although the record is relatively short, there does not appear to be any long-term declining trend to suggest pumping is not balanced by recharge.

To determine if the amount of seasonal variation in aquifer water levels (e.g. 0.8 m) is significant, it can be compared to the available drawdown in the well. The available drawdown is the height of the water column above the screen assembly to the static water level, with a 30 % safety factor. In practical terms, this is the amount the well can be drawn down without the pump cavitating and drawing in air. The log for Well 2 indicates the static level is 74. 3 ft (22.65 m) and the top of the screen assembly is 96.25 ft (29.34 m). Thus, the height of the water column is about 6.6 m. Allowing for a 30 % safety factor, the available drawdown is about 4.6 m. Therefore, the season change in aquifer water level (0.8 m) represents about 20 % of the available drawdown (4.6 m), which is quite significant. The amount of water that can be pumped from a well (well discharge) is proportional to the amount of available drawdown. Because the available drawdown is quite small, the well yield varies seasonally by about 20 % based on normal seasonal fluctuations in water level. This illustrates the importance of water level monitoring and maintaining the balance between pumping and recharge.

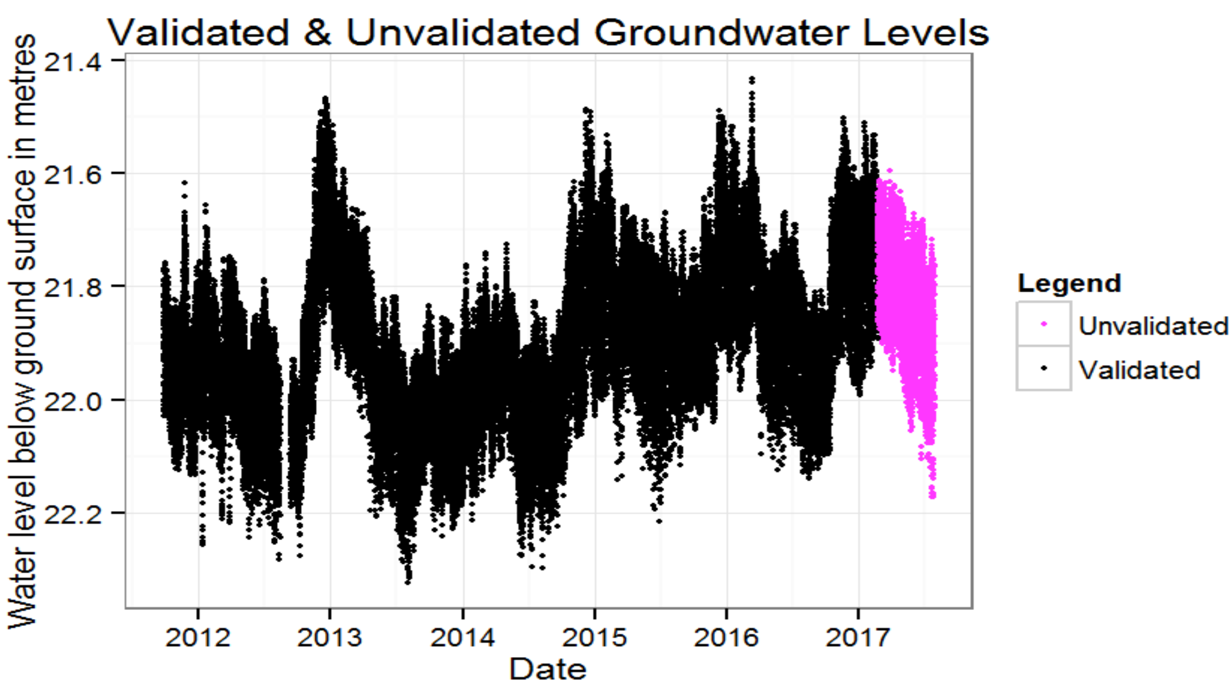
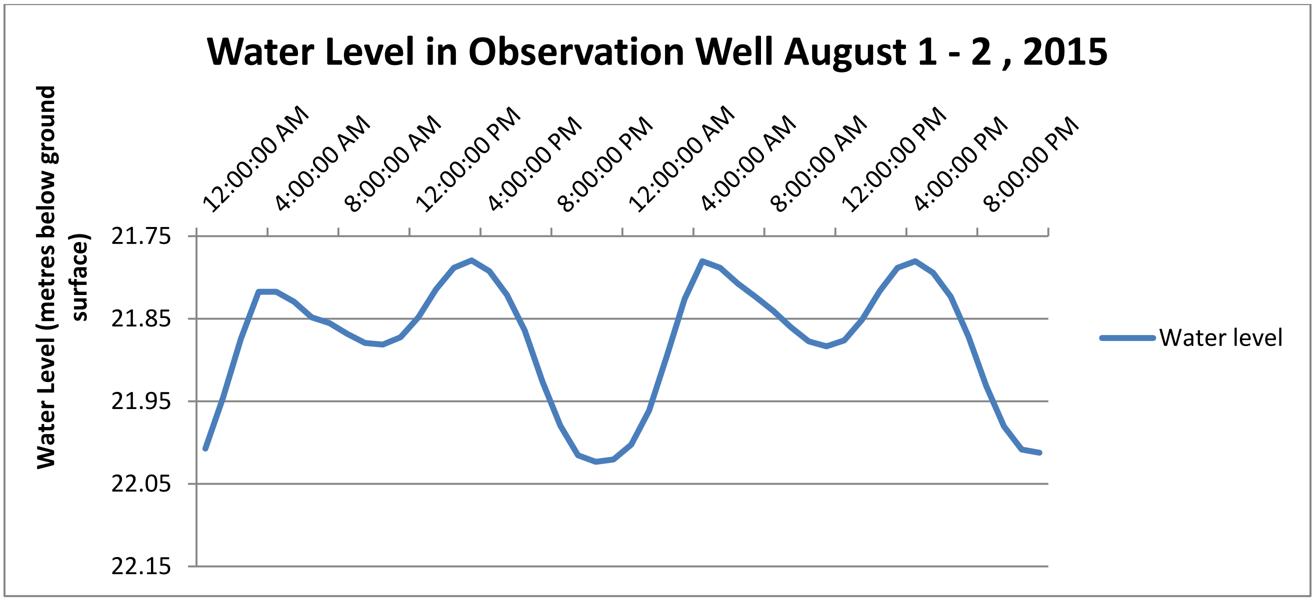


Figure 6: AQUIFER WATER LEVEL IN OBSERVATION WELL 408 (2011 – 2017)

In addition to the longer term seasonal water level trends shown above, water levels can also exhibit shorter term responses to pumping, intense precipitation events, or tidal oscillations. A detail plot of aquifer water levels over a 48 hour period is compared to the tidal range at Campbell River in Figure 7. Both records indicate three minima over the two day period in August 2015. Based on this comparison, it is likely that these short term oscillations are a tidal response as opposed to a drawdown response to pumping.



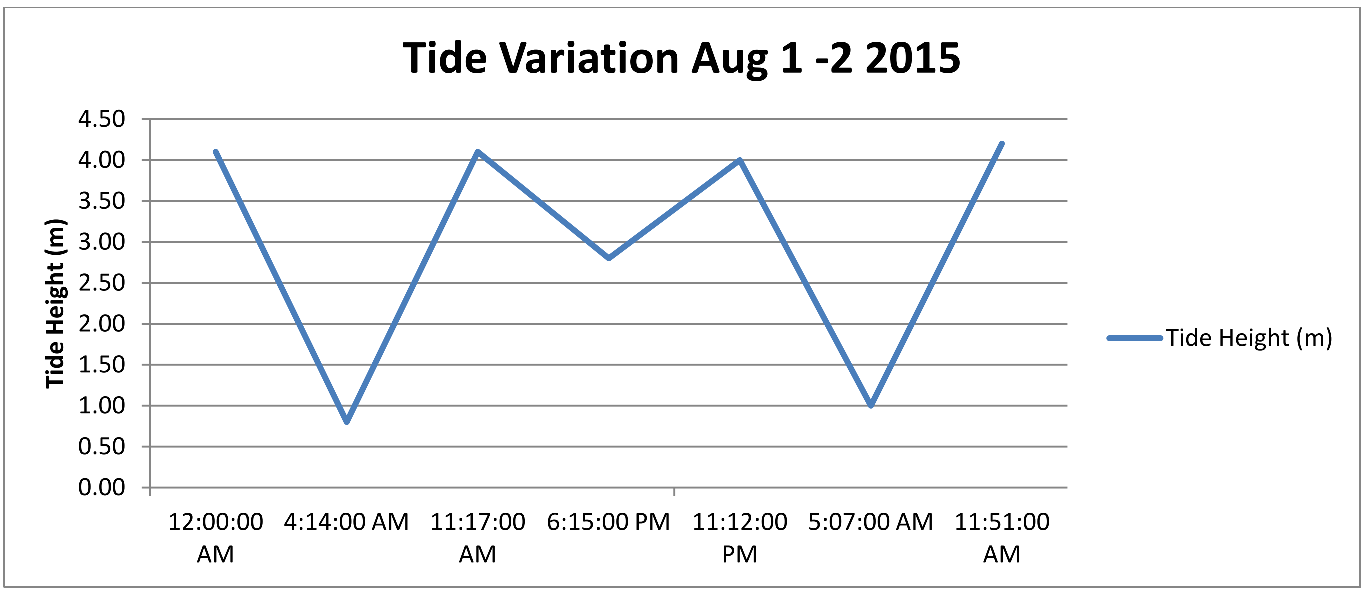


Figure 7: AQUIFER WATER LEVEL AND TIDE FLUCTUATION OVER A 48 HOUR PERIOD (AUGUST 1 AND 2, 2015)

It is noteworthy that although the observation well responds to tide, it does not appear to be significantly influenced by nearby pumping. This suggests that the observation well, which is situated just above the top of the aquifer zone, is in poor hydraulic connection with the aquifer.

5.0 WATER QUALITY

The wells provide raw water directly to the distribution system with no form of treatment. Vancouver Coastal Health reports that bacteriological quality has been excellent since some repairs to the water system were carried out in 2008.

There is a relatively long and complete water quality data set for both pumping wells. For Well 2 there are seven water quality tests since it was commissioned in 2011. For Well 1 there are 14 tests dating back to 1989. Since 2011, samples are collected separately from each well at the wellhead. There are also three data points available for Riggers, a restaurant located in close proximity to the SSID wells that has its own well source.

Two potential threats to groundwater quality for the SSID system are septic fields and saltwater intrusion. As shown in Table 2, the base of the pumping wells are about 7 to 8 m below mean sea level and therefore, there is a potential for saltwater intrusion if the wells were over pumped for a sustained period.

Nitrate (NO_3) is common in groundwater from influences of septic systems and leaching from livestock manure or fertilizers. It is regulated in drinking water as it can cause adverse health effects, particularly in infants as it affects oxygen uptake to the blood and causes oxygen deprivation. Nitrate is a health related parameter under the Canadian Guidelines for Drinking Water Quality with a Maximum Acceptable Concentration (MAC) of 10 mg/L (as nitrogen). Elevated nitrate in groundwater on Savary Island is the primary water quality concern. All available nitrate test results for Well 1 and Well 2 are shown in Figure 8.

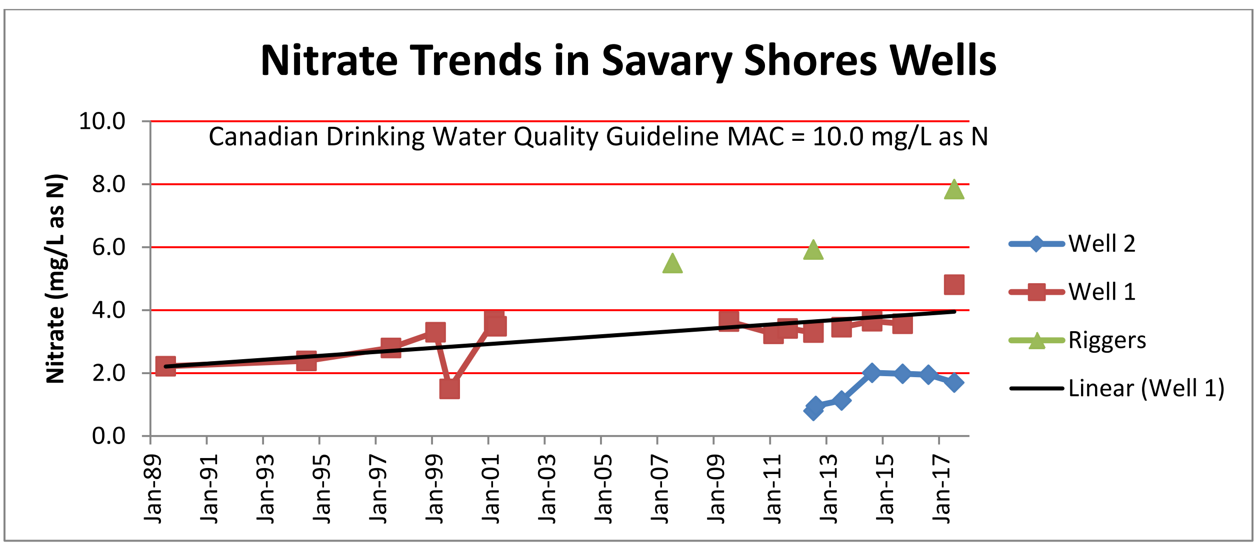


Figure 8: NITRATE IN SSID WELLS (1989 – 2017)

Note in Figure 8 the highest concentration measured to date in the SSID wells was 4.8 mg/L in Well 1 in 2017. This represents about 50 % of the 10 mg/L MAC. For Well 1 with the longer sampling record, there has been an overall upward concentration trend, although concentrations have remained quite stable at about 3.5 mg/L since 2001, except for the recent 2017 sample. Well 2, which is generally operated more frequently and pumps more water than Well 1, has shown stable concentrations of about 2.0 mg/L since 2014. The difference in nitrate levels between the two nearby wells is likely due to geologic stratification in the aquifer resulting in somewhat different quality. The highest levels are measured in the Riggers well with concentrations ranging between 5.5 mg/L up to nearly 8.0 mg/L.

Although nitrate levels have remained relatively stable since 2001 in Well 1 (except the 2017 sample) and since 2014 in Well 2, and are below drinking water guidelines, ideally the concentration should remain as low as practical.

Saltwater has highly elevated concentrations of a number of salts relative to freshwater. This contrast in concentration provides a number of elements and parameters that serve as good indicators of saltwater intrusion. Examples include electrical conductivity and chloride. For the purpose of this assessment, chloride has been chosen as an indicator. Other sources of chloride, such as road salt, are not expected on Savary Island and therefore, chloride is judged to be a good indicator. Chloride levels in the two pumping wells range from about 20 mg/L to 100 mg/L whereas the chloride content of saltwater is about 19,000 mg/L.

Available chloride data for the pumping wells is presented in Figure 9. Note that elevated chloride concentrations impart a salty taste and can damage plants at elevated concentrations. Chloride is limited for aesthetic purposes (taste) in drinking water to a concentration of 250 mg/L. Some plant species are intolerant to irrigation with chloride levels above about 200 mg/L.

Chloride concentrations in Well 1 have remained stable ranging from 20 mg/L to 30 mg/L since the mid 1990s. The chloride concentration in Well2 declined from about 100 mg/L initially and appears to be stabilizing at a concentration of around 40 mg/L. Declining chloride levels in Well 2 likely reflects the well drawing in fresher water from higher elevation in the well capture zone. Overall, the monitoring data indicate no problematic issues with saltwater intrusion.

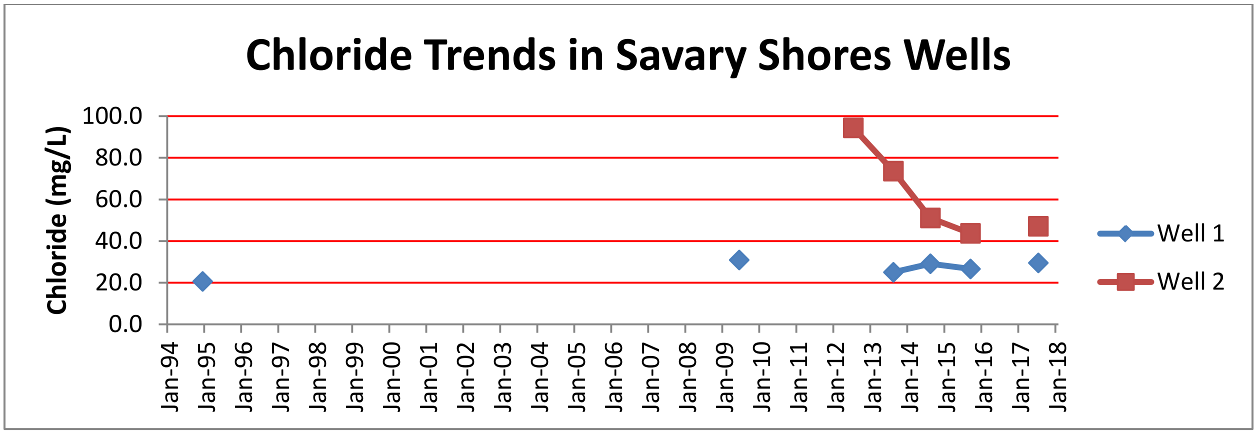


Figure 9: CHLORIDE IN SSID WELLS (1994 – 2017)

6.0 WELL CAPTURE ZONES AND TRAVEL TIMES

For estimating the extent of the well capture zones and travel times, analytical solutions for flow in a uniform aquifer with a sloping water table is judged to be appropriate for the SSID water system.

Capture Zone

The capture zone is described by a parabolic shape that is illustrated graphically in Figure 10.

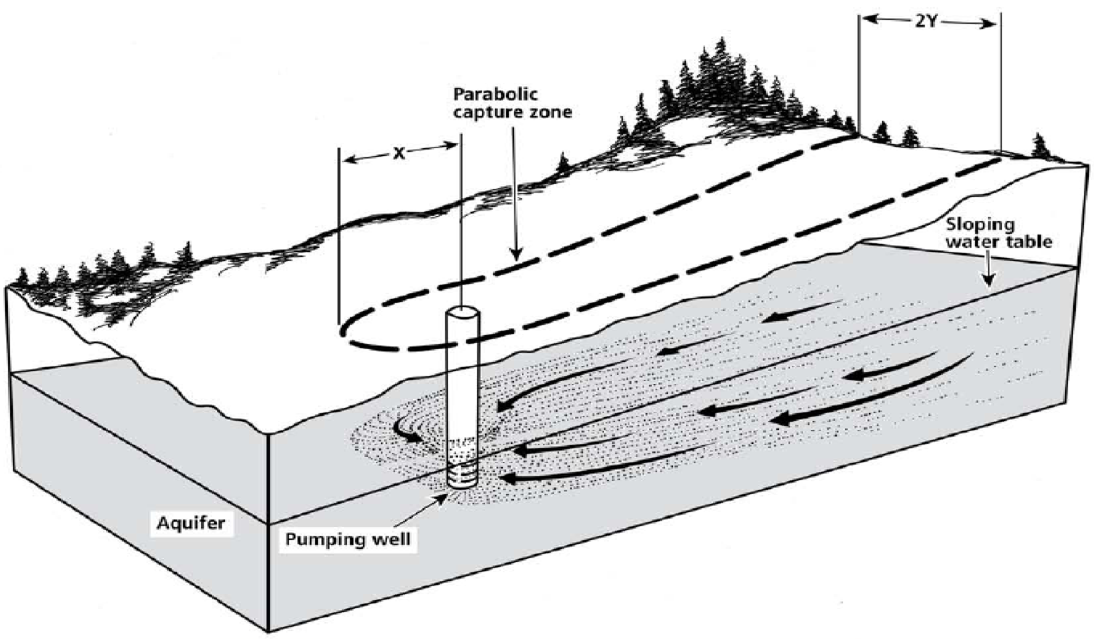


Figure 10: CONCEPTUAL MODEL FOR DETERMINING WELL CAPTURE ZONE FOR UNIFORM AQUIFER WITH SLOPING WATER TABLE (Source – Well Protection Toolkit)

The dimensions “X” and “Y” in the above diagram are given by the following formula:

$$Y = Q / (2000\ T\ i)$$

$$X = Y / \pi$$

Where:

Q= Well pumping rate (L/s)

T = Aquifer transmissivity (m^2/s)

i = hydraulic gradient (slope of the water table) - dimensionless

As discussed above, well pumping rate Q during the peak summer period is about 0.5 L/s to 0.6 L/s. To be conservative, it is judged that in future, when the SSID development is fully built out, the peak demand could be 1.0 L/s.

Hydraulic gradient i was estimated from information on the well logs and local topography. Available topographic mapping indicates the ground surface elevation at the wells is approximately 25 m above mean sea level (m asl). The depth to the water table below ground surface under non-pumping conditions (static water level) is noted in the well logs as 75 ft (22.9 m) in Well 1 and 74.3 ft (22.6 m) in Well 2. Subtracting the static level from ground surface elevation gives the water table elevation which is about 2 to 2.5 m asl. Mapping indicates the tideline is about 275 m south of the wells. Assuming the water table is at mean sea level at the foreshore, the hydraulic gradient is the difference in water table elevation divided by the distance between the well and foreshore. The hydraulic gradient is approximately 0.01 or a 1 % slope, which is common for a relatively permeable aquifer and is consistent with what would be expected.

The Quadra Sand is an important water supply aquifer along the east margin of Vancouver Island and elsewhere in the Georgia Basin and its hydrogeologic properties have been determined at a number of locations. Aquifer transmissivity is the product of its thickness and hydraulic conductivity. Data summarized in Tupper (1996) indicates transmissivity was calculated for the SSID well (assumed to be Well 1) from a 72 hour pumping test in 1969. The transmissivity value calculated from the test was 7,400 US gallons per day per foot, which equates to a metric value of $1 \times 10^{-3}\ m^2/s$.

As noted above, the width Y of the capture zone is inversely proportional to the aquifer transmissivity, T. In other words, if an aquifer is highly permeable, the capture zone will be quite narrow, and vise versa if the aquifer permeability is lower.

Table 3: CAPTURE ZONE DIMENSIONS

Transmissivity (m^2/s)	Capture Zone “Y” Dimension (m)	Capture Zone “X” Dimension (m)
1×10^{-3} (source Tupper)[1]	50	25

[1] Table 5 in Tupper (1996) – based on 72 hour pumping test in SSID well

Travel Times

For wellhead protection planning, it is instructive to estimate the time of travel for seepage through the aquifer to the well, from different distances within the capture zone. Aquifer water quality is more vulnerable to potential sources of contamination that are closer to the well with shorter travel times than the opposite. The travel distance for a given time t depends on the aquifer hydraulic conductivity, K, the hydraulic gradient i, and the porosity, n.

The distance for the time of travel for various periods of interest (e.g. 1, 5, 10 years) can be calculated from the following:

$$D_{TOT} = (t\ K\ i) / n$$

Where:

d_{TOT} = distance from the well for the time of travel t (m)

t = time of travel (yrs)

K = Aquifer hydraulic conductivity (transmissivity divided by thickness) (m/yr)

i = hydraulic gradient (slope of the water table) - dimensionless

n = aquifer porosity

Review of the lithology described in the well logs suggests the aquifer thickness is about 4 m in Well 1 and 5 m in Well 2. From the previous capture zone analysis, assuming a transmissivity of 1×10^{-3} m/s, and an aquifer thickness of 4 m, a hydraulic conductivity value of 7,900 m/yr (i.e. 22 m/day) is considered representative. The hydraulic gradient is estimated to be 0.01. A value of 0.25 (25 %) is considered representative for porosity. Using these input values, the distance for times of travel of 1, 5 and 10 years are summarized in Table 4:

Table 4: TRAVEL DISTANCE FOR VARIOUS TIMES OF TRAVEL

Time of Travel (yrs)	1	5	10
d_{TOT} (m)	320	1,600	3,200

Considering the local topography, and estimated well capture zone, the estimated time of travel within all areas of the capture zone is likely less than 2 years. It is noted that the time of travel refers to flow through the saturated zone. The time of travel for unsaturated flow, for example from the base of a septic field to the water table, is neglected in the calculations above. If the static water level in the wells is considered representative of the water table, the unsaturated zone thickness is about 22.5 m to 23 m, which is considerable.

There are two important processes that occur in the unsaturated or vadose zone which may influence nitrate concentrations in the saturated aquifer: 1) storage, and 2) denitrification. Storage refers to nitrate contained in moisture in the pores of the soil above the water table. Storage can result in a time delay, for example, between the time sewage effluent percolates from the base of a septic drainfield to the time it reaches the water table.

The potential effect of storage is that nitrate concentrations are delayed in time from the source (septic field) as it travels downwards with seepage to the aquifer where it is measured in samples from the wells. Denitrification is a naturally occurring beneficial process that can result in reduced nitrate concentrations in the groundwater by transformation of nitrate to nitrogen gas in the vadose zone. Given the relatively long record period (about 17 years) where nitrate concentrations have remained fairly stable in Well 1, the aquifer system is probably in an equilibrium situation with nitrate inputs such that significant increase or decreases in aquifer nitrate concentrations due to storage or denitrification are not likely in future. Changes in future nitrate concentrations could be expected, however, if additional nitrate sources such as new septic fields, or increased loading from existing fields occurs within the capture zone.

7.0 SITE RECONNAISSANCE AND CONTAMINANT INVENTORY

The writer visited Savary Island on August 15, 2017. He met with Trustees from the SSID, the water system operator and a local Registered Onsite Wastewater Practitioner (ROWP) responsible for constructing most of the septic systems on the island.

The pumphouse and surrounding area was neat and clean with no evidence of any deleterious materials except diesel fuel in the generator sets. The main generator, set back from the wellheads, was clean and has secondary containment. A new backup generator was located on the ground surface near the pumphouse. It is understood that the backup generator has recently been procured and the SSID are tendering work to build a proper enclosure.

The area surrounding the wellfield consists of developed lots and undeveloped forested lots. Lot sizes are typically about 0.25 acres in size with a variety of housing types. Commercial use in the general vicinity of the wellfield includes a restaurant (Riggers) and store located on Lot 48, and Lot 95 which is used as a market and for hosting wedding receptions. Typically, restaurants have a much greater wastewater loading rate in comparison to single family dwellings. The Riggers restaurant is supplied by its own well and is not connected to the SSID system.

Roadways are gravel with vehicles brought to the island by barge. There is no electricity on the island and residents use solar panels or generator sets for power, when required.

8.0 APPLICABLE GUIDANCE AND REGULATIONS

Regulations and guidance relevant to well operation and septic systems are contained in the following:

- *Water Sustainability Act*;
- *Groundwater Protection Regulation*;
- *Sewerage System Regulation*; and,
- Sewerage System Practice Manual (Version 3, 2014)

Section 58 of the *Water Sustainability Act* specifies that a well must be operated in accordance with the regulations and any directions of an engineer. This includes not operating a well in a manner that causes or is likely to cause saline or seawater, or contaminated water entering into the well or aquifer.

The *Groundwater Protection Regulation* specifies construction methods for wells and the necessary qualifications of persons involved with drilling wells and installing pumps.

The *Sewerage System Regulation* specifies setback distances between drinking water supply wells and holding tanks and sewerage systems. This specifies a minimum setback distance of 15 m for holding tanks and 30 m for septic tanks and sewerage systems. These distances may be decreased in circumstances where the modified setback distance is endorsed by a professional with competency in hydrogeology.

The Sewerage System Practice Manual provides further guidance on setback distances as shown in Table 5:

Table 5: SETBACK DISTANCES IDENTIFIED IN SEWERAGE SYSTEM PRACTICE MANUAL

Well Type	Setback from dispersal system (m)	Setback from watertight holding tank or septic tank (m)
Domestic supply well	30	30
Community supply well – high pumping rate	60	30
Community supply well – high pumping rate in unconfined aquifer	90	30

The guidelines from the practice manual identify a high pumping rate community well as one that is pumped at greater than 190 L/min (3.17 L/s) for more than three months of the year. The manual defines an unconfined aquifer as an aquifer where the water is not under pressure such that the water level in the well is the same as the water table outside the casing.

Based on a 30 day month, a pumping rate of 190 L/min works out to about 8,200 m^3/mo. As shown on Figure 4, for the three peak months of June, July and August, water consumption by SSID varied from < 800 m^3 to about 1,500 m^3. Thus, the wellfield supplying the SSID does not meet the definition of a high capacity well described in the guidelines and would be unlikely to even when the development is fully built out.

9.0 WELL PROTECTION AREA AND FUTURE LOT DEVELOPMENT

The goal of the well protection plan is to define the capture zone supplying water to the wellfield and take all reasonable steps to minimize or eliminate potential sources of contamination within this zone. Success of the groundwater protection measures is confirmed through monitoring to provide an early warning of adverse trends in water quantity or quality.

9.1 Groundwater Protection Area

The analysis in Section 6 provided an estimate of the dimensions of the capture zone and distances for various times of travel. The actual location of the capture zone is not well defined because the local direction of seepage in the aquifer is not determined. Determining the seepage direction generally requires survey control and measurement of the water table elevation at a minimum of three points in the aquifer with water level conditions at equilibrium (i.e. no drawdown influence from pumping). As two possible endpoints, the seepage direction may follow the slope of the topographic gradient, or it may follow towards the south from the topographic divide on the island consistent with the conceptual model shown in Figure 2. Capture zones for these two possible cases are illustrated on Figure 11.

As the location of the capture zone is not well determined, the groundwater protection area is defined based on the outer envelope of the two cases described above. The protection zone also considers a setback distance of 60 m between domestic wastewater dispersal systems and the wells for protection against pathogens. The rational for the setback is described below in Section 9.3. The resulting groundwater protection area, and locations of lots with and without septic fields in this area is presented in Figure 12.

9.2 Protection Goals

The groundwater quality protection goals are to prevent contamination by pathogens from septic systems or seawater intrusion, and to eliminate, to the extent practical, any further rise in nitrate concentrations.

The groundwater quantity protection goals are to maintain pumping withdrawals in balance with aquifer recharge.

9.3 Future Development and Land use

<u>Protection of Groundwater Quality</u>

Groundwater quality can be protected from pathogens by good well construction practices and setbacks for septic systems. Surface seals are constructed of low permeability material that surrounds the well casing to a depth specified in the *Groundwater Protection Regulation*. Review of the well logs indicates a seal has been installed on Well 2, the most recently drilled well. No information is available regarding seals on the logs for Well 1 and the observation well. Given the drilling date of these latter wells (1969/1970) there is a good chance seals were not installed. If these wells are to be structurally altered (e.g. deepened) in future, installation of seals is required.

In the professional judgment of the writer, a setback distance between the pumping wells and sewage dispersal system of 60 m is considered acceptable for protection against pathogens. A minimum setback distance from septic tanks of 30 m is also considered acceptable.

The concentration of nitrate in the wells is determined by the nitrogen loading rate in the capture zone. The loading rate can be thought of as the mass of nitrate per unit area of land surface (e.g. kilograms of nitrogen per hectare) and the loading rate increases with the density of septic systems. If no additional septic systems were constructed within the capture zone, and there was no significant change in loading to existing systems (e.g. more dwelling occupants on a sustained basis), nitrate concentrations would be expected to remain stable. The key for protection of water quality for nitrates is then to eliminate or minimize future inputs of ammonia nitrogen from septic fields.

Because of dilution effects in the aquifer, septic systems in the capture zone that are closer to the wells, or that have higher loading rates present a higher risk of increasing nitrate concentrations. Based on the foregoing analysis, and our professional judgment, lots in the vicinity of the wellheads are classified on a relative scale as "higher risk" and "lower risk" as shown in Table 6.

Table 6: RISK CLASSIFICATION

Risk Classification	Lot Numbers
Lower Risk	40, 41, 42, 43, 44, 45, 46, 47, 124,
Higher Risk	118, 125, 126, 127, 128, 48 (Riggers)

There are several methods that could be used to minimize or eliminate additional loading of nitrate to groundwater in the protection zone from lots that are currently undeveloped. It is suggested that these methods take into account the relative degree of risk identified above.

The highest level of protection would involve purchasing lots and dedicating them to parkland. Similarly, holding tanks could be used but servicing these is problematic. Both of these options present considerable expense. Relatively recent advances have been made in septic system technology that makes nitrogen removal from domestic wastewater feasible at reasonable cost. As an example, information on a system developed in Waterloo, Ontario is provided in Appendix B. To ensure the system operates as claimed, it has been accredited by both Canadian and US technology verification programs. These systems can achieve up to 95 % removal of nitrogen. It is judged that such systems provide a relatively high level of protection for nitrate in the aquifer, but less than lot purchase or holding tanks.

Aside from septic systems, the only other potential contamination sources would include the diesel fuel at the generator sets and a sewage spill if the pump out truck that periodically visits the island to pump out holding tanks were to have an accident near the wellheads which is considered to have a low probability. Effects from potential diesel spills can be mitigated with use of sorbents which should be stored in the generator building. A contingency plan in the event of a sewage spill from a tank truck should be developed by the local volunteer fire department.

Protection of Groundwater Quantity

Based on the initial extensive testing of Well 1 in 1969 / 1970, the consumption monitoring by SSID, and the water level hydrograph from the observation well, there is no evidence of over pumping. Aquifer withdrawal rates appear to be well balanced by recharge.

Recharge rates can be decreased due to hard surfaces such as roofs and paved roads and driveways. Collection of stormwater and diversion in pipes to disposal areas can also reduce recharge rates. The current situation on Savary with gravel roads and driveways, and no collection of stormwater in pipes is conducive to maintaining recharge and sustainability of the aquifer. Paving of roads and driveways, and construction of a formal piped stormwater collection system should be discouraged.

10.0 CONCLUSIONS

Based on the review of available information, data analysis and site visit, the following conclusions are made:

1) The principal aquifer on Savary Island is a saturated thickness of Quadra Sand. Where the SSID wells penetrate the aquifer, it ranges from about 4 m to 5 m in thickness and the base of the aquifer is about 8 m to 8.5 m below mean sea level.

2) The static water level at the well field area is relatively deep such that the available drawdown is quite small, about 4.5 m. Seasonal fluctuations in the water table in response to pumping and precipitation recharge are about 0.8 m or 20 % of the available drawdown. The relatively low available drawdown indicates the aquifer yield is sensitive to recharge and pumping rates. Operating the wells to keep a balance between recharge and pumping is key for maintaining a sustainable yield from the aquifer.

3) Chloride concentrations in the well samples provides a very good indicator of potential saltwater intrusion because of the contrast in chloride in freshwater compared to seawater. The monitoring record provides no indication of any rising chloride trends to suggest seawater intrusion to the aquifer.

4) There is a good monitoring program of aquifer water levels with a provincial observation well located about 7 m from Well 1 that has been in operations since 2011. This monitoring indicates no evidence of a declining aquifer water level to suggest it is being over pumped.

5) The SSID system pumps raw untreated water into the distribution system. The bacteriological quality of the water has been excellent since repairs conducted to the distribution system in 2009.

6) A site visit was made to inspect the immediate area surrounding the wellheads and the capture zone to identify and inventory any likely potential sources of aquifer contamination. Aside from residential septic systems, the only commercial activities in the capture zone are a store and the Riggers restaurant. General housekeeping in the area surrounding the wellfield is very good and the only potential contaminant source is diesel fuel for the generators. The primary generator has secondary containment and the recently purchased back-up generator will soon have secondary containment.

7) There has been a good monitoring record of physical and chemical water quality dating back to 1989 in Well 1 and 2012 in Well 2. Nitrate levels in Well 1 appear to have remained stable at about 3.5 mg/L since 2001 and at about 2 mg/L in Well 2 since 2014. Nitrate is limited in drinking water supplies due to health reasons. Although these levels are below the drinking water Maximum Acceptable Concentration of 10 mg/L, ideally the concentrations should be as low as practical.

8) Nitrate levels in the well at Riggers restaurant has ranged from 5.5 mg/L up to nearly 8 mg/L, quite close to the MAC. Based on capture zone analysis, the Riggers septic system is probably within the capture zones of the SSID wells, and is likely a contributing source of nitrate as are developed residential lots in the capture zones.

9) Based on well capture zone analysis and professional judgment, a groundwater protection area has been defined that was determined from a conservative estimate of the largest probable capture zone. The time of travel through the saturated zone to the wells within all areas of the capture zone is likely less than two years.

10) Surface sanitary seals along the annulus of a well casing provide protection from introduction of pathogens or other deleterious substances to the aquifer along the well bore. The most recently drilled well (Well 2) was constructed with a surface sanitary seal in accordance with the *Ground Water Protection Regulation*. The status of sanitary

seals on Well 1 and the provincial observation well are unknown, but given the age of the wells it is suspected seals would not be present.

11) Groundwater quality protection goals are to prevent introduction of pathogens to the aquifer and to limit any further increase in nitrate concentrations. It is judged that a setback distance of 60 m from the wells to any septic dispersal system and 30 m to any septic tank would be protective of aquifer water quality. Methods to limit any further increase in nitrate concentrations from future development of lots within the protection zone include one or a combination of holding tanks, septic systems designed to remove nitrogen, and purchase of lots with dedication to parkland.

12) Groundwater quantity protection goals are to maintain the well pumping rate in balance with aquifer recharge. Development of paved roads and driveways, or piped stormwater collection systems can decrease recharge and should be avoided.

11.0 RECOMMENDATIONS

The following recommendations are made in efforts to monitor and maintain aquifer water quantity and quality:

1) Specific recommendations for measures to control nitrate loading on higher and lower risk lots are as follows:

   - Purchase lots 126, 127 and 128 and dedicate them to park space in perpetuity;

   - Prescribe refits of existing septic systems on Lots 48 and 125 to install nitrogen removal components. Equipment must be capable of removing a minimum of 50 % of the nitrogen and verified by a Canadian technology verification program;

   - Development of septic systems on lots 42, 43, 44, 45, 46, 47 and 118 should require installation of nitrogen removal systems as described above. The septic system on Lot 118 should be constructed as far as practical to the southeast of the lot.

2) The combination of water consumption as currently recorded by SSID monthly by connection, and the ongoing monitoring of aquifer water level by the province is considered completely adequate for monitoring aquifer water quantity and identifying any adverse trends to suggest over pumping of the aquifer. No suggested changes or improvements were identified.

3) The program of annual monitoring of chemical and physical water quality parameters is considered completely appropriate for the SSID water system. Samples should continue to be collected individually from both wells, at or near the wellhead. In the event of a "spike" in concentrations, the wells should be re-sampled as soon as practical. We would consider a deviation of 1 or 1.5 mg/L above or below historical results to be a spike.

4) It is recommended that a geoscientist or engineer qualified in hydrogeology review the operational data every five years or more frequently if adverse trends are observed. The purpose of the review would be to identify any adverse trends and recommend corrective actions, where warranted, based on the operational data.

5) Display signage on Lot 129, and Lots 126, 127 and 128 if they are purchased for parkland indicating the area is a groundwater recharge area and protection zone.

Respectfully submitted,

Enterprise Geoscience Services Ltd.

John Balfour, M.Sc., P.Eng.

Hydrogeologist

REFERENCES

1. Carmichael, V., 2013. Compendium and Re-evaluated Pumping Tests in the Regional District of Nanaimo. Report prepared by Ministry of Environment.

2. BC Ministry of Environment., Well Protection Toolkit.

3. Tupper, D.W., 1996. A Preliminary Assessment of the Groundwater Resources of Savary Island, British Columbia.

4. Clague, J.J., 1977 , GSC Paper 77-17 "Quadra Sand: A Study of Late Pleistocene Geology and Geomorphology of Coastal Southwest British Columbia".

5. Livingston, E. 1970. Report on Pump Test of a Well Owned by Marineland Investments Ltd. at Savary Island, BC.

GLOSSARY

Aquifer - Geological formation capable of storing, transmitting and yielding exploitable quantities of water.

Capture zone – the part of an aquifer that contributes water to a pumping well.

Hydraulic conductivity (K) - the volume of fluid that flows through a unit area of porous medium for a unit hydraulic gradient normal to that area.

Hydraulic gradient (i)- the change in hydraulic head with direction.

Perched Aquifer - a local, unconfined aquifer at a higher elevation than the regional unconfined aquifer. An unsaturated zone is present between the two unconfined aquifers.

Static water level - the level of water in a well that is not affected by pumping.

Transmissivity (T) - the discharge through a unit width of the entire saturated thickness of an aquifer for a unit hydraulic gradient normal to the unit width sometimes termed the coefficient of transmissibility.

FIGURES

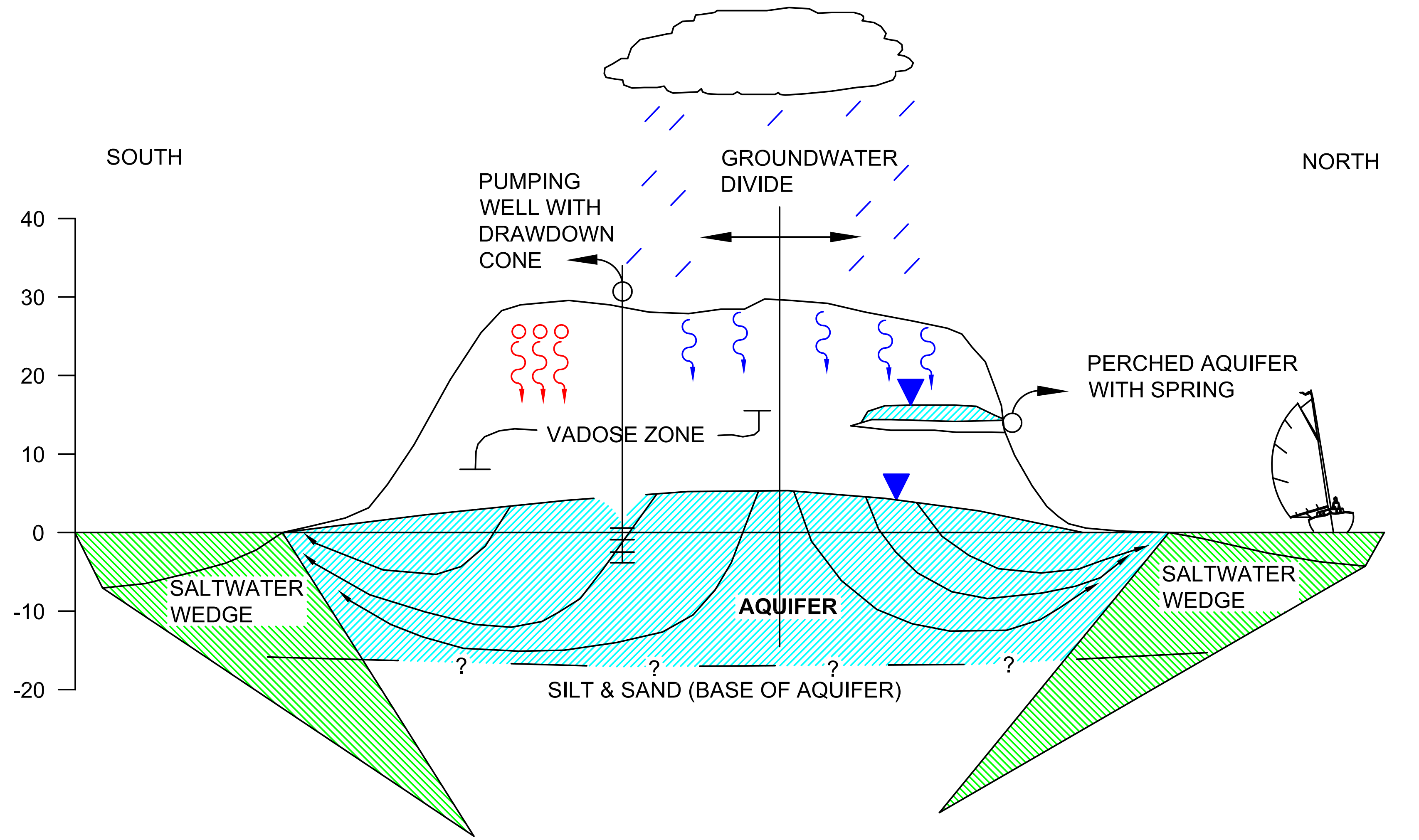
Note:
Base Data from Powell River Regional District, 2017.
Base Imagery from ESRI Basemaps, 2017.
Map Projection is NAD 83 UTM Zone 10.

1:20,000

0 250 500 1,000 1,500 2,000 Meters

Enterprise Geoscience Services Ltd.
203-2902 West Broadway
Vancouver, BC, V6K2G8

CLIENT:	Savary Shores Improvement District		
PROJECT:	Well Protection Plan		
TITLE:	Area Plan		
DRAWN BY:	YL	CHK BY:	JB
DATE:	2017/08/11	REVISED	
PROJ #:	201704		Figure 1



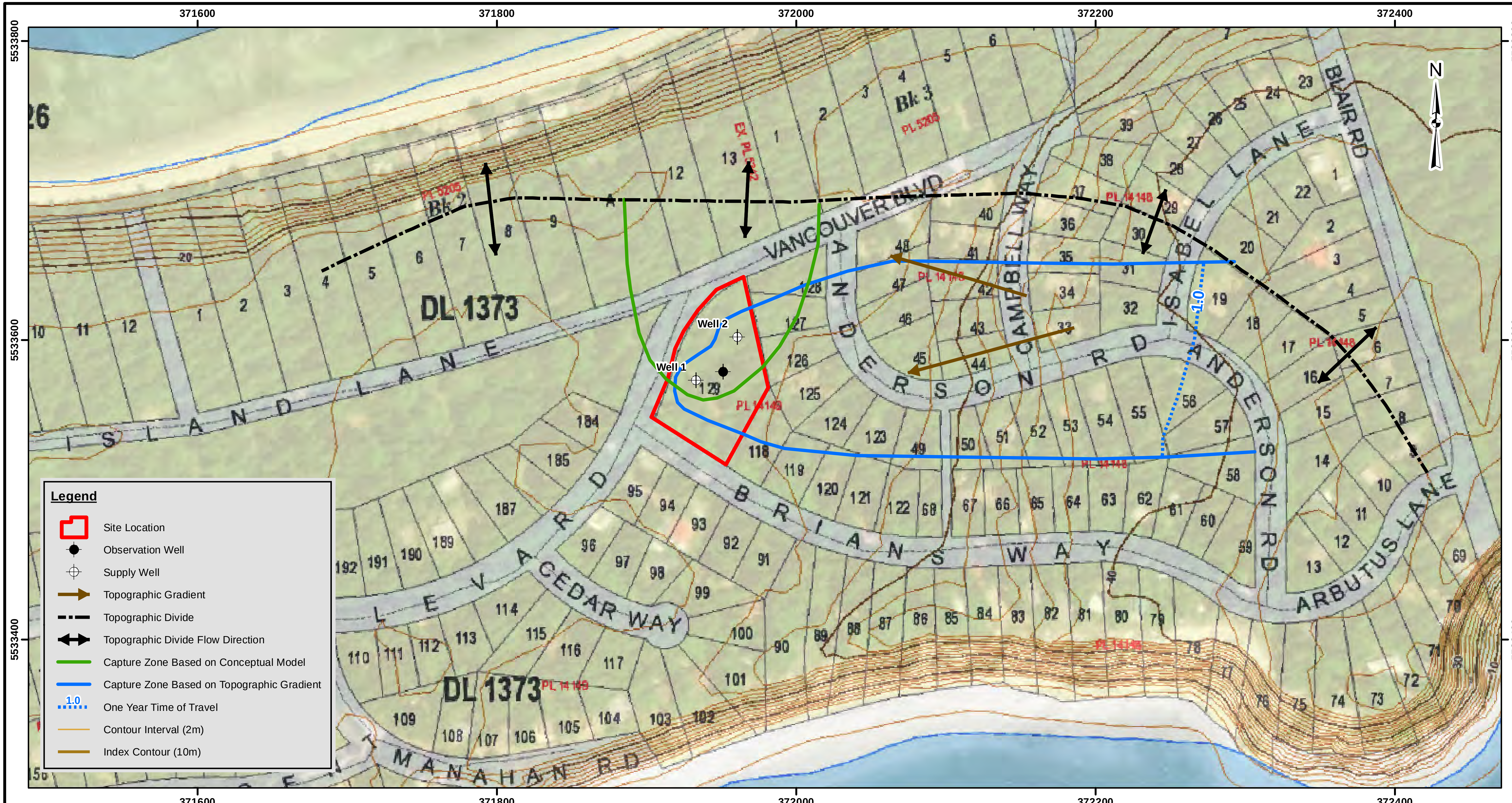
NOT TO SCALE

LEGEND

- WATER TABLE
- GROUNDWATER SEEPAGE FLOW DIRECTION
- INFILTRATION OF PRECIPITATION (AQUIFER RECHARGE)
- PERCOLATION/LEACHING FROM SEPTIC FIELDS

Enterprise Geoscience Services Ltd.
203 - 2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT: **Savary Shores Improvement District**	
PROJECT: **Well Protection Plan**	
TITLE: **Conceptual Hydrogeologic Model for Savary Island**	
DRAWN BY: YL	CHK. BY: JB
DATE: 2017/08/25	REVISED:
PROJ #: 201704	FIGURE 2



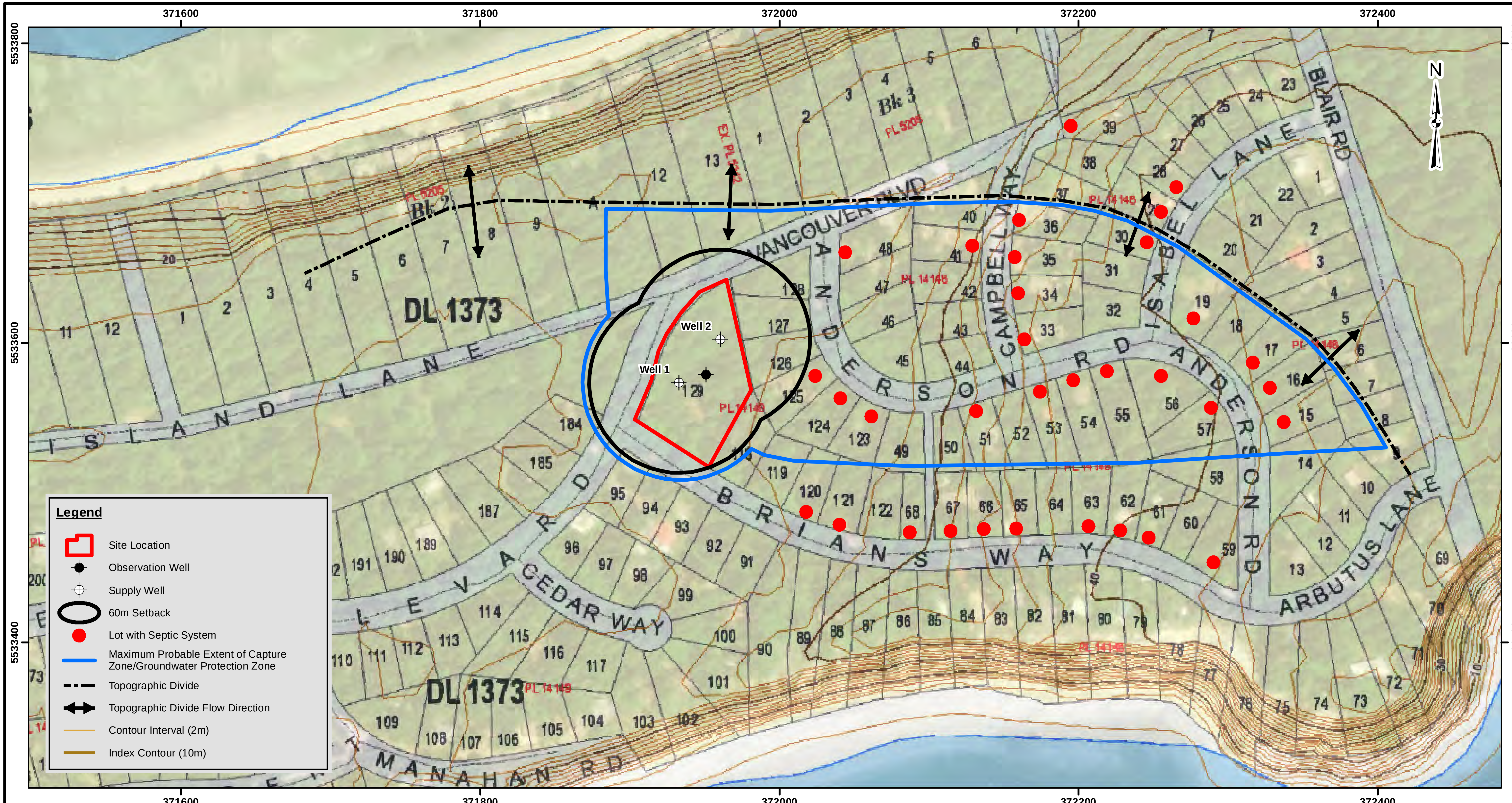
Note:
Base Data from Powell River Regional District, 2017.
Base Imagery from ESRI Basemaps, 2017.
Map Projection is NAD 83 UTM Zone 10.

1:2,500

0 50 100 200 300 400 Meters

Enterprise Geoscience Services Ltd.
203-2902 West Broadway
Vancouver, BC, V6K2G8

CLIENT:	Savary Shores Improvement District		
PROJECT:	Well Protection Plan		
TITLE:	Detail map and Well Capture Zones		
DRAWN BY:	YL	CHK BY:	JB
DATE:	2017/08/24	REVISED	
PROJ #:	201704		Figure 11



Note:
Base Data from Powell River Regional District, 2017.
Base Imagery from ESRI Basemaps, 2017.
Map Projection is NAD 83 UTM Zone 10.

1:2,500

0 50 100 200 300 400 Meters

Enterprise Geoscience Services Ltd.
203-2902 West Broadway
Vancouver, BC, V6K2G8

CLIENT: Savary Shores Improvement District	
PROJECT: Well Protection Plan	
TITLE: Maximum Probable Extent of Well Capture Zone and Land Use	
DRAWN BY: YL	CHK BY: JB
DATE: 2017/08/24	REVISED
PROJ #: 201704	Figure 12

Appendix A

WELL LOGS

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 44211 Owner: MARINELAND INVESTMEN **Owner name should be: Savary Shores Improvement District** Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: 1373 Plan: Lot: 129 Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: SAVARY BCGS Number (NAD 83): 092F097133 Well: 1 Class of Well: Subclass of Well:	Construction Date: 1980-01-01 00:00:00 Driller: Friesen Drilling Well Identification Plate Number: **20738** Plate Attached By: **John Friesen** Where Plate Attached: **well casing** PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 38 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 75 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: 1401653

Orientation of Well: Status of Well: New Licence General Status: UNLICENSED Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 8.0 inches Casing drive shoe: Well Depth: 105 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Water Chemistry Info Flag: Y Field Chemistry Info Flag: Site Info (SEAM): Y Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from to feet	Type	Slot Size	
Casing from to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

```
LITHOLOGY INFORMATION:

From      0 to      4 Ft.    sand

From      4 to     22 Ft.    till

From     22 to     26 Ft.    gravel

From     26 to     55 Ft.    fine gravel

From     55 to     71 Ft.    fine sand

From     71 to     91 Ft.    sandstone

From     91 to     98 Ft.    clay and gravel

From     98 to    111 Ft.    fine gravel becoming silty in bottom
```

- Return to Main
- Return to Search Options
- Return to Search Criteria

Information Disclaimer

BRITISH COLUMBIA
The Best Place on Earth
Ministry of Environment

☒ Well Construction Report
☐ Well Closure Report
☐ Well Alteration Report

Stamp company name/address/ phone/fax/e-mail here, if desired.

Ministry Well ID Plate Number: 34152
Ministry Well Tag Number: ~~34152~~ 108810
☐ Confirmation/alternative specs. attached
☒ Original well construction report attached

Red lettering indicates minimum mandatory information. See reverse for notes & definitions of abbreviations.

Owner name: Savary Shores Improvement District
Mailing address: 38-10460 N03 Road Town Richmond Prov. BC Postal Code V8A-4W5
Well Location: Address: Street no. Street name Vancover Blv Town
(or) Legal description: Lot 129 Plan 14149 D.L. 1373 Block Sec. Twp. Rg. Land District
(or) PID: (and) Description of well location (attach sketch, if nec.): Group 1 New Westminster District

NAD 83: Zone: 10U (see note 2) (and) UTM Easting: 0371966 m UTM Northing: 5533628 m (or) Latitude (see note 3): Longitude:
Method of drilling: ☐ air rotary ☒ cable tool ☐ mud rotary ☐ auger ☐ driving ☐ jetting ☐ excavating ☐ other (specify):
Orientation of well: ☒ vertical ☐ horizontal Ground elevation: ft (asl) Method (see note 4):
Class of well (see note 5): Water Supply Sub-class of well:
Water supply wells: indicate intended water use: ☐ private domestic ☒ water supply system ☐ irrigation ☐ commercial or industrial ☐ other (specify):

Lithologic description (see notes 7-14) or closure description (see notes 15 and 16)

From ft (bgl)	To ft (bgl)	Relative Hardness	Colour	Material Description (Use recommended terms on reverse. List in order of decreasing amount, if applicable)	Water-bearing Estimated Flow (USgpm)	Observations (e.g., fractured, weathered, well sorted, silty wash), closure details
0'	1'	L	BR	Topsoil		
1'	6'	L	T/Y	Layerd Tan Sand (fine)		
6'	28'	ST	T/GY	Tan Layerd Gray Sand (fine)		
28'	35'	ST	GY	Layerd Grey Fine Gravel Sand		
35'	68'	L	GY	Layerd Medium Sand /With Silt Lens		
68'	92'	ST	T/GY	Packed Layerd Fine Sand /With Silt Lens		
92'	109'-6"	L	T/GY	Layerd Fine To Medium Sand -ThinLayers Of Gravel		

Casing details

From ft (bgl)	To ft (bgl)	Dia in	Casing Material / Open Hole	Wall Thickness in	Drive Shoe
0"	96'-4"	8"	Steel	.280	Weld
			Total Casing used 98'	.	on

Screen details

From ft (bgl)	To ft (bgl)	Dia in	Type (see note 18)	Slot Size
96'-3"	96'-11"		K-packer	
96'-11"	104'-2"	Tel	Stainless /Riser/Screen	S/.15
104'-2"	109'-6"	Tel	Stainless/Screen	S/.15

Surface seal: Type: 3/8" bentonite chips Depth: 0'-- 26" ft
Method of installation: ☒ Poured ☐ Pumped Thickness: 2" in
Backfill: Type: N/A Depth: ft
Liner: ☐ PVC ☐ Other (specify): N/A
Diameter: in Thickness: in
From: ft (bgl) To: ft (bgl) Perforated: From: ft (bgl) To: ft (bgl)

Intake: ☒ Screen ☐ Open bottom ☐ Uncased hole
Screen type: ☒ Telescope ☐ Pipe size
Screen material: ☒ Stainless steel ☐ Plastic ☐ Other (specify):
Screen opening: ☒ Continuous slot ☐ Slotted ☐ Perforated pipe
Screen bottom: ☐ Bail ☒ Plug ☐ Plate ☐ Other (specify):
Filter pack: From: ft To: ft Thickness: in
Type and size of material: N/A

Developed by:

☐ Air lifting ☐ Surging ☐ Jetting ☐ Pumping ☒ Bailing
☐ Other (specify): Total duration: 31 hrs
Notes:

Well yield estimated by:

☐ Pumping ☐ Air lifting ☒ Bailing ☐ Other (specify):
Rate: Est 35' USgpm Duration: 31hr hrs
SWL before test: 74'-4" ft (btoc) Pumping water level: ft (btoc)

Obvious water quality characteristics:

☒ Fresh ☐ Salty ☒ Clear ☐ Cloudy ☐ Sediment ☐ Gas
Colour/odour: Clear no odour. Water sample collected: ☒

Well driller (print clearly):

Name (first, last) (see note 19): Anderson Paul
Registration no. (see note 20): WD06061501
Consultant (if applicable; name and company): Canwest Well Drilling Ltd

DECLARATION: Well construction, well alteration or well closure, as the case may be, has been done in accordance with the requirements in the *Water Act* and the Ground Water Protection Regulation.

Signature of Driller Responsible

Final well completion data:

Total depth drilled: 109'-6" ft Finished well depth: 109'-6" ft (bgl)
Final stick up: 20" in Depth to bedrock: N/A ft (bgl)
SWL: 74'-4" ft (btoc) Estimated well yield: 35gpm USgpm
Artesian flow: N/A USgpm, or Artesian pressure: ft
Type of well cap: Vermon Proof Well disinfected: ☒ Yes ☐ No
Where well ID plate is attached: 6" below top of casing

Well closure information:

Reason for closure: N/A
Method of closure: ☐ Poured ☐ Pumped
Sealant material: Backfill material:
Details of closure (see note 17):

Date of work (YYYY/MM/DD):

Started: April-2011 Completed: May-2011
Comments:

PLEASE NOTE: The information recorded in this well report describes the works and hydrogeologic conditions at the time of construction, alteration or closure, as the case may be. Well yield, well performance and water quality are not guaranteed as they are influenced by a number of factors, including natural variability, human activities and condition of the works, which may change over time.

white: Customer copy
canary: Driller copy
pink: Ministry copy

Sheet ____ of ____

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 44210	Construction Date: 1980-01-01 00:00:00
Owner: MARINELAND INVESTMEN	Driller: Unknown
	Well Identification Plate Number:
Address:	Plate Attached By:
	Where Plate Attached:
Area: SAVARY ISLAND	
	PRODUCTION DATA AT TIME OF DRILLING:
WELL LOCATION:	Well Yield: 0 (Driller's Estimate)
CAMERON Land District	Development Method:
District Lot: 1373 Plan: Lot: 129	Pump Test Info Flag: N
Township: Section: Range:	Artesian Flow:
Indian Reserve: Meridian: Block:	Artesian Pressure (ft):
Quarter:	Static Level:
Island: SAVARY	
BCGS Number (NAD 83): 092F097133 Well: 2	WATER QUALITY:
	Character:
Class of Well: Monitoring	Colour:
Subclass of Well: Permanent	Odour:
Orientation of Well:	Well Disinfected: N
Status of Well: New	EMS ID: 287071
Licence General Status: UNLICENSED	Water Chemistry Info Flag: Y
Well Use: Observation Well	Field Chemistry Info Flag:
Observation Well Number: 408	Site Info (SEAM):
Observation Well Status: Active	
Construction Method: Other	Water Utility:
Diameter: 1.5 inches	Water Supply System Name:
Casing drive shoe:	Water Supply System Well Name:

Well Depth: 91 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: N File Info Flag: N Sieve Info Flag: N Screen Info Flag: N Site Info Details: Other Info Flag: Other Info Details:	SURFACE SEAL: Flag: N Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
OBSERVATION WELL -THIS IS LOCATED 22.8' FROM THE MAIN PUMPING WELL
DIVER SENSOR INSTALLED ON FEB 22, 2011

LITHOLOGY INFORMATION:

From	0	to	5	Ft.	dry silty sand, few stones
From	5	to	8	Ft.	sand
From	8	to	10	Ft.	tan clay
From	10	to	91	Ft.	sand with several very compact beds,
From	0	to	0	Ft.	especially below 55'

- Return to Main
- Return to Search Options
- Return to Search Criteria

Appendix B

INFORMATION ON SEPTIC SYSTEMS THAT REMOVE NITROGEN FROM DOMESTIC WASTEWATER

WaterNOx-S & WaterNOx-LS Nitrogen Removal

Removes up to 95% of total nitrogen from residential or commercial septic systems with a simple, passive, and cost-effective denitrification filter.

Available upgrade for *all* Waterloo Biofilter advanced wastewater treatment systems

Nitrogen is a nutrient naturally found in human wastewater. Excess nitrogen in groundwater is a public health concern, while excess nitrogen in surface waters can stimulate algae blooms and lake eutrophication. Not only can this be a nuisance and interfere with the enjoyment of water bodies - but serious health and ecosystem problems can result such as 'blue baby' syndrome, fish kills, and 'brown or red tide' algae toxins that accumulate in shellfish.

Excess nitrogen in the environment can:

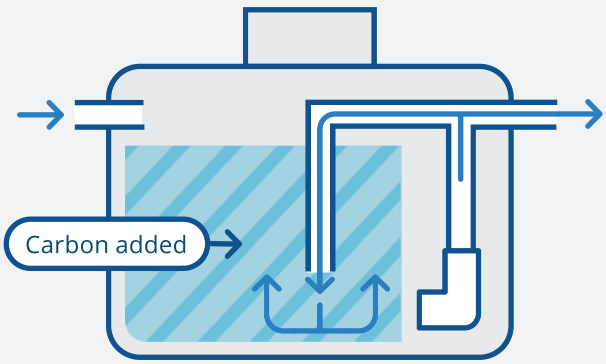
- Contaminate Drinking Water Sources with High Levels of Nitrate
- Limit Recreation Activities such as Swimming, Boating, and Fishing
- Lower Property Values by Impairing Quality of Surface Water
- Lower Dissolved Oxygen Levels and Reduce Fish Populations

Multiple Levels of Removal

The Waterloo Biofilter system itself removes 25-35% of total nitrogen with a single-pass configuration, and 50-65% of total nitrogen with a double-pass configuration where treated effluent is recirculated back to the septic tank. With a WaterNOx-S or WaterNOx-LS denitrification filter installed after the Waterloo Biofilter treatment unit, up to 95% total nitrogen removal can be achieved.

WaterNOx-S

The WaterNOx-S recirculates nitrified effluent up through a plastic filtration media with external carbon source added for denitrification.



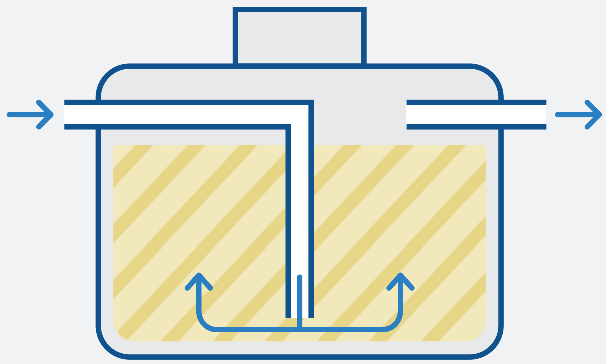
A pump re-circulates the water through the filtration media. External carbon is added.

WaterNOx-S Benefits

- Permanent filtration medium
- Easy set-up and servicing
- No filter media backwashing
- Safe, non-toxic carbon source
- Low energy use
- New or retrofit applications

WaterNOx-LS

The WaterNOx-LS uses autotrophic bacteria to denitrify nitrified effluent in a proprietary blend of agricultural minerals.



Water goes down to the bottom of the tank, then flows up through the media and out the outlet.

WaterNOx-LS Benefits

- 100% passive, no energy used
- No extra pump necessary
- No chemical addition
- Long, 10+ year filter media lifespan
- Self-buffered to neutral pH
- Minimal increase to BOD and TSS

For more information:

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