GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

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Assessment of Groundwater Resources on Savary Island - Qayɛ qʷən

Prepared for:

qathet Regional District, Planning Services

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qɛyɛ qʷən – Island of the Freshwater Springs

qɛyɛ qʷən (Qaye qwun) is the place name for Savary Island in ʔayʔaǰuθəm (Ay-A-Ju-Thum), the language spoken by the Tla'amin, Homalco, Klahoose, and K'òmoks people. The word qɛyɛ qʷən means freshwater spring. The island has this name because of the three freshwater sources on the island. The springs on the island also carry the name qɛyɛ qʷən.

The name qɛyɛ qʷən was given to the island after the transformer came and transformed ʔayhos (Ay hos), a double-headed serpent, into the physical island we see today. When ʔayhos was feasting near maƛ nač (Mutl nach / Mitlenatch), χaχyɛ ti qaymɩxʷ (the transformer) came and transformed the serpent into an island to stop him from getting to his cave at χaχa giɬ (XaXa geetl / Hurtado Point). The solid rock at the end of the island is where the transformer stopped ʔayhos. At χɛχaǰeyɩs (XeX yales / Beacon Point), the transformer speared ʔayhos, which left a water hole that never goes dry, even in the summer.

Since time immemorial, Tla'amin people have occupied qɛyɛ qʷən. Tla'amin people living on qɛyɛ qʷən participated in ceremonies and spiritual gatherings, clam digging, root digging, and berry picking. Near the reef, there was also a herring spawning area in the past. To this day, ancestral remains and burial sites are still being found on qɛyɛ qʷən, often on private property. The island continues to be an important place in ʔəms gijɛ (Tla'amin territory) for these uses. Today, Tla'amin Nation is a modern self-governing Nation with a desire to restore Tla'amin Nation's rightful place and decision-making role throughout Tla'amin territory.

Place names are important and reflect the relationships between ʔayʔaǰuθəm speakers and their territories. Colonial place names on the island have erased the knowledge held by ʔayʔaǰuθəm place names, with some English place names on the island being racist and derogatory. Work is being done to officially change derogatory place names. While Elders were able to share teachings and identify place names on qɛyɛ qʷən, many place names were lost because of the impacts of colonization and residential schools.

- Tla'amin Nation Lands and Resources Department and Culture, Language & Heritage Department

ʔayʔaǰuθəm Place Names

English Place Name	ʔayʔaǰuθəm Place Name (Pronunciation)	Meaning
Savary Island	qɛyɛ qʷən (Qaye qwun)	Fresh Water Spring
Along Sunset Trail	t̓i: t̓i: may (T'eet'ee may)	Many Wild Cherry Trees
Indian Spring	qɛyɛ qʷən (Qaye qwun)	Fresh Water Spring
Indian Point	θatɛq (Thah teq)	Broken Off
Beacon Point	χɛχaǰeyɩs (χɛ χa jey is)	Little rocks

Resources:
Tla'amin Video with information about qɛyɛ qʷən: https://www.youtube.com/watch?v=aYT-OL17F-8
ʔəms gijɛ (Our Land) Map of Traditional Place Names of the Tla'amin Nation (available at: powellriver.ca/pages/photo-history-of-powell-river)

This report endeavors to use the ʔayʔaǰuθəm (Ay-A-Ju-Thum) place names where possible, in recognition of the First People of this land, and to avoid use of disrespectful labels commonly used in the past.

Executive Summary

Savary Island, also known as qɛyɛ qʷən (Qaye qwun) is a small (5 km^2 island), located in the qathet Regional District (qRD), west of Lund, B.C. In 2024, this groundwater assessment project was initiated by the qRd to review current groundwater conditions and hydrogeology of the island and provide essential background for revision of the Savary Island Community Plan. This report presents the results of the comprehensive overview of current groundwater conditions on the island, including water availability and use, water quality, and vulnerability to hazards related to land use, climate change and sea water intrusion.

Data Summary: A comprehensive summary of water-related data for the island was prepared, including locations and depths of registered and known wells, springs, water use and water quality data from the local water supplier (Savary Shores Improvement District (SSID), land use, geology and findings from previous hydrogeologic studies. An online survey was completed in which residents provided information on their water sources, water use, quality and quantity concerns, and sanitary (wastewater) practices. Issues related to aquifer vulnerability, water carrying capacity, and household well maintenance were highlighted as very important to the people who responded.

Aquifer Model: A three-dimensional (3D) hydrogeologic model of the island's aquifers was created. The model represents the topographic, geologic and hydrogeologic features of Savary Island in three dimensions, including soil and sediment layers, locations and depths of wells, groundwater levels, and the ocean surface. A total of 233 registered and field-verified wells were captured in the model. Potentially over 400 additional wells may exist on the island based on the number of developed lots. The 3D model was used to interpret the characteristics (location, depth, thickness) of the island's aquifers and water sources. The presence and thickness of materials such as clay, silt and till were identified, which influence aquifer recharge and vulnerability to contamination. The model was used to map and describe the local hydrogeologic conditions, including groundwater depth, elevation and flow direction, aquifer vulnerability, and the approximate depth and thickness of the freshwater lens beneath the island. Cross-sections (vertical slices through the model) were prepared to interpret underground features, hydrogeologic processes and hazards in representative areas. Savary Island was divided into six groundwater management areas used for subsequent analyses, based on the differences in hydrogeologic conditions and hazards in each region. The model is provided as a Leapfrog viewer file that can be used as an educational and interpretive tool.

Water Balance Model: A water balance model was prepared to assess groundwater availability on the Island. The model considered historical average, current and future water inputs from precipitation, minus losses to plants and the atmosphere. Groundwater recharge was estimated, considering factors such as slope, groundwater discharge zones, land cover, and the characteristics of the soil and sediments that influence runoff or infiltration of rainfall. A detailed analysis of local water use and land use data was used to estimate water demand under current seasonal occupancy and potential buildout scenarios. Yearly, groundwater pumping currently uses up to 7% of groundwater recharge over the entire Island over the entire year, however there is a seasonal deficit as most water use occurs during the summer months when no groundwater recharge occurs. Aquifer stress (demand vs recharge) and seasonal deficits are likely to increase if there is more full-time occupancy and buildout on the island. Climate change is anticipated to reduce annual groundwater recharge and extend the length of the dry season which could lead to a lowering of the water table and a reduction in baseflow to springs. This will make the island aquifers more vulnerable to seawater intrusion.

Field Survey and Well Protection Assessment: An important aspect of this study was the completion of a field assessment and point-in-time evaluation of water quality. Over a five-day period in September 2024 over 77 sites on the island were visited, including 54 wells where information was collected on the well type, construction characteristics, and groundwater levels and field water quality was recorded.

Proper well construction, maintenance and operation are critical for the protection and sustainability of groundwater resources. Most wells inspected were compliant with well construction and maintenance standards in the *Water Sustainability Act*, Groundwater Protection Regulation (GPR). Some observed well construction and maintenance practices that could be improved include ensuring that bentonite surface seals are installed and maintained and ensuring that foreign materials and contaminant sources are kept away from the well. In Thah teq (Indian Point) on the west end of the island, many residents use sand point wells, which is relatively unique to this island and management area.

Groundwater quality: During the field survey, groundwater samples for laboratory analysis were collected from selected sites (27 wells and 1 spring) distributed across Savary Island and compared to samples of ocean water (two sites) and rainfall (1 site). Groundwater quality is generally fresh and meets Canadian drinking water quality guidelines. Samples from a small number of sites exceeded the guidelines for pH, chloride, sodium, TDS, iron, or manganese. Nitrate concentrations were below drinking water guidelines, but the median and maximum concentrations have increased in some areas of the island over the past 25 years. Nitrate and chloride values above the estimated background concentrations and observed long-term trends were linked to the influence on groundwater quality of septic system discharges, well construction practices and regional differences in groundwater recharge, discharge and the intrinsic aquifer vulnerability to contamination.

Aquifer hazard assessment: This groundwater assessment highlighted island-wide characteristics as well as regional differences that could be considered when developing a long-term aquifer protection strategy. Aquifer and well characteristics, vulnerabilities and water supply options within the six groundwater management areas on Savary Island were described. Hazards such as pollution from septic systems and seawater intrusion are likely to affect all areas of the island.

Septic systems: Groundwater quality on Savary Island is vulnerable to the impacts of septic system discharges. Current regulations require a minimum setback distance of 30 m between a well and a septic field. However the high density of small lots each with their own well and onsite waste disposal increases the hazard of groundwater contamination by nutrients (i.e., nitrate) and pathogens such as bacteria and viruses. The shallow soils and sandy materials common on Savary Island promote rapid infiltration of septic leachate, limiting the time for bacterial processes such as denitrification to occur. Property owner education should emphasize the importance of ensuing these systems are properly installed and maintained to prevent adverse impacts on groundwater quality.

Seawater intrusion: Freshwater supplies on islands and in coastal aquifers are at risk of salination from mixing with seawater. Seawater intrusion (SWI) is considered one of the most significant hazards to long-term water sustainability on Savary Island. Mapping of groundwater levels shows that the freshwater is present as a shallow lens, and the water table has an elevation of 3 meters or less above sea level. The depth to the freshwater-saltwater interface is estimated as 25 metres (~80 ft) below sea level or less over most of the island footprint, and less than 10 meters (30 ft) below sea level in the highest risk areas such as Thah teq (Indian Point). Climate change related effects, including reduced recharge, increased groundwater demand, longer dry seasons, rising sea levels, and storm surges will exacerbate current stresses. While only a small number of wells are currently impacted by SWI, there is apparent trend of replacing shallow sand points with deeper drilled wells, and construction of larger homes that may be associated with increased water demand, which could exacerbate this hazard. Well owners should employ best practices including conserving and reducing water use, managing pumping rates and groundwater level drawdown and monitoring water quality compared to saltwater intrusion indicators (chloride, electrical conductivity and total dissolved solids). Well drillers and pump installers play a critical role and must employ caution to assess water quality while drilling and installing pumps, and avoid drilling too deep in high-risk areas, while educating property owners regarding the hazards.

Groundwater protection and management plan: The sustainability and protection of groundwater supplies on Savary Island depends on the shared actions of community members, regional government, businesses, tradespeople, and visitors to the island. Strategies for groundwater protection management were identified in the following priority areas:

Private well protection and operation and septic system maintenance: Support should be provided to increase well owner education and awareness of well protection measures, water testing and treatment methods, and best practices to reduce risks from hazards such as seawater intrusion. Proper operation and maintenance of onsite sewerage systems including septic systems is also critical to protect water supplies.

Rural Water Supply and Servicing Options: Apart from within Savary Shores Improvement District, water supplies on Savary Island have typically been obtained from privately operated water wells (drilled, sand point or dug wells). Options for shared domestic systems, community water supplies (utilities) or non-conventional sources such as rainwater could also be considered.

Water conservation planning and education: Freshwater resources on Savary Island are limited and must be carefully conserved to ensure long-term viability of the community. Most long-term residents and property owners are highly aware and extremely cautious about water use. Large homes with high indoor and outdoor water demand are less compatible with sustainability. Tools and actions to educate and promote water conservation and changed behaviour of visitors and others remain an important component of a long-term water strategy.

Groundwater level monitoring: Savary Island benefits from two official provincial observation wells (OW408 and OW511) and one additional location (OW500) where groundwater level and temperature are currently monitored. Monitoring should continue at these locations. Additional monitoring locations such as through volunteer monitoring of domestic wells could be considered to enhance understanding of aquifer conditions in other areas of the island.

Well driller and pump installer education and compliance enforcement: Savary Island has exceedingly high density of private wells, and yet the well inventory in the provincial databases is only a fraction of the known and inferred wells. Drilling and operation of deep wells may contribute to long-term alteration of water quality and impacts to adjacent groundwater users. Older or new wells with failing or inadequate surface seals can create preferential pathways for contaminants to enter the aquifer. Greater education and compliance enforcement is needed by provincial authorities with respect to well registration, adherence to Groundwater Protection Regulation requirements, and application of best practices to prevent seawater intrusion.

Land Use Planning

This assessment has highlighted the importance of groundwater to the Savary Island community, and the unique assets and vulnerabilities in different management areas. Further work could be completed to consider and develop water-focused strategies and actions to be incorporated within the community vision and planning process.

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1 BACKGROUND

Savary Island, referred to as qɛyɛ qʷən (Qaye qwun) by the Tla'amin First Nation in whose territory the island resides, is a small strip island (~5 km^2 in area), located 3 km southwest of Lund, in the qathet Regional District (qRD). As with many BC island communities, the population of Savary Island varies seasonally, with 100 or fewer year-round residents that increases to around 2800 residents and visitors during the peak summer tourist season (BC Hydro, 2012; qathet Regional District, 2007; Rural Coordination Centre of British Columbia, 2024; Tupper, 1996) (There is limited public data are available on population statistics for rural communities with seasonal recreational use.)

With no natural streams or lakes on the island, water supply for mainly residential use is entirely reliant on groundwater from provincial mapped Aquifer 834, a partially confined, unconsolidated sand aquifer (Province of BC, 2024a). The centre of Savary is a protected ecological zone, while much of the remaining area is developed into small lots created in 1910 during early subdivision of the island. Water supply is obtained from drilled wells, shallow driven sand point wells, excavated wells, and springs (Tupper, 1996; Golder & Associates, 1997). The Savary Shores Improvement District provides water within their service area on the southeastern side of the island (Savary Shores Improvement District, 2024). It was noticed during the site visit that efforts were made by a small number of residents to implement rain collection systems in their homes to either supplement or entirely use as source of water. A map of the subject area is shown in Figure 1.

Previous studies have identified significant risks to water supplies and ecological sustainability of the island including:

- Seasonal water demand pressures due to the high summer population, and uncertainty regarding long-term carrying capacity of the local aquifer (Golder Associates, 1997);
- Impacts to groundwater quality from disposal of sewage effluent from residential septic systems, and increasing trends in nitrate concentration within groundwater from water system wells (Enterprise Geoscience Services Ltd., 2017; Savary Shores Improvement District, 2024);
- Vulnerability of the aquifer to sea water intrusion, potentially affecting water quality (salinity) and long-term sustainability of freshwater resources (Chesnaux et al., 2021; Tupper, 1996)
- Groundwater discharge and freshwater runoff influencing conditions coastal ecosystems: for example, nutrients, bacteria and pathogens from sewage in groundwater seepage and land runoff affecting the health of shellfish, aquatic organisms, and potential linkages between freshwater flux to coastal areas and the health of nearshore eel grass beds (Golder Associates, 1997);
- Vulnerability of the island to climate change impacts, including changes in precipitation and aquifer recharge, sea level rise, and coastal erosion (Chesnaux et al., 2021; Tetra Tech, 2023a).

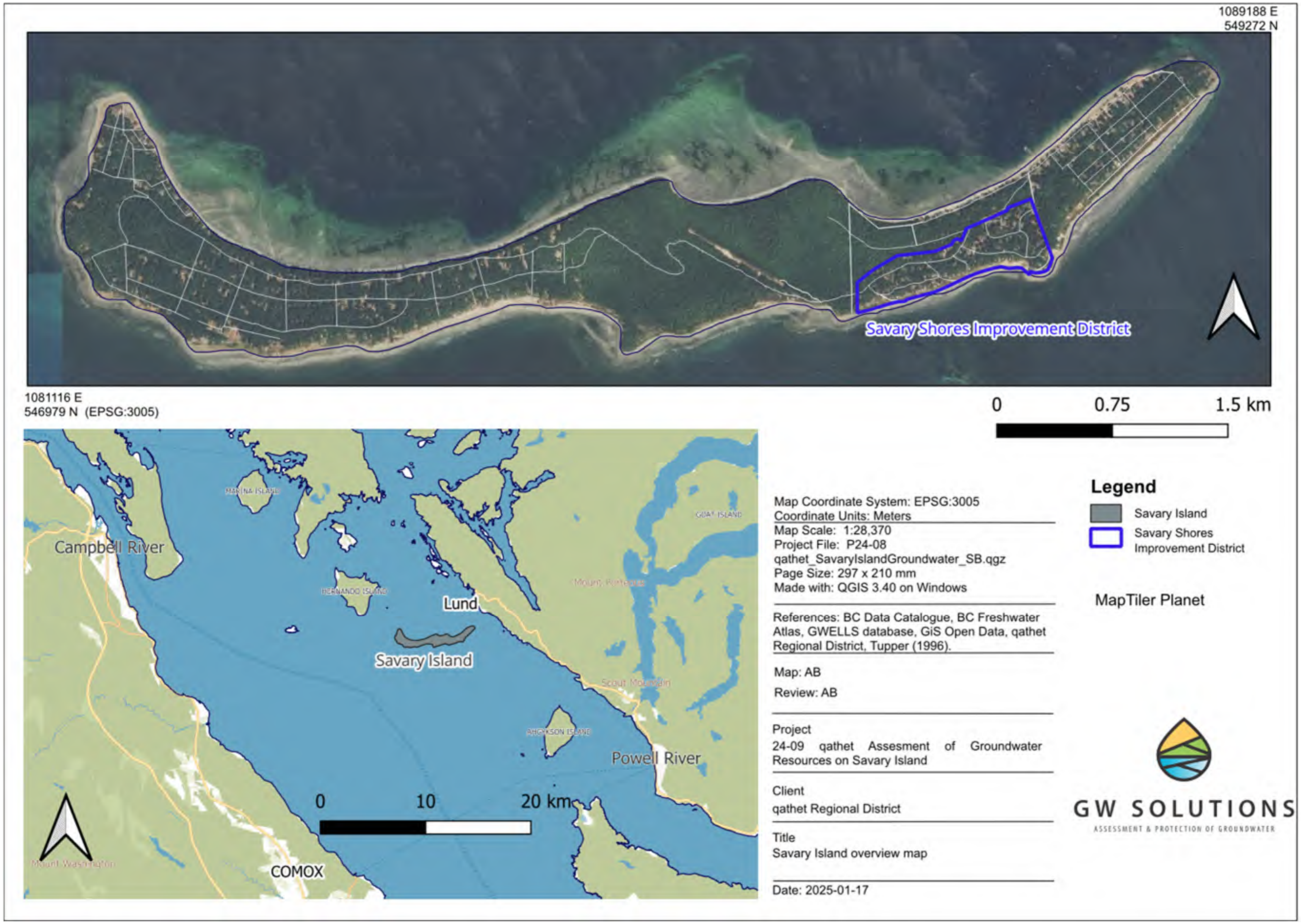


Figure 1. Savary Island overview map.

The qathet Regional District (qRd) initiated the groundwater assessment project in September 2024, to provide a review of current groundwater conditions and hydrogeology of the island that will be used during the process of updating of the Savary Island Community Plan.

The objectives of the study were to:

- Complete an in-depth assessment of current groundwater conditions on Savary Island;
- Develop strategies for aquifer protection and sustainability that will help guide land use and planning affecting water resources on the island.

2 SCOPE

For the groundwater resource assessment project, the following tasks were completed:

- Compile and update water-related information for Savary Island:
  - Update the mapping of water sources (wells, springs).
  - Gather existing monitoring & land use data.
  - Collect information on water sources, water usage and property wastewater treatment methods using an online resident survey.
  - Collect current data on water conditions (groundwater levels, field and laboratory analyses of water quality).
  - Prepare a hydrogeologic model of the island's aquifers which incorporates the results of the data compilation.
- Complete a current assessment of groundwater quantity and quality assessment:
  - Develop water balance for island (water availability vs demand).
  - Assess impacts of climate change on the water balance.
  - Evaluate aquifer vulnerability to contamination from the land surface.
  - Assess sea water intrusion hazard and impact.
- Develop an aquifer protection plan and monitoring strategy:
  - Identify target areas and methods to expand the water monitoring network.
  - Determine planning & other measures to help preserve and protect water resources on the island.
  - Prepare a report (this report) and presentation to share the project results with qRD leadership and planners, Tla'amin Nation, and Savary Island residents and community members.

3 DATA COMPILATION

The initial step was to catalogue and compile existing information on geology and hydrogeology of the island. The primary data sets and sources compiled for the study are described in Table 1. Additional sources and references are described in the report sections below.

Table 1. Data sources and application within the study.

Source	Category	Data processing and application within the study
Province of BC	Groundwater Wells and Aquifers Database (GWELLS)	Data from GWELLS (Province of BC, 2024a) provided information on the locations and depths of wells, aquifer materials, depths of water bearing zones, groundwater levels, and relative aquifer productivity (estimated yield). Well construction information was gathered from property owners during the field survey, and additional well records were requested and obtained from registered well drillers that work in this area. Lithological data were cleaned and standardized to develop the Leapfrog model.
Province of BC and geospatial analysis	Mapped aquifers and lithological strata	There is one provincially mapped aquifer on Savary Island, AQ834 ((Province of BC, 2024a). The boundaries of lithological strata and aquifer sub-regions appropriate for management scale were further defined through development of a conceptual model in two-dimensional and three-dimensional formats using QGIS and Leapfrog modelling software.
Province of BC	Aquifer Vulnerability to Sea Water Intrusion	Mapping of aquifer to vulnerability to sea water intrusion maps was obtained from the BC data warehouse (Water Protection and Sustainability, 2022). Methods and parameters used for sea water intrusion hazard mapping (Klassen and Allen, 2016; Sivak and Wei, 2021) and additional criteria were considered to refine the categorization for each groundwater management area, and ground-truthed using water quality data collected in the field.
Province of BC	Water licenses	The provincial Water Rights Database contained information on the locations and licensed volumes for surface water Points of Diversion (POD's), including licensed springs, and groundwater Points of Well Diversion (PWD's) (Water Management, 2024a, 2024b).
Province of BC and water systems	Groundwater monitoring data	Groundwater level and temperature data were compiled for Provincial Observation Wells OW408, OW511 from the Aquarius Database (Real-Time Water Data Tool) (Ministry of Environment and Parks, 2024). Unpublished data for OW500 were also provided on request from provincial staff. The data were used to interpret long-term trends in groundwater level fluctuation, seasonal and long-term aquifer discharge and recharge cycles.
Fisheries and Oceans Canada	Tidal fluctuation	Tidal data were obtained for the Campbell River Station (08074 – sea level observations) and Lund Station (07885 – sea level predictions) (Fisheries and Oceans Canada, 2024).
Province of BC	Surficial and Quaternary geology	Surficial geology mapping provided information on material types, formation process and origin (e.g. pre-glacial, glacial and post-glacial events, coastal processes such as the rise and fall sea level over geologic time). The developed surficial geology map as part of Slope Hazard Study

Source	Category	Data processing and application within the study
		(Tetra Tech, 2023a) were incorporated into the geospatial database. Detailed soil mapping data not available for the Savary Island area.
Province of BC	Digital Elevation Model	Topographic elevation of the landscape was obtained as digital elevation model (DEM) layer derived from high-resolution Light Detection and Ranging (LiDAR) imagery published on the BC Lidar Data Portal (GeoBC Branch, 2024). The LiDAR imagery was obtained already processed to derive a "bare earth" Digital Elevation Model (DEM) of the landscape, which revealed subtle geological structures not visible from the ground (REF). The data were used to develop a three-dimensional conceptual model of the island, highlighting surface topography, depressions, landforms and physiographic features that influence groundwater recharge and movement. Topographic elevation data were also be used to calculate slope (inclination of the ground) and aspect (direction of the slope) affecting precipitation infiltration and surface runoff, and to map groundwater flow direction, and the locations of recharge and discharge zones. The LiDAR raw data, Tree Light, is also used for generating a high-resolution raster layer for vegetated/forest area for land cover map.
Province of BC and local authorities	Water quality	Available data on groundwater and surface water quality was compiled from Savary Shores Improvement District, the Provincial Observation Well Network (Lindsay Eenkooren, Groundwater Technician, Ministry of Environment and Parks, personal communication, Sept. 2024) the Provincial Environmental Management System (EMS) database and digitized from historical reports.
Various	Water demand	Water usage data was obtained from Savary Shores Improvement District and Provincial water license records (licenced volumes from Surface Water Points of Diversion, and Points of Well Diversion). Water demand was estimated based on the property owner survey, population numbers, lots and land use, and compared to empirical references i.e. per capita demand in nearby communities with similar land use.
Province and local authorities, qathet Regional District	Cadastral mapping (lot boundaries) and land use	Current cadastral lot boundaries and BC Assessment actual land use categorization were obtained from the qRD and used to estimate the population size, water use, and density of sewage discharge locations (e.g. septic systems or other methods of sewage disposal).
Various (Federal government, qathet Regional District)	Land cover, vegetation and land-use	Vegetation and land use play an important bearing on the amount of evapotranspiration and runoff and were used to estimate groundwater recharge potential. Land cover classification was obtained from Natural Resources Canada. Surficial geology map layers were obtained from qRD, compiled by Tetra Tech (2023a).
Environment and Climate Change Canada and	Historic climate data (long-term records and climate normals) and geospatial grid	Statistical analysis of historic records on temperature and precipitation were completed based on compiled data from appropriately located climate monitoring stations (Environment and Canada, 2024).

Source	Category	Data processing and application within the study
Pacific Climate Impacts Consortium (PCIC)	climate data (climate normals and future projections)	The water balance model utilized gridded climate data (e.g. temperature and precipitation) and modelled future scenarios from the Pacific Climate Impacts Consortium (PCIC) (Pacific Climate Impacts Consortium, 2024)
Various	Existing hydrogeologic and environmental assessments	A detailed literature search was completed to gather and review information from previously prepared hydrogeologic and environmental studies.
First Nations	Traditional knowledge and history	GW Solutions and qRD met with staff from the Tla'amin Nation to obtain information on traditional place names, known water sources and historical land-use.
Property owner survey and field data collection	Local water resource inventory	Data on water sources, well construction characteristics, water use and sewage treatment practices were obtained through an online written survey and field assessment completed in fall 2024.

3.1 Previous groundwater studies

Results and data from historical reports were reviewed and collated, including from the following sources:

- A preliminary assessment of the groundwater resources of Savary Island, British Columbia. (Tupper, 1996)
- A review of the groundwater situation on Savary Island (Pacific Hydrogeology Consultants, 1987)
- An analytical methodology to estimate the changes in fresh groundwater resources with sea-level rise and coastal erosion in strip-island unconfined aquifers: illustration with Savary Island, Canada (Chesnaux et al., 2021)
- Completion Report Evaluation of Groundwater Resources on D.L. 1375 of Savary Island (Pacific Hydrology Consultants, 1995)
- Optical dating of stabilized parabolic dunes, Savary Island, British Columbia (Biln, 2017)
- Savary Island Dune and Shorelines Study (Thurber Engineering Ltd, 2003)
- Savary Island Official Community Plan Background Information (Golder Associates, 1997)
- Savary Island Official Community Plan, Bylaw No. 403, 2006 (qathet Regional District, 2007)
- Savary Island Slope Hazard Study (Tetra Tech, 2023a)
- Savary Shores Improvement District Water System Assessment (Kerr Wood Leidal, 2008)
- Savary Shores Improvement District Wellhead Protection Plan (Enterprise Geoscience Services Ltd., 2017).

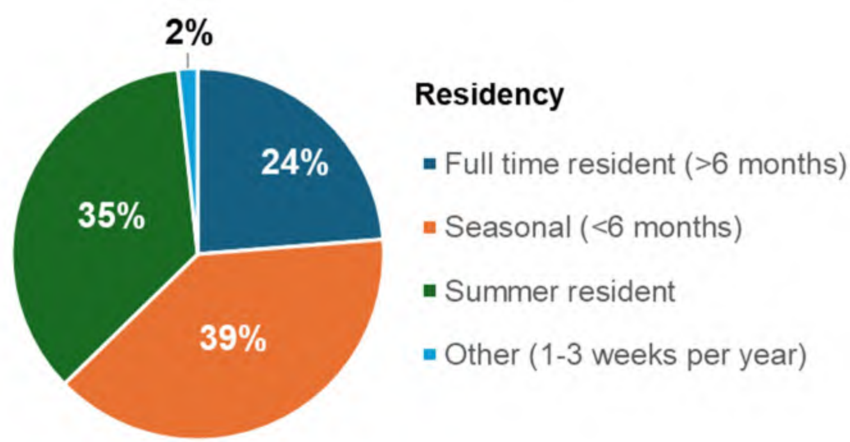
3.2 Savary Shores Improvement District studies and data

Previous hydrogeologic studies, data on water use, and water quality laboratory results were provided by the Savary Shores Improvement District (Janine Reimer, personal communications, August and September 2024). The data are summarized within the related report sections below, e.g. water demand and water quality.

3.3 Online resident survey

An online survey was completed in fall 2024 to provide information on water related issues including water sources and methods of sewage treatment used on Savary Island properties. The survey was implemented using the SimpleSurvey online platform and open from September 11 to October 15, 2024. It was promoted through the groundwater assessment project launch (virtual presentation on September 11, 2024), on the qRD project website, posters on island bulletin boards, and email distribution through local groups and networks. In total 59 responses were received. The results of the 2024 survey are summarized briefly below. The summary includes some responses which were re-categorized or grouped (e.g. responses in an “other” category). The full survey results are included in Appendix A. The water survey was also used to connect with volunteers for the field survey and helped to inform the estimates of water demand, and to evaluate potential impacts of land use on water quality discussed in subsequent report sections.

Table 2. Summary 2024 water survey responses

Graphical result	Category and description
	**Residency and occupancy** • A total of 59 responses were received, 100% identified as landowners. All (98%) but one of the survey respondents indicate that their property has a constructed residence or building. • Twenty-four percent of respondents (14 respondents) indicate that they are full-time residents, defined as residing on the island 6 or more months of the year, compared to 39% (23) who reside on the island seasonally for less than 6 months and 36% (21) who reside there in summer only or for a limited period during the year. • The number of people residing on each property ranged from 0 to 15, and the average number of people per parcel was 3. Similarly, the number of people per residence or building was

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<tr><td></td><td>an average of 3, ranging from 0 (unoccupied) up to 10 residents per household.</td></tr>
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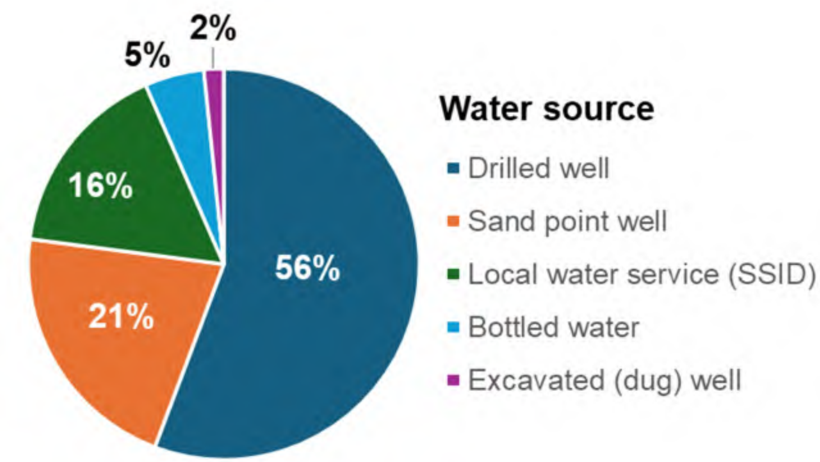

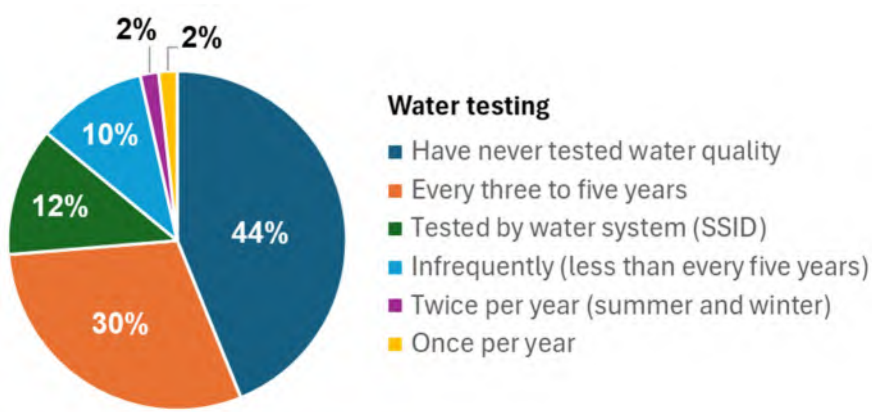

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Water sources

Most respondents 58% (34 responses) utilize a drilled well for their water supply, followed by driven sand point wells 22% (13 responses), while 17% (10) obtain water from the local water service, Savary Shores Improvement District. Only one respondent (2%) reported using an excavated (dug) well. A small number of properties use bottled water brought over for potable use (5%, 3 properties). Although it is known that some properties on the island have rainwater collection (based on field observations, and self-reporting at outreach events), none of the survey respondents indicated that this was their current water source.
Most properties, 81% (48) have their own, independent, water supply, compared to 19% (11) which use a shared source (this category includes respondents within the SSID service area in addition to others with a shared private well).
An onsite well is reported for 75% (44) of properties. Many owners, 38% (18) do not have or are unsure if they have a well construction record 23% (11), compared to 38% (18) who possess a construction record for their well.
Water is used for domestic use (drinking water, hygiene) at 100% of sites, while 45% (27) of respondents indicate use of water for irrigating a garden, and 7% (4) reported use for a vacation rental.
Use of water storage was common, including above or below ground cisterns and pressure tanks 51% (30) and rain barrels

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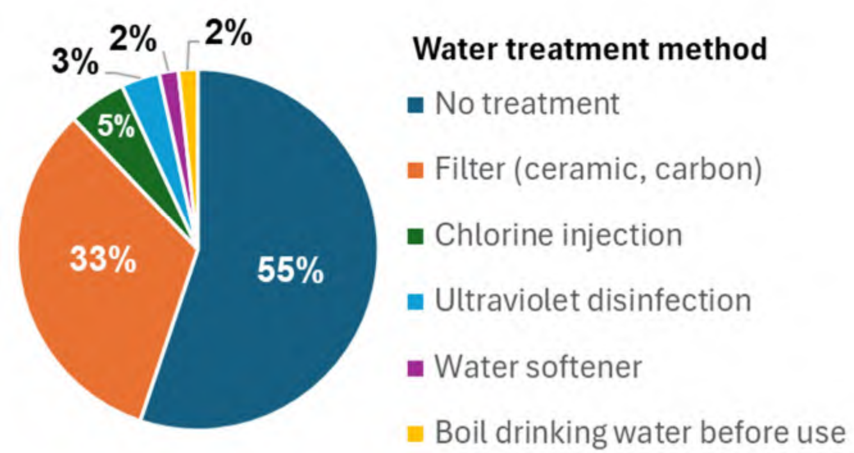

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14% (8 sites) compared to 42% (25) respondents that don’t have water storage.

Most 95% (56) participants report that their well produces sufficient water for their needs. No one reported having seasonally limited supply or running out of water. At one site the well never produced water (dry hole since construction).
Most 71% (42) report that the groundwater is fresh and meets drinking water guidelines. In comparison, 14% (8) report high mineral content, 7% (4) report saline taste or high salinity, 8% report noticing seasonal changes in quality, while 18% (11) are unsure or have never tested the quality. (Participants were allowed to select more than one answer.)
Property owners test their water quality rarely or infrequently: 39% (23) indicated that they had never tested the water quality, while 37% (12%) reported testing the water every 3 to 5 years or less often. Only 4% (2 sites) of sites test the water once or twice per year. Some respondents 12% (7) were aware that SSID test the water monthly. (Participants were allowed to select more than one answer.)
More than half of respondents, 54% (32) do not use any form of water treatment or disinfection. Where used, the most common form of water treatment was filtration (e.g. carbon or ceramic filters including countertop jugs) for 32% (19) properties. Other forms of water treatment reported included chorine injection (5%, 3 sites), ultraviolet disinfection (3%, 2 sites), water softener (2%, 1 site) or boiling drinking water before use (2%, 1 site).

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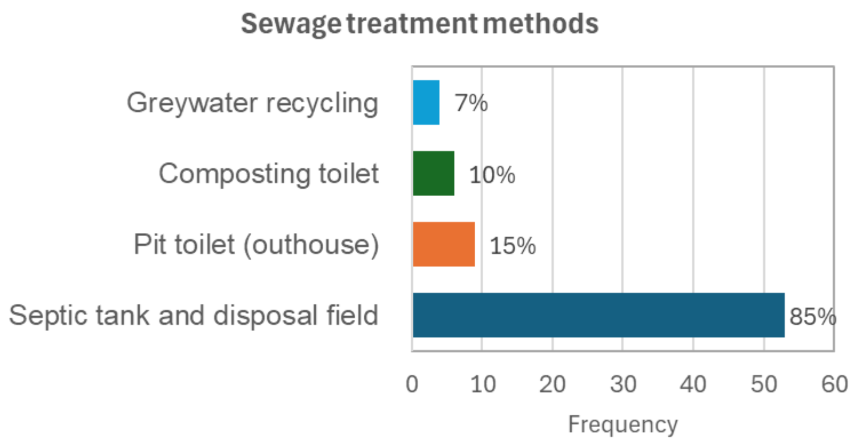
<tr><td>
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<td rowspan="2">Wastewater and sewage

In terms of sanitation, 39% (23) report having a flush toilet compared to 15% (9) that have a pit toilet/outhouse, and 10% (6) that have a composting toilet. The most commonly used method of sewage and wastewater treatment reported was a septic field (90%, 53 sites). At least 7% (4) report using some greywater recycling. (Participants were allowed to select more than one answer.) In most cases the sewage treatment is not shared with any adjacent properties (95%, 56 responses).
Approximately one third (32%, 14) report that they have never maintained their sewage system. Reported maintenance includes pumping solids from the septic tank at a varying frequency, every 3 to 5 years 37% (22 sites), every 8 to 10 years 5% (3 sites), and “when needed” 8% (5 sites).
A total of 28% (17) respondents report that they inspect their wastewater treatment system annually.
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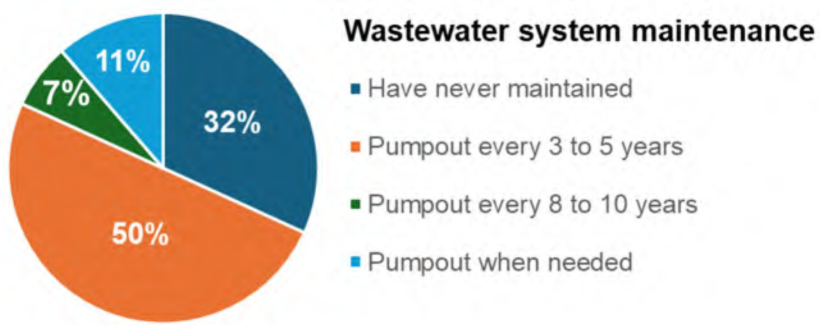
<tr><td>
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The final survey question asked respondents to indicate the level of importance of water related topics (from not important to very important). Table 3 lists the topics identified as very important by the percent and number of respondents. Topics related to aquifer vulnerability and carrying capacity were very important for the greatest number of individuals, followed by household well operation, climate change and sea water intrusion.

Table 3. Water topics ranked as very important by survey respondents

Topic	Response %	Response #
Aquifer vulnerability and groundwater contamination	88	52
Water balance and aquifer carrying capacity	75	44
Household well and water system construction, operation, and maintenance	73	43
Climate change impacts on water resources	68	40
Seawater intrusion	61	36
Wastewater treatment system construction, operation, and maintenance	59	35
Water conservation, recycling, and reuse	56	33
Groundwater connection with coastal ecosystems	47	28
Rural rebate programs and financial supports (e.g. for well repairs, quality testing, water storage, or low water use fixtures)	36	21
Rainwater harvesting	20	12
Abandoned wells	12	7

A previous online survey of island residents and visitors was completed by the Association of the Savary Island Community (ASIC) in August-September 2023 (Association of Savary Island Community, 2023). The ASIC survey included questions related to residency, water sources, liquid and solid waste management practices and use of island amenities. The ASIC survey had 427 responses, 89% of which (380 people) identified as property owners (Association of the Savary Island Community, 2023). Savary Island was reported as the primary residence for 11% of respondents, compared to 79% who indicated that Savary was not their principal residence. Most respondents (84%) reported spending 3-4 weeks on the island during the summer period, while spring and fall respectively 47 to 52% indicated being on the island from 1-2 weeks. The lowest occupancy was reported in winter (51% indicating not being on the island at all, and 37% indicated they were on the island for 1-2 weeks, compared to 5% who were present for the whole winter season. During summer 57% reported a daily average number of people staying on each property in the range of 3-6 people, compared to 14% who indicated a higher occupancy (7-10 people) or 85% (greater than 10 people per property); in comparison most respondents indicate 0-2 residents or visitors per property in the spring, fall and winter. Regarding water sources, 62% of respondents to the ASIC survey reported using a drilled well with an electric pump, 12% reported using sand point well with electric pump, 18% use a communal water supply, 9% bring bottled water, 2% use a well with a hand pump, and 1% collect surface water (i.e. use water from “The Springs”). In terms of sanitary services, 87% of respondents indicated using a flush toilet with a septic system, 20% report using an outhouse or pit latrine, 8% use a composting (bio) toilet on the property, and 1% use a chemical toilet (port-a-potty).

To assess community energy needs, a previous mail distributed survey had also been conducted by BC Hydro that provided information on seasonal occupancy (BC Hydro, 2012, 2011). In total there were 318 respondents, out of 1063 distributed surveys (a 30% response rate). A total of 95% of respondents indicated that they are on the island seasonally, with variable number of days on island from <30 days annually (16%), 30-60 days (42%), 61-100 days (27%), up to >100 days (15%). In comparison 5% identified as year-round residents. The months of greatest occupancy July and August, followed by June and September. While the lowest occupancy was during the months of November to February. The average number of people living at each property was year-round was 1.9 people, compared to the seasonal average of 3.4 people per residence.

Based on comparison of similar questions, the 2024 qRD online survey results were generally consistent with the results of the previous (ASIC and BC Hydro) surveys and are considered broadly representative of practices within the community.

3.4 Field assessment

A field assessment of current information on hydrogeologic conditions on Savary Island was conducted from September 21-26, 2024. Contact with property owners was made at local events including the community planning open house, and farmers market, August 26-27, 2024, through email received following the online project presentation September 11, 2024, through submission of a volunteer request form on the qRD groundwater project website, and through word of mouth. Additional sites were identified in the field via local contacts and neighbourhood canvasing. The intent was to visit as many sites as possible, spatially distributed across different sub-regions or management areas on the island.

Observations of hydrogeologic conditions were collected at a total of 77 sites, including 54 private properties with wells. At each well site information was collected including on the well construction characteristics and site conditions (e.g. coordinates, construction method, diameter, well identification plate number, casing stickup, etc.). Where possible groundwater level was measured using an electronic tape, and the well depth was measured, if unknown or unreported. Field water quality parameters were measured (temperature, conductivity, total dissolved solids, pH and oxidation reduction potential). In situ measurements and vertical downhole profiles of water quality (conductivity) were conducted at 12 sites using a Heron Conductivity plus meter. Water quality samples were collected at selected locations for laboratory analysis. The results of the field assessments and water quality sample results are described within relevant sections below.

4 AQUIFER MODEL

4.1 Wells and aquifers

As of November 2024 there were 90 registered wells in the Groundwater Wells and Aquifers (GWELLS) database on Savary Island ranging from 1 to 55 m (4 to 180 ft) in depth (Province of BC, 2024b). It is known that the provincial database is missing a significant proportion of existing wells on the Island. Since February 2016, when the *Water Sustainability Act* came into effect, submission of well construction records to the database by well drillers became mandatory (Province of BC, 2014). However, prior to this well record submission was voluntary, and compliance has been inconsistent among drilling contractors. It is recognized that the inventory of wells in GWELLS is incomplete, and many unregistered wells exist on the island. In addition, the spatial location of a well on the property is often inaccurate, and wells may be mislocated and shown on the incorrect property, especially for older wells constructed prior to the widespread use of Global Positioning System (GPS) technology.

David Tupper's (1996) study estimated that there were 257 active wells on the island and since then many more lots have been developed. As there are limited alternate sources of water, it is assumed that most developed lots utilize a groundwater source, as reported in the community surveys.

There is one mapped aquifer 834 (AQ834) on Savary in the GWELLS database, re-mapped to amalgamate the lowland area on the western tip of the island, θatɛq (Thah teq, or Indian Point), which was previously differentiated as a separate aquifer 909 (Wei, 2020). The lithology and description of geologic units and interpretation of sedimentary exposures along the coastal bluffs are described in significant detail in Tupper (1996). The aquifer conceptual model is described further below.

4.2 Groundwater management areas

The topography of Savay Island is relatively flat, with slightly higher elevation areas in the central-west and southeastern sections Figure 2. Coastal bluffs up to 50 m high border the southern island. From the southern cliffs on the east island the land slopes towards the north. While on the central-west island the topographic gradient is toward the west and southwest. Thah teq (Indian Point) on the western tip of the island is low lying, with elevation generally less than 5 meters above sea level.

The island was divided into groundwater regions or management areas, shown in Figure 2. The regions were differentiated based on interpretation of the hydrostratigraphic model, differences in well depth, lithology, groundwater elevation, topography, land use, direction of groundwater flow, and vulnerability to different hazards (e.g. saltwater intrusion). The groundwater region boundaries are similar but not identical to areas identified in previous studies, which were primarily based on the district lots from the original subdivision of the island. The identified groundwater regions were used within subsequent analyses including calculating the water balance, summarizing water quality, and identifying management priorities.

The groundwater management areas are as follows:

A. Thah teq: Lowland area on the northwest end of the island.
B. West Island: Meadowlands and partially forested, mostly high-density residential area west of the central conservation area
C. Central Island: Unsubdivided conservation area which separates western and eastern sections of the island
D. Savary Lane: Eastern-central part of the island incorporating area north of and outside of water service area.
E. Savary Shores: Eastern-central part of the island within Savary Shores Improvement District service area.
F. East Island: Eastern section of the island, including fractured bedrock at Mace Point.

4.3 Aquifer conceptualization and hydrostratigraphic model methods

To provide the foundation for hydrogeological analysis, a three-dimensional stratigraphic and conceptual hydrogeologic model (3D model) was developed to summarize the geology, well construction data, and groundwater characteristics on Savary Island. The objective was to develop a 3D model for the island using Leapfrog Geo (Seequent Ltd.) software, including meshes, surfaces, and volumes, in addition to developing a generalized model in Leapfrog Viewer, and interpreted cross-sections to assist with education and interpretation of the physical hydrogeology of the island (i.e. recharge, water table depth, direction of groundwater flow, etc.).

The model inputs included:

- Light Detecting and Range (LiDAR) Bare Earth Topography (1 m resolution) (GeoBC Branch, 2024);
- Bathymetric Maps (10 m resolution) (Fisheries and Oceans Canada, 2025); and
- Drilling logs from the well inventory.

The LiDAR topography, combined with bathymetric maps, was deployed to develop the primary surfaces for the 3D Model. These sources proved useful for delineating the contact between unconsolidated (Cowichan Head Formation) and bedrock units exposed offshore, for example, based on characteristics of the sea floor. The LiDAR topography was overlaid with a recent satellite image, enabling the delineation of the contact between the Quadra Sand and the underlying Cowichan Head Formation based on visual differences in sediment characteristics e.g. Cowichan Head representing a generally courser unit including boulders and gravel.

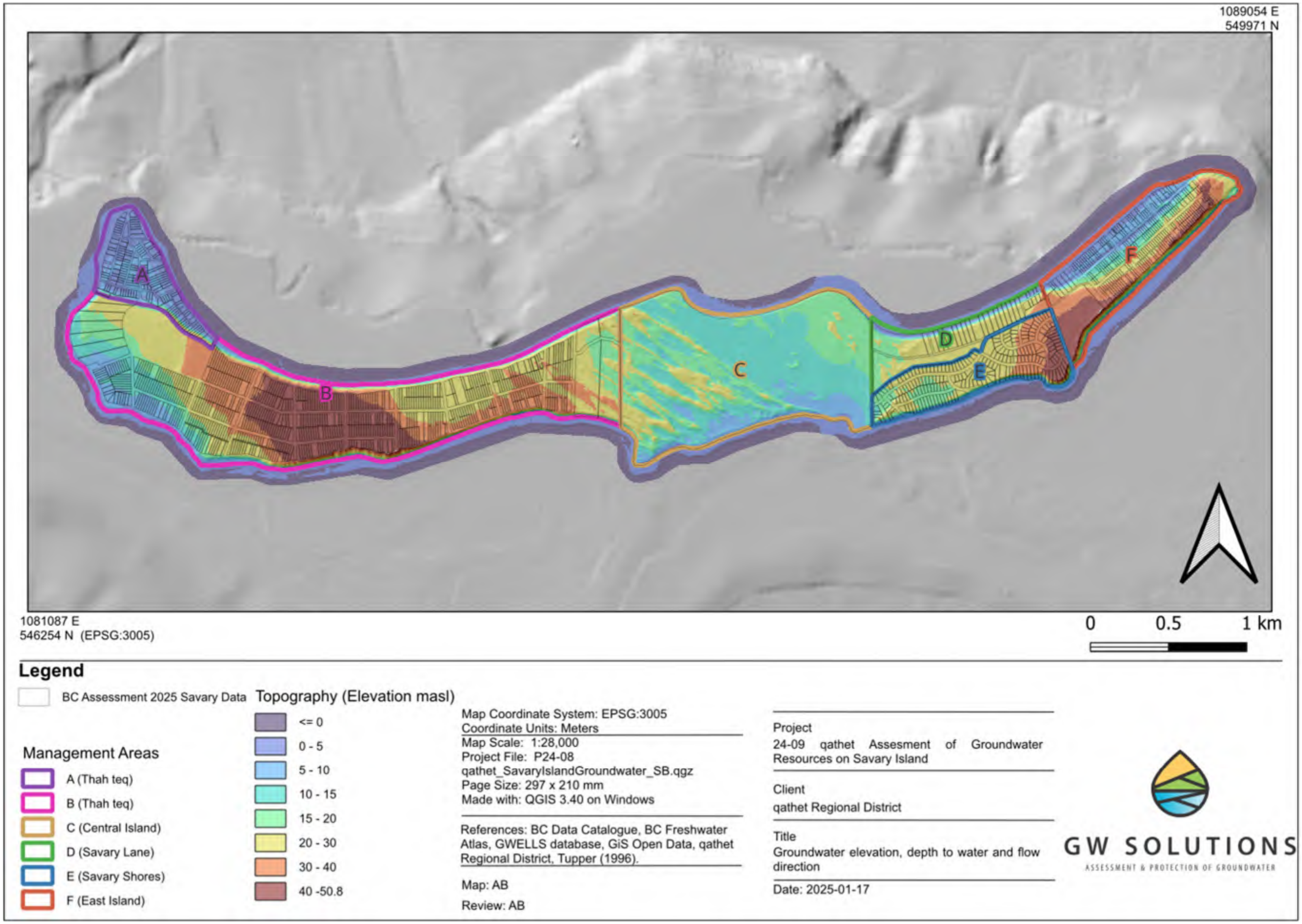


Figure 2. Savary Island topography and groundwater regions

4.3.1 Well inventory

The Province maintains the GWELLS database where groundwater well information is stored (Province of BC, 2024a). Records of registered wells within the GWELLS database were utilized to develop the subsurface stratigraphy of the geospatial model. The GWELLS database includes lithology tables useful for describing wells constructed in unconsolidated (sand and gravel) materials. The various units encountered during drilling help define aquifers (water-bearing formations) and aquitards (low permeability, confining units). Detailed description of bedrock type (lithologies) is less consistently recorded within the database. Groundwater presence and movement in bedrock aquifers depends on the occurrence, width and connectivity of bedrock fractures, and fracture zones. None of the inventoried wells on Savary Island encountered bedrock.

In addition to GWELLS, the geospatial model incorporated the inventory of wells and springs from the previous hydrogeologic study of Savary Island (Tupper, 1996). In total 85 drilled wells, 44 dug wells, 42 sand points, and 4 springs were inventoried by Tupper, including several wells also registered in GWELLS. Unfortunately, this study did not include spatial coordinates or groundwater level measurements apart from for four wells. Much effort was employed to spatially locate these historically surveyed wells based on the District and lot numbers and comparing the previous and new cadastral (parcel) maps. Where it was possible to cross-reference reported well locations spatially, the well characteristics documented in Tupper’s study were used to refine the geological units in 3D model (128 wells from the previous study were included in the model). Nine properties/wells inventoried by Tupper were also included in the 2024 field survey.

In September 2024, GW Solutions staff surveyed and collected detailed information regarding 55 groundwater sites, 12 of which were wells recorded in the GWELLS database. Field observations (groundwater levels, well depth, and in situ water quality measurements) were used in the model along with the other sources to build the groundwater level surface and define the aquifer extent. Well records for field surveyed sites were requested from local drilling companies, and 11 additional construction records were provided reports (eight from Canwest Well Drilling Ltd and three from Red Williams Well Drilling Ltd.). Results of the field survey are discussed further in sections 7 and 8.

Based on the 2024 BC Assessment land use data (BC Assessment, 2024) it was inferred that developed (non-vacant) residential properties on Savary Island located outside of the SSID Service Area are likely supplied by a well. Therefore “inferred” wells were added to the model on these lots. The inferred well location on each lot was approximated by comparing the location of wells on adjacent lots. For example, wells are commonly sited along driveways or near the edge of the closest accessible roadway. The depths of the inferred wells were predicted according to the depth of wells on adjacent properties, and the depth of the regional groundwater table interpolated from field measurements and reported water levels in existing drilling records. The land use datasets are discussed further in section 5.4.

GW Solutions extracted, cleaned, and standardized all the well information from GWELLS, Tupper's (1996) study, the 2024 field survey. In total, nearly 660 wells were known or inferred on Savary Island and included within the 3D Model, including 233 (unique) registered or field verified wells. A map of the well inventory and inferred well locations is shown in Figure 3.

Table 4. Well inventory summary

Data source	Number of wells	Comment
GWELLS database	90	
Tupper (1996)	128	Includes 17 wells registered in GWELLS and 9 wells surveyed by GW Solutions in 2024
GW Solutions field survey 2024	55	Includes 12 wells registered in GWELLS
Inferred well locations	426	Based on 2024 land use categories
Total	**659**	

The completed well depth indicates at what depth sufficient cumulative yield (water production) was obtained from a well during its construction. From the population of 659 wells:

- 47% are less than 30 m (100 feet) deep;
- 47% are between 30 and 60 m (100 and 200 feet) deep; and
- 6% are from 60 to a maximum of 90 m (300 feet) deep.

GW Solutions used geological contacts mapped at the ground surface, in conjunction with stratigraphic contacts interpreted from the well construction records, to interpret the location of layers with lower permeability, including silts, clay, and till, and to model the island aquifers in 3D.

4.3.2 Groundwater levels

Groundwater level measurements were sourced from the GWELLS database, the Groundwater Level Data Interactive Map (Ministry of Environment and Climate Change Strategy, 2024), and the September 2024 field survey. Additional unpublished water level data were also provided by the province for the observation well on DL 1375 (central island). These measurements were used to construct the regional groundwater surface, water table or top of the main island aquifer. It is important to note that the continuous (observation well) and point-in-time measurements were collected during different seasons, and over many different years, while the modelled groundwater level represents an interpolated average over the period of recorded data.

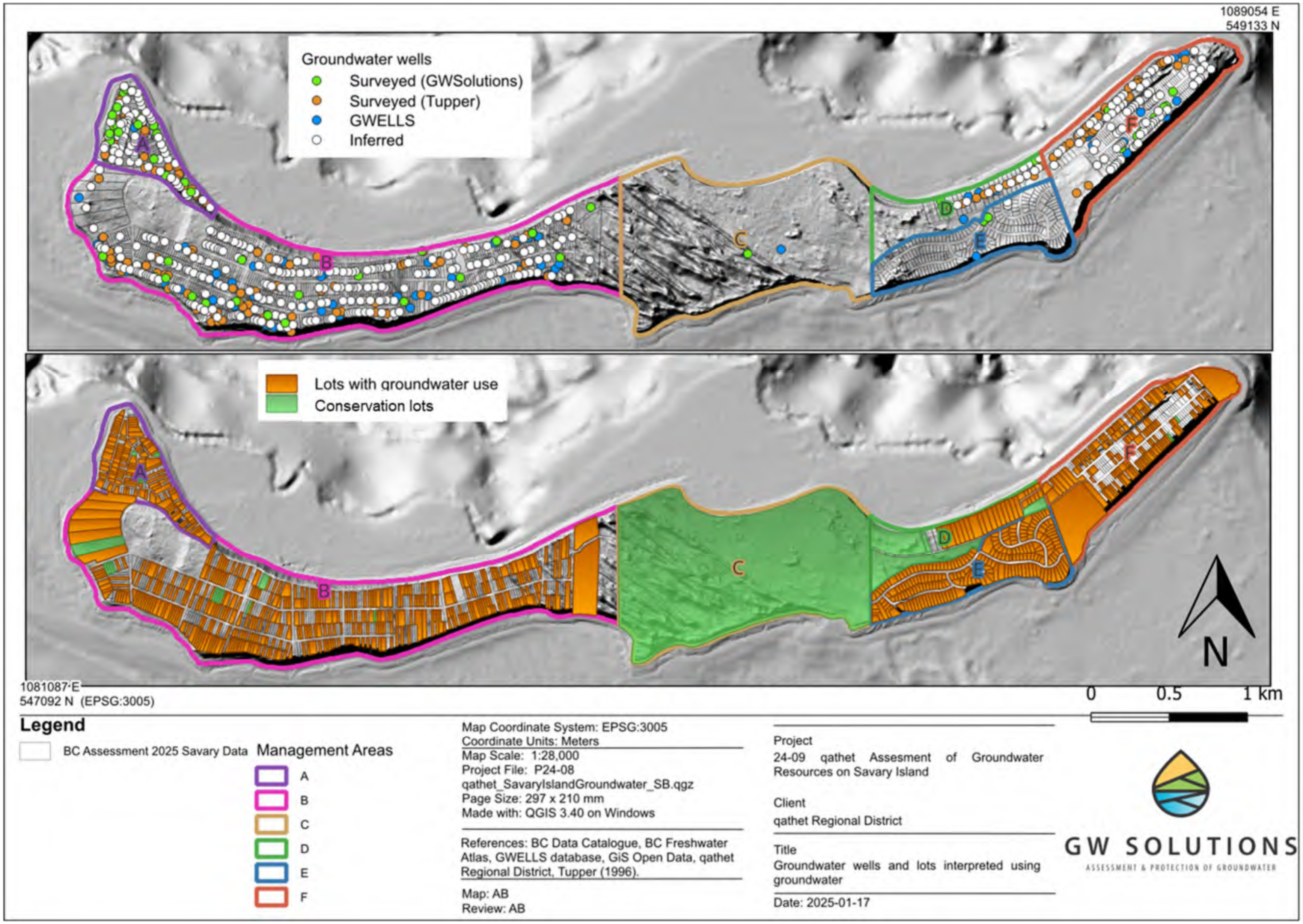


Figure 3. Wells and lots with inferred groundwater use on Savary Island.

4.3.3 Springs

Freshwater springs were a historical source of drinking water for island residents and visitors thus these sources were included in the field inventory. Qaye qwun Spring on the north side of the island is the only spring still reported as in use by a handful of residents who haul drinking water from this source. Neilsen Spring on the south side is overgrown, inaccessible and no longer in use as a water supply source (as reported by water licensees), however it may be a source of water for wildlife, as there is a deer trail down the slope near the spring and river otters were observed in the area during the field assessment. Other spring sources were inaccessible or not observable, and these sources are not considered a significant source of current water supply by islanders, who are largely reliant on drilled wells.

4.4 Hydrostratigraphic conceptual model results and interpretation

On overview of the Savary Island hydrostratigraphic Leapfrog model is shown in Figure 4. The model was used to interpret the depth of aquifer units on the island, to identify the locations of low permeability sedimentary layers that influence groundwater recharge and provide aquifer protection. The geospatial model was also used to develop interpretive maps and analyses of groundwater conditions on the island, including evaluating the direction of groundwater flow, the depth and elevation of the water table, aquifer vulnerability, and depth of the transition zone between freshwater and seawater.

4.4.1 Stratigraphy

The main stratigraphic units present on Savary Island are described in Table 5.

Table 5. Savary Island stratigraphy and hydrogeologic importance

Formation name	Origin and age	Description	Hydrogeologic importance
Salish sediments	Modern deposits modified through processes (<10,000 years old)	Soil and sands, including dunes, and beach deposits. Locally includes soil, peat, organics, loose, brown and dry sand.	Soil layers are generally thin, with high permeability which allows rapid infiltration of precipitation.
Capilano-Vashon sediments	Fluvial and glaciofluvial deposits formed during and following the Fraser Glaciation (18,000-12,000 years old)	Capilano sediments consist of post-glacial meltwater materials deposited during the period of higher sea level following the Fraser Glaciation. These can include alluvial and colluvial sands, gravels, and glaciomarine to marine silt, sand and clay. Interpreted mainly as materials overlying the “till” layers, if present.	Coarser grained sandy to gravel Capilano sediments form unconsolidated shallow deposits in which perched groundwater conditions may occur locally or seasonally. Though not consistently saturated, water held in sand lenses or zones overlying low permeability layers can be a source of

Formation name	Origin and age	Description	Hydrogeologic importance
		Vashon sediments generally consist of lower permeability materials including, silt, clay and till (sandy, and clay rich poorly sorted dense layers). described as “till” in well logs, interpreted as dense, consolidated mixed sediments containing sand, silt and clay, with gravel.	water for shallow wells and spring discharge at the coast. Vashon sediments form low permeability confining layers which overlie the principal Quadra Sand aquifer. The thickness and presence of confining layers is spatially variable, with windows and areas where the sediments are thin or absent.
Quadra Sand	Outwash deposits formed in front of advancing glaciers during the Fraser Glaciation (28,000 to 15,000 years ago)	Where documented in the Vancouver Island and coastal regions Quadra Sand includes thick deposits of well sorted fine to coarse sand with minor gravel and silt, and thin discontinuous beds of silt and clayey sand. Generally described in well logs as light brown or grey fine, medium to coarse grained sand, silty sand, or laminated (layered) sand.	Quadra Sand forms the main regional aquifer on Savary Island in which most drilled wells are constructed.
Cowichan Head Formation	Formed during the Olympia non-glacial interval (23,000 – 41,000 years ago) before the Fraser Glaciation	Consists of river deposits (fluvial, estuarine), and marine sediments including clay, silt, sand and gravel. These are the deepest sedimentary layers that occur on Savary, below Quadra Sand, believed to be intercepted by the deep well in area C at the centre of the island, with materials described as compact very fine sand and silt.	Where present, occurs at or below sea level overlying bedrock. Few wells intercept this layer. Due to the depth and lower permeability, it is not an important groundwater source for the island.
Bedrock	Intrusive igneous rocks (granodiorite) (Interpreted as associated with Late Jurassic to Early Cretaceous, (97-157 million years old) unit mapped north of the island)	Bedrock is below sea level and not exposed on Savary, except at Mace Point at the eastern tip of the island where large blocky outcrops can be observed.	No registered wells are constructed in bedrock. In general water availability and productivity in the bedrock is anticipated to be low.

References: (Bednarski, 2015; Biln, 2017; Hicock and Armstrong, 1983; Clague, 1981; Cui et al., 2019).

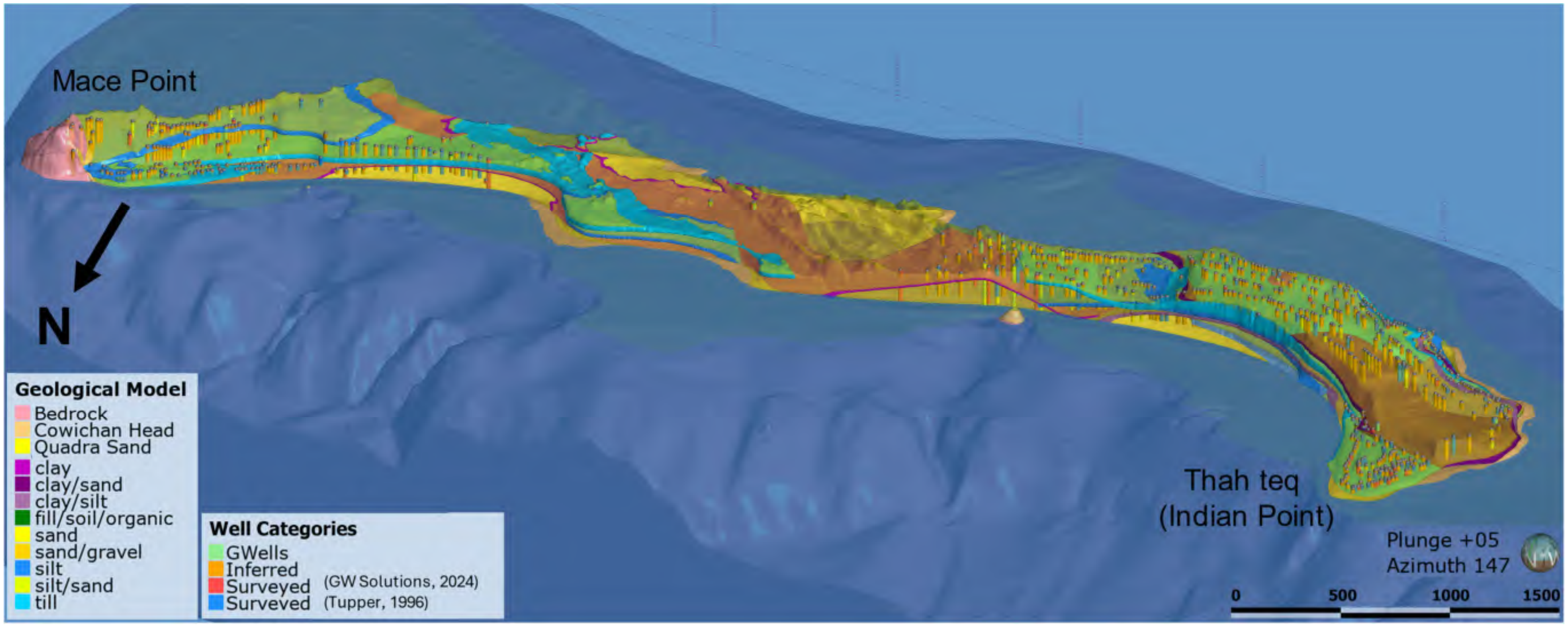


Figure 4. Conceptual overview of the Savary Island 3D hydrostratigraphic model showing wells and major geologic materials.

4.4.2 Aquifer interpretation

The hydrostratigraphic model allows the user to visually examine the sedimentary units and structures at any location on the island. The model was also used to interpret the depth and distribution of surfaces such as aquifer confining layers, or depth to groundwater table. The following observations were made with respect to hydrogeology of the island based on the 3D model.

Groundwater depth and flow direction

Two maps illustrating measured and interpolated groundwater levels on Savary Island are shown in Figure 5. The upper figure shows the groundwater level in meters below ground (mbg), which varies from less than 3 mbg at Thah teq on the west island, and along the beaches, up to 52 m below ground in the highest elevation area on the west central island (Area B), and southeast ridge (Area E). The lower image in Figure 5 shows the groundwater elevation in meters above sea level (masl) and blue arrows illustrating the direction of groundwater. From this figure we observe that the groundwater table is a very shallow lens (<3 m above sea level) over most of the island. The importance of this to seawater intrusion hazard and its prevention is discussed further in section 9.

Cross-sections

One can further conceptualize the subsurface of the island by making a visual slice or cross-section through the model. Figure 6 shows the locations of cross-section developed from the 3D model. The cross-sections depict the different geological units using a simplified colour scheme, with permeable units including the Capilano-Vashon sediments and Quadra Sand represented in yellow, low permeability units including silt, clay or till represented in grey, underlying stratigraphic unit, Cowichan Head formation, shown in orange, and igneous bedrock represented in a pink colour. The cross-sections also illustrate the inventory of wells along each cross-section line, which included wells projected up to 200 meters distance. Wells are identified by their Well Database Tag Number (from GWELLS), the Tupper (1996) location number, or the GWS 2024 field inventory site number which are identified by water management area (e.g., A1, B8, etc.). The interpolated groundwater table is shown by a dotted blue line, and water level measurements (inverted blue triangles) are also presented. Figure 7 presents an example cross-section used to interpret the hydrogeology of Savary Island. Cross-sections for representative areas with interpretations and results of the hydrogeologic assessment are presented and discussed in Section 10. Additional hydrogeological cross sections are included in Appendix B.

Perched Aquifers

Historically, water supply within some areas such as Area B (Meadowlands) included shallow excavated wells. These wells likely intercepted groundwater in sand and gravel seams locally perched above the lower permeability till, silt and clay layers. Tupper (1996) reported shallow dug wells within perched aquifers but even at the time of his assessment around 40% were not in active use. During the 2024 field inventory, only three dug wells were observed, one in Area A and two in Area D, and it is likely that these “perched” aquifers and dug wells are not a major source of water supply on the island, having been replaced in most areas by drilled wells constructed into the deeper regional aquifer.

Shallow groundwater flow in sandy zones overlying lower permeability silt and clay confining layers have previously been linked with the discharge to coastal springs. On the southwest island, shoreline vegetation species and growth patterns suggested wetter zones within areas of previously documented springs (e.g. Meadow Spring and Neilsen Spring) but no visible flow was observed in autumn 2024. On the north side of the island Qaye qwun Spring had visible flow (3.8 L/minute, 1 US gallon/minute) which emerged from a narrow PVC pile driven into the cliffside above a clay-rich layer.

Quadra Sand aquifer

The Quadra Sand formation is the main source of groundwater on Savary Island and is comprised of thick, well sorted sand layers, with interbedded less permeable layers including silt, clay or till. Low permeability layers described as till and interpreted as dense, poorly sorted clay, silt, sand and gravel layers are discontinuous or variably present above the Quadra Sand. Most wells intercept the deeper regional aquifer that extends across Savary Island. While the regional aquifer is considered partially confined lithologically, due to the presence of these low permeability confining materials, in terms of hydraulic properties, the aquifer is mainly unconfined, and the water table defines the top of the aquifer.

It was believed that only one well (Well Tag Number (WTN) 107896 in the central conservation area) penetrated through the Quadra Sand and reached the Cowichan Head Formation. However, due to a lack of data, the depths of the contacts between the Quadra Sand and Cowichan Head Formation, and the contact between the Cowichan Head Formation and the underlying bedrock, remain ambiguous. The material properties of the Cowichan Head Formation in this locale are also poorly understood. No wells are constructed on the island that reach the bedrock layer. Bedrock is locally exposed on the east island at Mace Point, but there were not reported well logs from this area. Anecdotally, unsuccessful wells or dry holes have been attempted in this area in the past.

Thah teq (Indian Point) Aquifer

Although amalgamated with the regional Quadra Sand aquifer (AQ834) in recent provincial mapping (Wei, 2020), the hydrogeologic conditions on Thah teq at the western tip of the island differ in comparison to other areas. Groundwater levels are much shallower below ground, and surficial sedimentary materials consist mainly of beach (marine) unconsolidated sand deposits. Shallow (<6 metres or 20 ft deep) sand point wells with hand pumps or jet pumps are still in widespread use. There may be a trend toward replacing the sand points, as numerous newer drilled wells were observed in the area. A thin silt or till layer is interpreted to be present below loose, beach-type sediments based on a limited number of well construction records, however the sand points appear mainly to be installed within sandy materials above this layer (i.e. in a shallow unconfined aquifer). This area is extremely vulnerable to both contamination from land use and seawater intrusion, necessitating careful planning and management to protect the freshwater resource.

4.4.3 Model limitations

The following limitations and potential sources of error should be considered when interpreting the 3D model and results:

- Well construction information (lithology) is sparse or unavailable for some areas. One example is Area C in the central island, which had only two well records with which to develop the model layers. Another example is near Mace Point on the east island, which has lower level of development and fewer known wells.

- Well records vary in spatial accuracy. Some records may be mislocated on the wrong property, especially for older wells constructed prior to widespread use of field GPS units.
- Many of the field verified wells lack well construction records with detailed lithology (i.e., only basic information about the well was known, such as water level and/or well depth).
- Well drillers describe and interpret lithological materials in varied ways. For example, one person may record a material as “till” but it could also be described as compact, silty sand and gravel. Similarly, fine silt and clay appear similar in the field when discharged as drill cuttings. During the well lithology standardization, the material descriptions were kept as close as possible to the original description from the well record, to avoid bias in re-interpreting the material type.
- The subsurface stratigraphy including depths and thicknesses of low permeability sediments (clay, silt, till) is complex and challenging to represent in a simplified model. As such, the model zones with low permeability materials such as till, silt and clay should be considered qualitative, i.e. indicating presence/absence and relative thickness, rather than accurately defined.
- Groundwater levels were measured during different seasons and over many years. However, most of the measurements used to interpolate the groundwater surface were collected recently, during the September 2024 field survey, or were obtained from long-term monitoring locations like the Provincial Observation Wells.

Despite the above limitations, the model is useful to describe and understand hydrogeologic conditions and processes within the Savary Island aquifers.

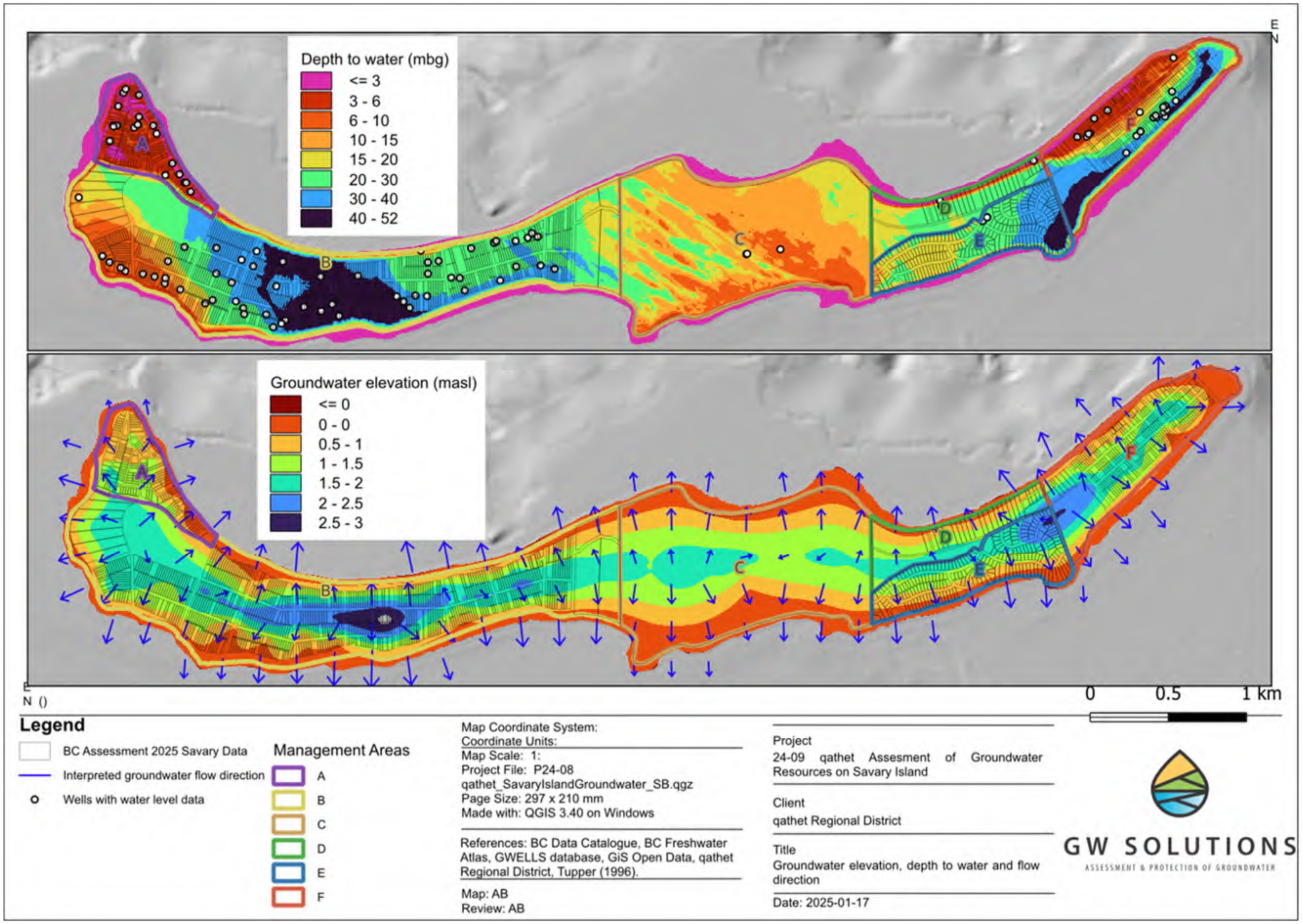


Figure 5. Groundwater levels and flow direction

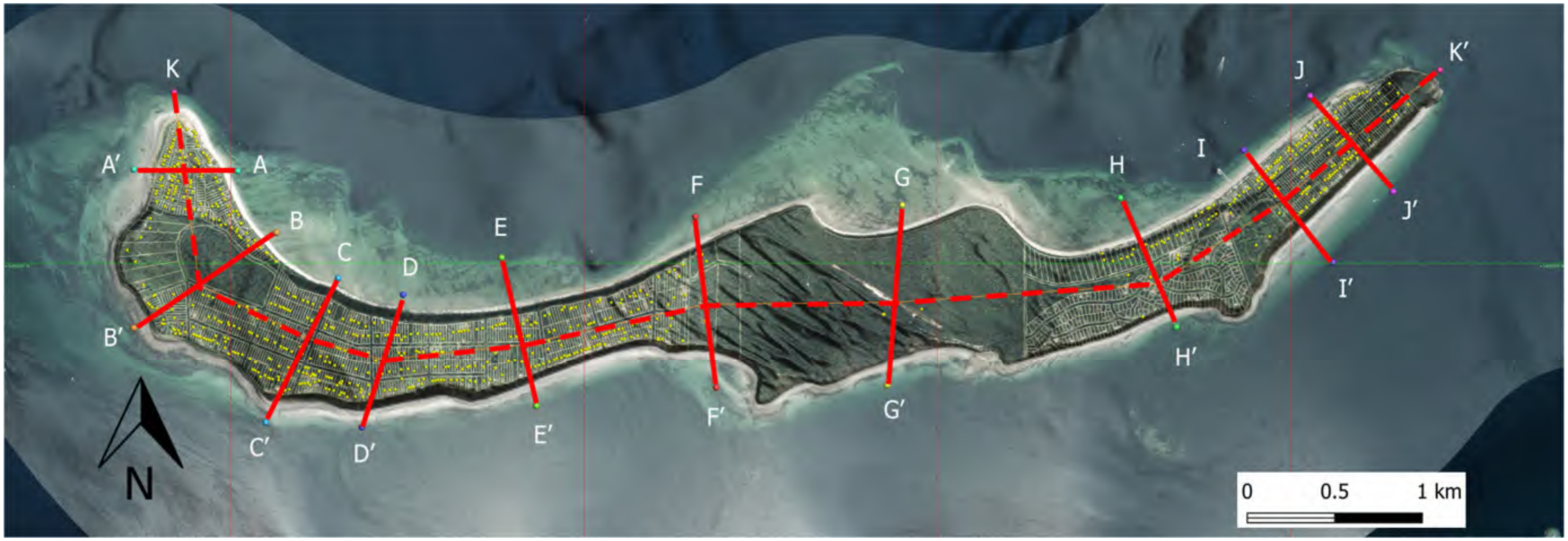


Figure 6. Plan map of cross-sections derived from the 3D model; corresponding cross sections are detailed in Appendix B.

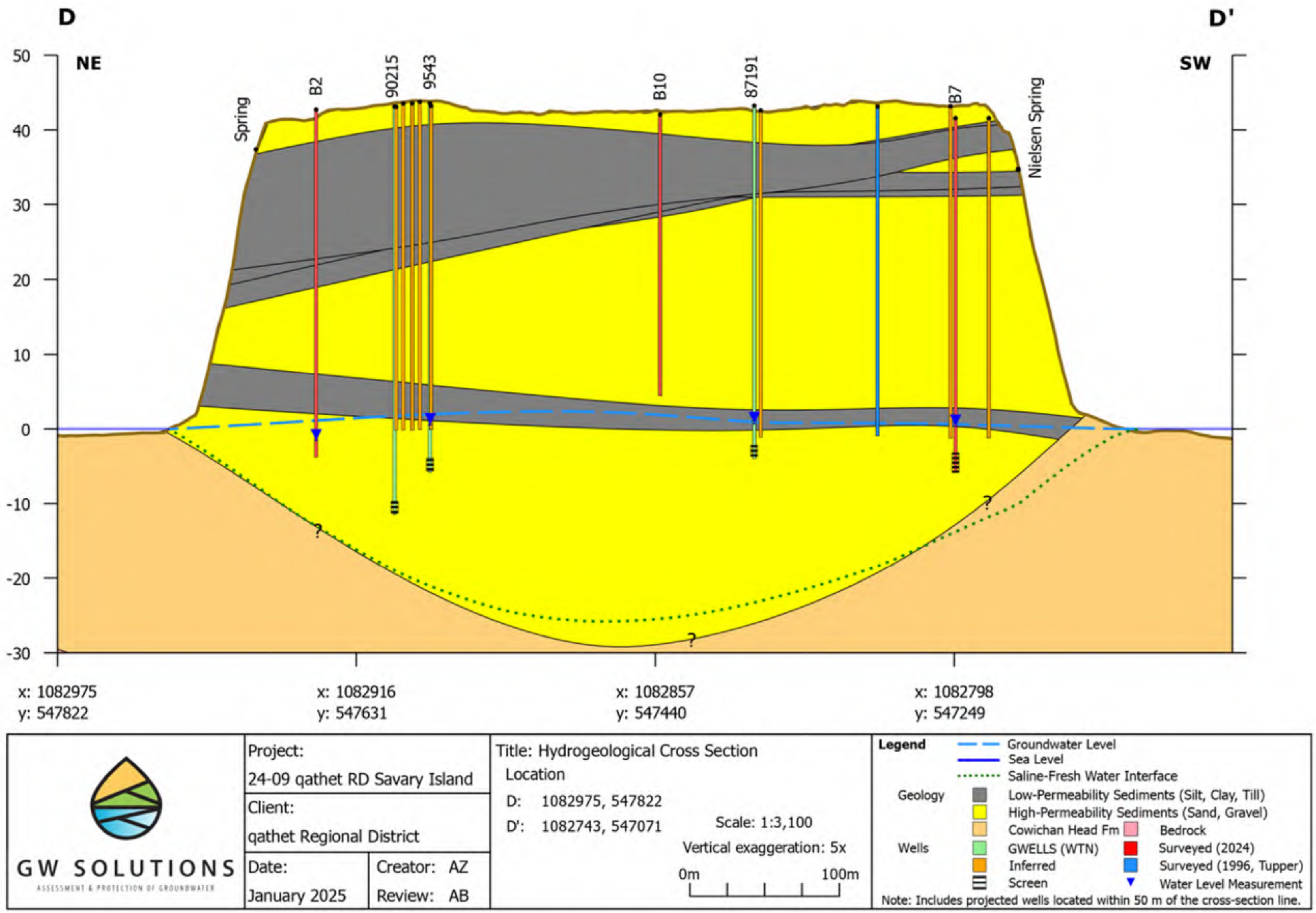


Figure 7. Savary Island example cross-section D-D' Groundwater Management Area B, West Island)

4.5 Groundwater monitoring

Long-term groundwater monitoring data were available for three sites on Savary Island, currently operated by staff from the provincial Ministry of Environment and Parks as part of the Provincial Groundwater Observation Well Network (PGOWN) (Ministry of Environment, 2024). A summary of the observation well characteristics is included in Table 6. OW408 (WTN44210) is located within the Savary Shores Improvement District (SSID) well field, approximately 15 m from SSID Well 1, OW500 (WTN107896) is located within Area C at the centre of the island (District lot 1375), and OW511 (WTN128292) is located in Area A, the Thah teq (Indian Point) area. Each site is equipped with a continuous logger which monitors water level and temperature at an hourly frequency. The data from OW408 and OW511 are published on the provincial Groundwater Level Interactive and Aquarius data portals (Ministry of Environment, 2024). OW511 provides data in real-time, updated daily via satellite telemetry. Data from OW500 are currently being collected by ENV staff but not published.

Table 6. Long-term groundwater monitoring locations

Obs Well Number	Well (Database) Tag Number	Well ID Plate Number	Year drilled	External casing diameter (inches)	Screen diameter (inches)	Screen diameter (m)	Total Depth (m bgs)	Depth well screen (m bgs)	Casing stickup (m)	Surveyed elevation (masl)	Monitoring period
OW408	44210	20863	1970	6	1.25	0.032	27.74	26.2-27.7	0.60	22.7	2011-Sept -present
OW500	107896	53718	1994	10	8	0.203	52.43	28.0-31.1 35.1-36.6 41.5-44.5	0.51	15.9	2019-Oct -present
OW511	128292	63996	2022	6	6	0.152	9.14	7.3-9.1	0.87	4.66	2022-Nov -present (telemetry)

References: (Livingston, 1970; Pacific Hydrology Consultants, 1995; Province of BC, 2024a). Elevation of the ground surface at the well was surveyed for ENV in September 2019 and January 2023 by Polaris Land Surveying.

A hydrograph showing groundwater elevation over time in the observation wells is shown in Figure 8. The data were filtered to show daily maximum elevations, which reduces the observed effects of adjacent well pumping and tidal interference on the groundwater levels. OW408 has been monitored for the longest period and shows a stable long-term trend since 2011. Groundwater levels in coastal BC vary seasonally according to the amount of rainfall, with the shallowest (highest) groundwater levels observed in the winter period (December-January), and deepest (lowest) groundwater levels observed in the summer and early fall (August-September). Over the longer term groundwater conditions are also impacted by multi-year climatic cycles such as the Pacific Decadal Oscillation (PDO)(Allen et al., 2014). On Savary, seasonally OW408 fluctuates by approximately 0.5 m between winter and summer water levels; in comparison, groundwater levels in OW500 and OW511 fluctuate by roughly 0.8 m annually.

Figure 9 shows the level of OW408 plotted in comparison to precipitation and tide level. Precipitation was measured at the Comox Airport (Environment Canada Station 1021830) located 27 km to the southwest, and the tide level was measured at Campbell River (Fisheries and Oceans Canada, Station 08074) 35 km to the northwest (Environment and Canada, 2024; Fisheries and Oceans Canada, 2024). Tidal predictions at Lund (DFO Station 07885) follow a similar pattern and magnitude as measured tide heights at Campbell River but are approximately one hour later. Comox Airport climate station was similarly chosen as the reference station for analysis, as it has the most complete long-term dataset compared to other nearby stations.

Tidal fluctuations range up to 4 m over an annual period (Figure 9). Groundwater levels in OW408 respond to precipitation inputs, and peak winter groundwater levels are higher in years with higher precipitation. Summer water levels OW408 are affected by groundwater pumping in the SSID well field, with slightly deeper levels exhibited in years with higher water use (e.g. 2020 and 2021) (SSID water use is presented in Section 5.4.3).

Daily groundwater levels in all observation wells are influenced by tidal fluctuation, however the magnitude of the effect and the lag time between tidal cycles and groundwater response varies depending on the location. For example, Figure 10 shows the groundwater levels in Savary Island observation wells in comparison to measured tidal level over a period of four days. The tide levels exhibit two daily maxima and two daily minima of different magnitude. During this period, in OW511 (closest to shore and screened into shallower sediments) groundwater levels fluctuated by <0.10 m daily and exhibited one daily maxima and minima, with a lag time greater than 12 hours between tide level fluctuation and groundwater level response. OW500 is screened much deeper below sea level (two screens, up to -28.6 masl), and groundwater levels fluctuated by approximately 0.10 m daily, and exhibited a pattern correlated to sea level flux, with two minima and two maxima daily and a less than 6-hour lag time. In OW408 which that has a lower permeability drive-point screen driven into compact sand, groundwater levels exhibited two minima and maxima, fluctuated up to 0.2 m daily, with a lag time of approximately 12 hours. The observation well response during the period shown was also influenced by precipitation.

Based on this analysis, it is inferred that all wells on Savary Island are influenced by tidal fluctuation to a variable degree depending on the distance from the coast and depth of construction.

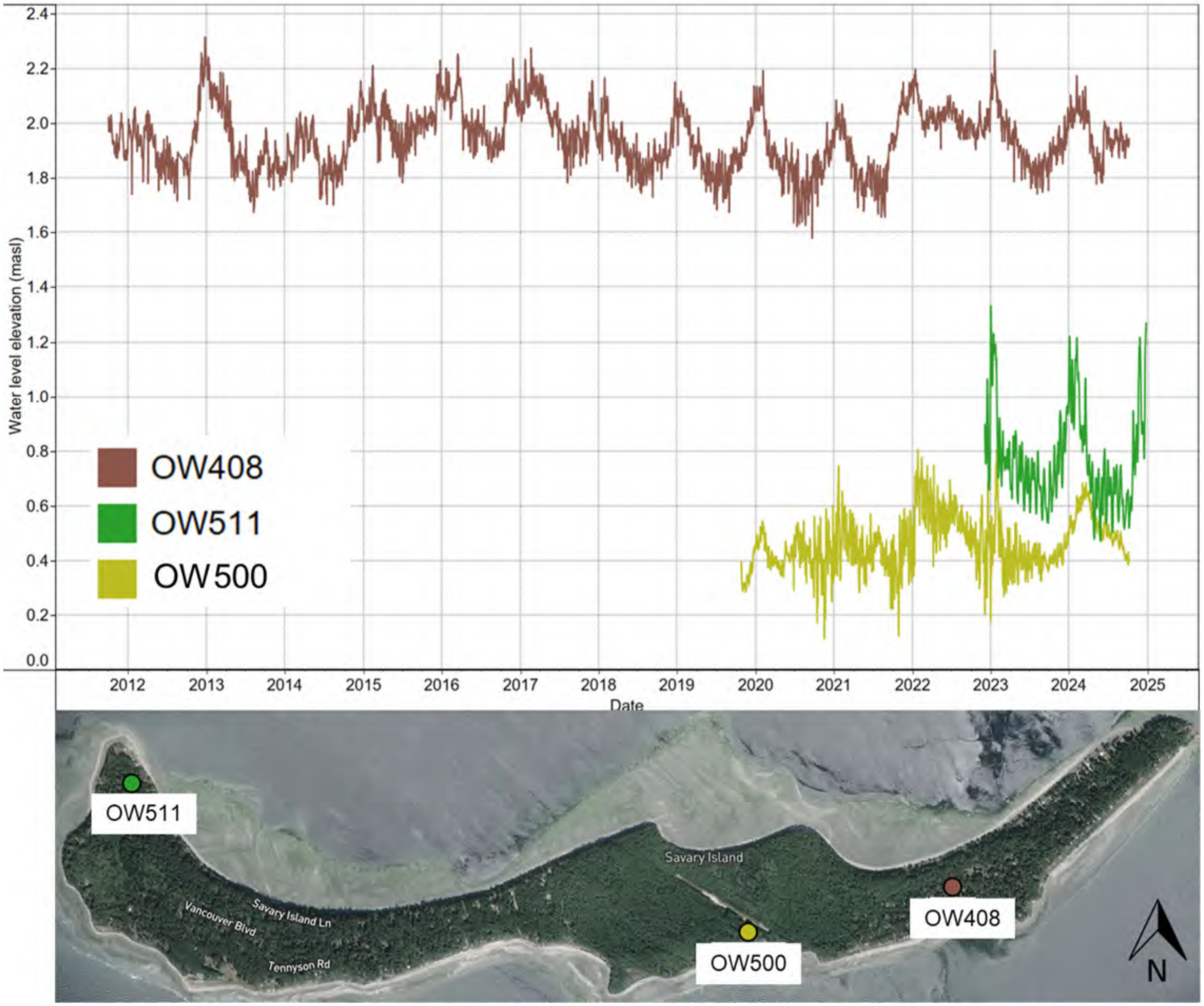


Figure 8. Groundwater elevation (meters above sea level) in Observation Wells OW408, OW411 and OW500.

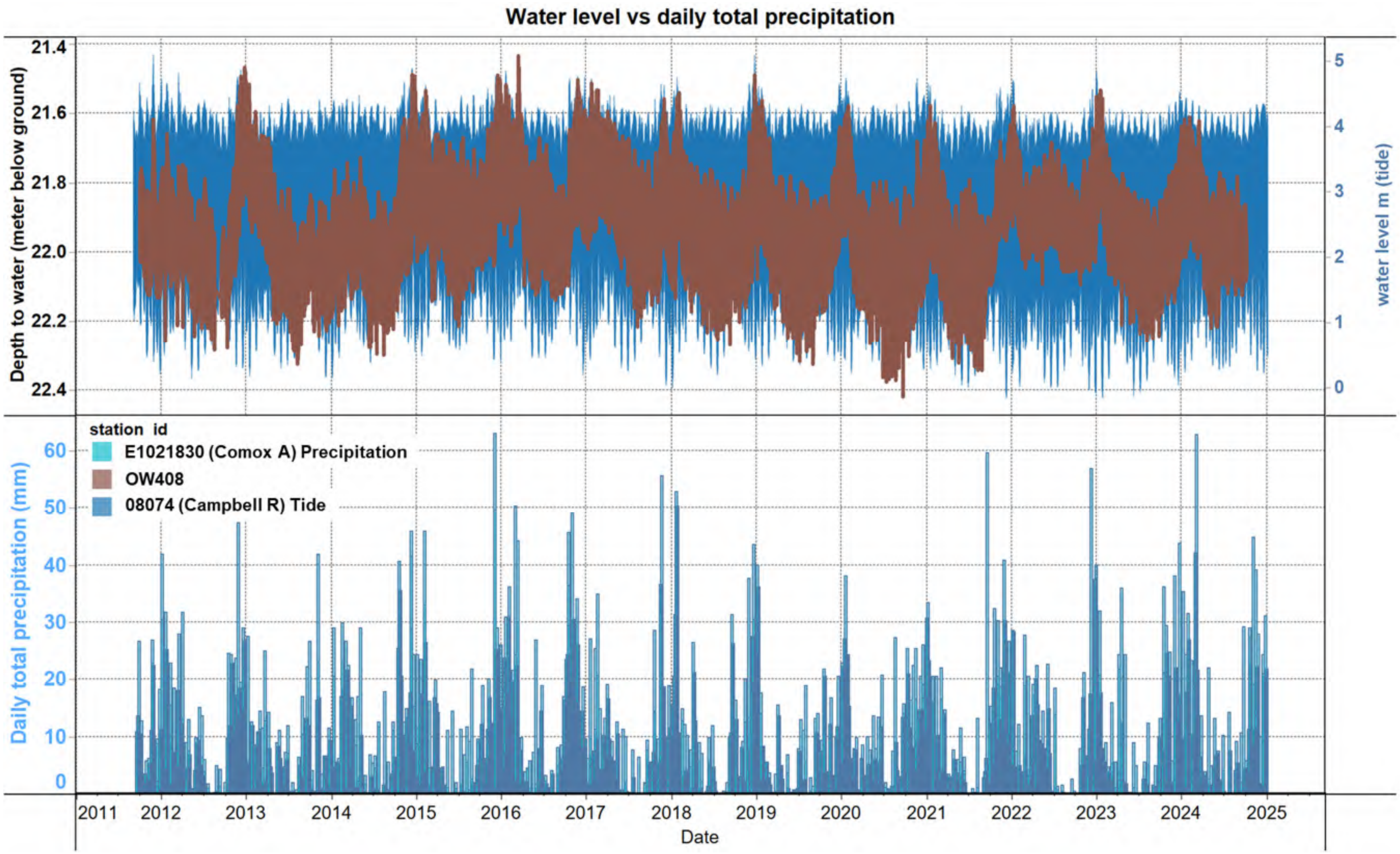


Figure 9. OW408 groundwater level compared to tide level (Campbell River) & daily precipitation (Comox Airport) 2011-2024.

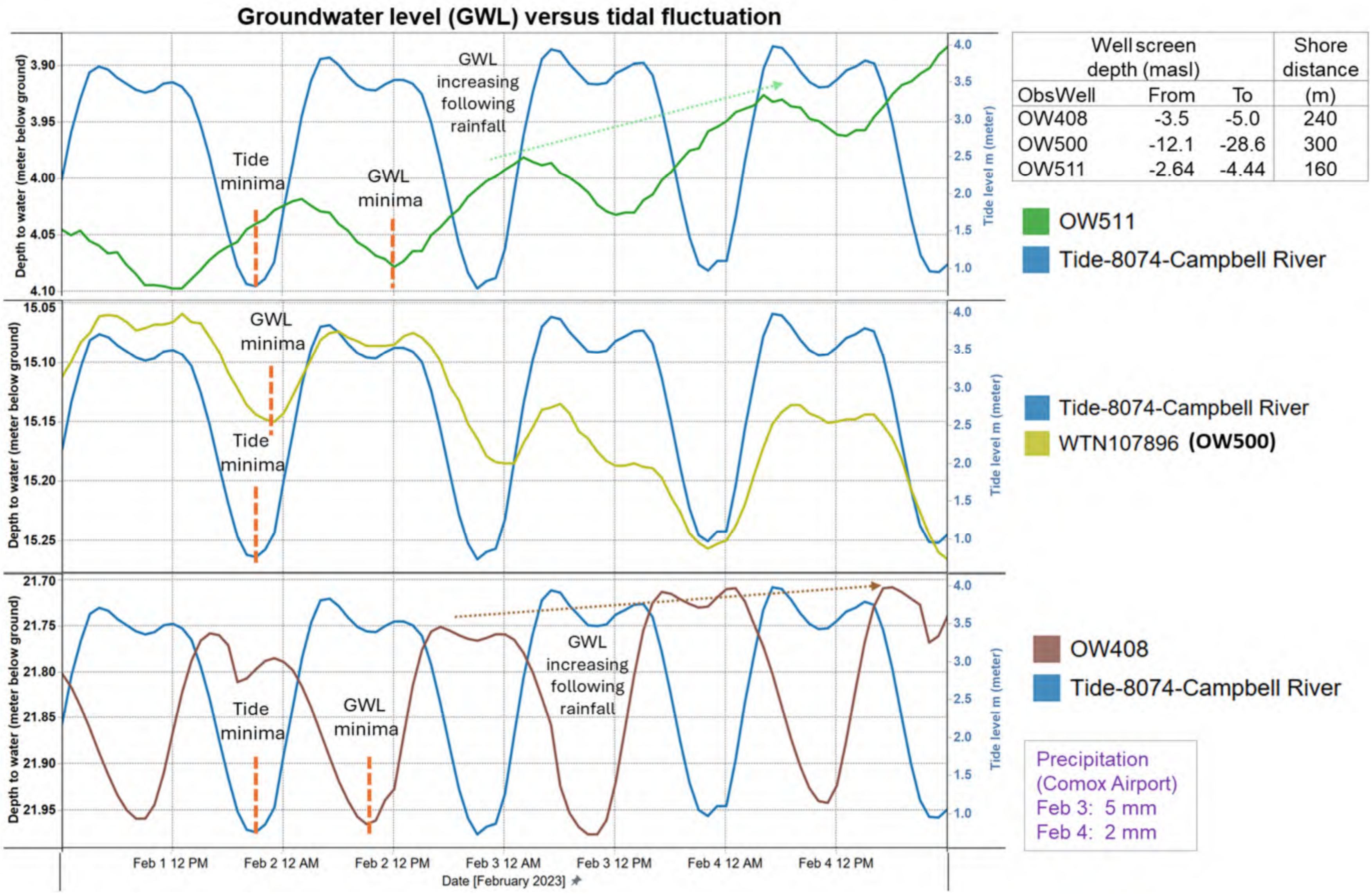


Figure 10. Groundwater level vs tidal fluctuation in OW511, WTN 107896 (OW500) and OW408.

5 WATER BALANCE MODEL

A gridded water balance model was developed to assess groundwater availability on Savary Island. The model considered inputs including precipitation, temperature, solar radiation and soil available water capacity that affect evapotranspiration and soil moisture surplus, factors which influence the availability of water for groundwater recharge. A schematic representing the parameter inputs and outputs for development of the water balance model is shown in Figure 11.

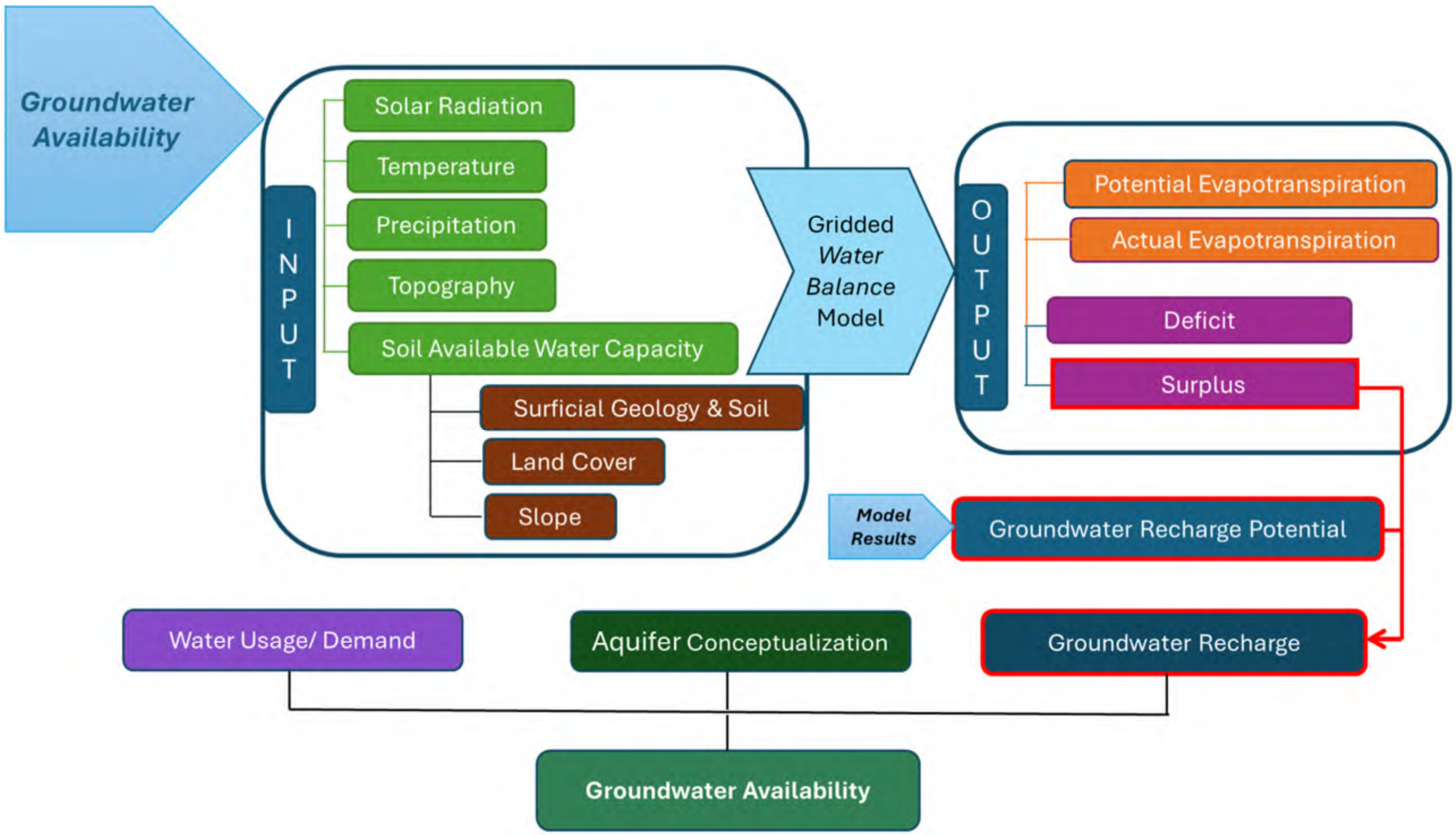


Figure 11. Water balance inputs and methodology to assess groundwater availability on Savary Island.

5.1 Gridded Water Balance Model Approach

To estimate the water balance, the study used GW Solutions R-code implemented from the ArcGIS-based model developed by James Dyer from the University of Ohio (Dyer, 2021, 2019). The model estimates monthly potential evapotranspiration, soil moisture storage, actual evapotranspiration, soil moisture deficit, and soil moisture surplus using a grid-based, Thornthwaite-Mather approach (Steenhuis and van der Molen, 1986). The main data inputs include a digital elevation model (DEM), soil available water capacity (AWC), monthly temperature (average), precipitation, and solar radiation.

The outputs of the model are:

- **Potential evapotranspiration (PE)** is estimated using the Turc method. PE is the evaporative water loss from a vegetation for which water is not a limiting factor. PE depends mainly on heat and solar radiation.
- **Actual evapotranspiration (AE)** refers to water loss from vegetation given actual water availability (from precipitation and soil moisture storage). If water is not a limiting factor, actual evapotranspiration is equal to potential evapotranspiration.
- **Deficit** represents moisture stress and occurs when the evaporative demand is not met by available water. In other words, it is the difference between potential and actual evapotranspiration.
- **Surplus** is excess water (not evaporated or transpired). It leaves a site through runoff or subsurface flow or a combination of both. There can be no surplus if soil storage is not full.

5.1.1 Water Balance Model Methods

The Thornthwaite-Mather water balance method uses the following logic:

a) Precipitation minus potential evapotranspiration (P-PE):

    a. If supply from precipitation (P) < demand (PE), plants utilize soil water.
    b. If supply (P) > demand (PE), there is more water than is needed by vegetation.
    c. Available water is prioritized as follows:
        i. Plants use what they need (first from precipitation, then from soil storage);
        ii. If there is still excess water, and the soil is not saturated, water is used to replenish soil storage;
        iii. Any excess water becomes surplus.

b) The calculation begins with soil water storage (ST) assumed to be full (equal to soil available water capacity (AWC)) based on consecutive values of P-PE. It can be assumed that soil storage is fully replenished if the sum of consecutive positive P-PE values exceeds AWC.

c) The change in storage (∆ST) from month to month depends on water use by plants (i.e., negative change in storage) or availability of excess water (positive change in storage).

d) Actual evapotranspiration (AE) is the actual amount of water used by plants or evaporated. If water is not limited, plants will use what they require for metabolic processes (AE=PE).

   a. Whenever storage (ST) = AWC, AE = PE (water comes from Precipitation (P)).
   b. As soil storage (ST) is depleted, it becomes increasingly difficult for plants to extract the water they need.
   c. When ST < AWC, AE = P + |∆ST|.

e) Water Deficit (D) = Potential Evapotranspiration (PE) – Actual Evapotranspiration (AE).

f) Surplus (S) is water left over after plant needs and soil storage are full. If ST is full (ST = AWC), there is expected to be “excess precipitation” if plants do not use it all.

   a. If ST < AWC, there can be no Surplus.
   b. If ST = AWC, then S = P - AE.
   c. Note that the month when ST equals AWC, S = P - AE - ∆ST (excess first goes to fill storage).

g) The balance in water supply and demand at a location can be expressed by two relationships:

   a. PE = AE + D (Moisture demand is equivalent to moisture transpired, plus the “shortfall.”).
   b. P = AE + S (precipitation is equal to actual evapotranspiration plus surplus not needed).

The above values are calculated for each month from January to December.

5.1.2 **Data Inputs**

Digital elevation model (DEM), aspect and slope

Slope and aspect (slope direction) rasters (gridded data) were derived from the 1-m resolution digital elevation model (DEM) (GeoBC Branch, 2024). The DEM was up scaled to 10 m x 10 m resolution to match the water balance model scale.

Soil Available Water Capacity (AWC)

Soil-related data was retrieved from the British Columbia Soil Information Finder Tool (Province of BC, 2024b). The BC Soil database includes soil composition (mineral or organic), soil texture, coarse fragment content, drainage, soil layer thicknesses and characteristics, soil physical and chemical properties, as well as landform and parent material. Soil mapping also includes available water holding capacity at different depths (0.15, 0.30, 0.45, 0.60, 0.75, 0.90, 1.05 and 1.20 m). In temperate forests, 95% of root mass occurs within the top 1 m of soil. Therefore, available water holding capacity at 0.90 m depth was used for the model input. Where data is not available, values were inferred from similar soils from Vancouver Island.

Geology (surficial geology, geomorphology)

Available surficial geology and soil mapping for the Savary Island was also integrated in the model (Province of BC, 2024b; Tetra Tech, 2023b).

Solar Radiation

Solar radiation can be estimated based on topography (DEM), geographic location and the time of the year. Solar radiation data (kJ m^{-2} day^{-1}) was obtained from WorldClim (http://worldclim.org/version2) at a resolution of 30 seconds (~1 km). The data were converted to watt-hours per square meter (Wh/m^2) per month for input to the model.

Average temperature and total precipitation

Gridded monthly total precipitation and maximum and minimum temperatures for Savary Island were obtained from the Pacific Climate Impact Consortium (PCIC) (Pacific Climate Impacts Consortium, 2024). Two scenarios were utilized:

a) Environmental conditions based on climate normal data from 1981-2010. The climate model parameters were compared to monitoring data from the study area (e.g. Comox Airport Climate Station EC1021830, the closest station with the most complete long-term dataset). Annual total precipitation in this region is an average of 1120 mm, ranging from 723 mm to 1671 mm/year from 2000-2024 (Figure 12).

b) Climate conditions modelled for 2025 (the current year) based on the Shared Socio-economic Pathway SSP 2.6 from PCIC.

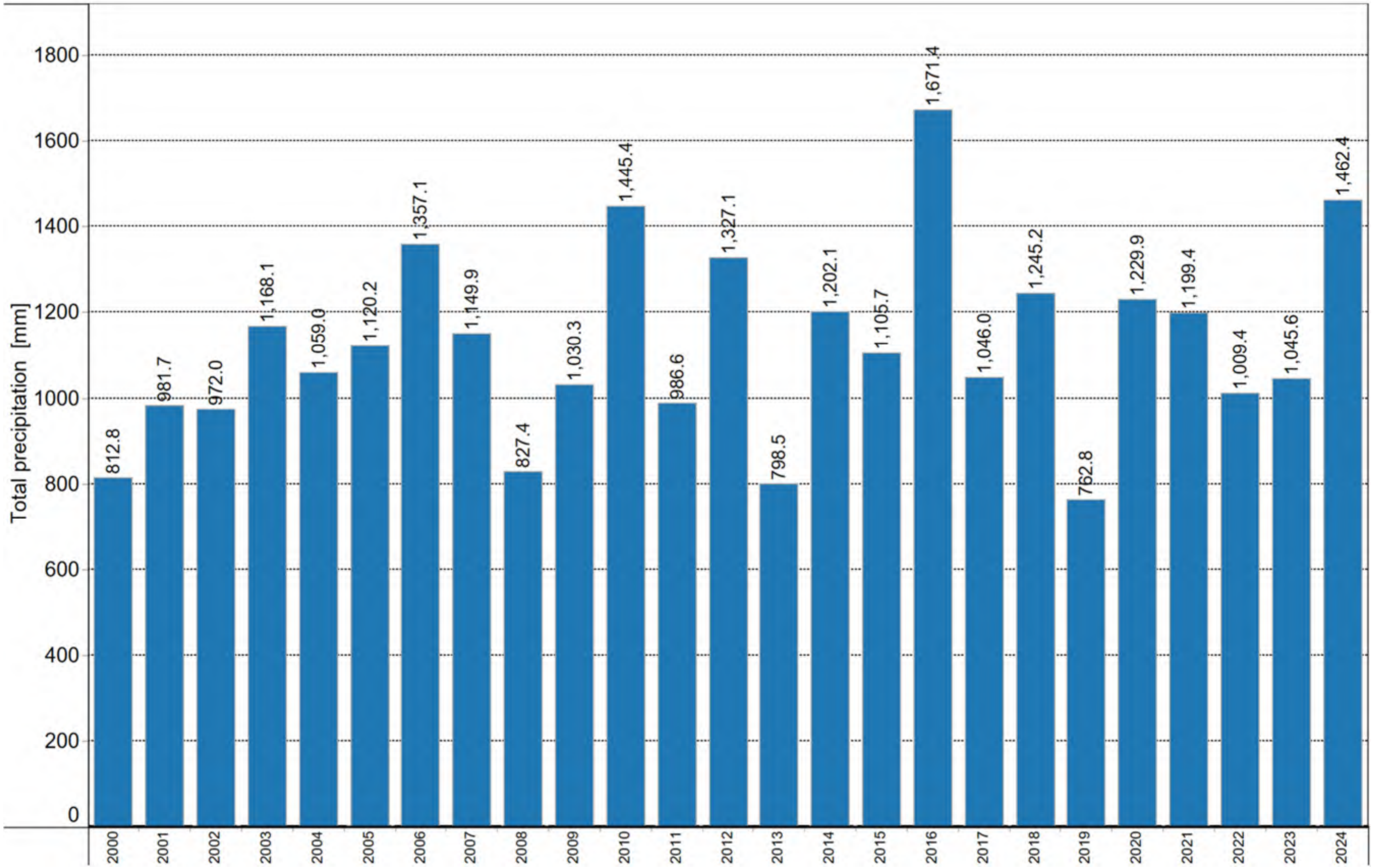


Figure 12. Annual total precipitation 2011-2024 (Comox Airport EC1021830), southwest of Savary Island.

5.1.3 Gridded Water Balance Model Data Outputs

Estimation of Annual Actual Evapotranspiration

Actual evapotranspiration was estimated for the grid cells across the Savary Island using the R-code and GIS based water balance tool (Dyer, 2021, 2019). The plot of monthly actual evapotranspiration for Savary Island (based on 1981-2010 Climate Normal) is included in Appendix E, Figure E1.

Surplus (water that can contribute to runoff or groundwater recharge)

Surplus is the remaining water (not evaporated or transpired) that leaves a site through runoff, infiltration into the subsurface, or a combination of both. There can be no surplus if soil storage is not full. The estimated water surplus for Savary Island (based on Climate Normal 1981-2010) is included in Appendix E, Figure E3.

To estimate the actual recharge that will reach the groundwater, the next step was to determine the *groundwater recharge potential*, which reflects the ability of water to infiltrate into the subsurface based on the topography and characteristics of surficial materials.

5.2 Groundwater recharge potential

The estimation of groundwater recharge potential considers slope, land cover, physiography and other factors which influence water infiltration and runoff. GW Solutions has developed a GIS-based methodology that incorporates diffuse and localized recharge pathways to estimate the spatial variability of potential recharge. The method uses infiltration or groundwater recharge coefficients for each of the spatial variables controlling recharge.

Across Savary island, diffuse or spread out recharge is the dominant recharge mechanism due to the widespread movement of water from the land surface to the water table with spatial and seasonal variability. The percentage of precipitation that becomes diffuse recharge is dependent on factors such as the drainage capacity of the soil, the type of land cover, the amount of local topography or slope, and the depth to the water table.

In other settings, such as larger islands with more extensive bedrock exposures, localized recharge can occur along discrete, bedrock lineaments (fractures, faults and geologic bedding planes and contacts). Similarly, recharge can occur where there is water accumulated within surface water bodies, which can provide a recharge source. These recharge sources are limited on Savary Island due to small area of bedrock and limited capacity of the granitic fracture networks to store or transmit water. Furthermore, there are no surface water features (such as lakes or creeks) that could contribute to the localized groundwater recharge sources.

5.2.1 Methods and assumptions

Groundwater recharge potential (GRP) was determined in QGIS by developing a raster grid which estimates the relative capacity of each area to absorb or intercept precipitation. The GRP estimation combines the values of different deterministic or conditional factors-such as elevation, slope, drainage capacity of surficial sediments, land cover, geomorphology, and depth to groundwater that influence the how precipitation is received on the landscape, infiltrates and percolates into the ground. The data sources, key deterministic factors and their relative weighting have been adapted from previous studies in the southern Gulf Islands (GW Solutions Inc, 2021, 2023) and enhanced by developing and running multiple scenarios for Savary Island.

The conditioning factors were classified, normalized and processed in QGIS using a weighting approach. In some other studies, (e.g. Nguyen Ngoc Thanh et al., 2022) those processes are utilized with different statistical models such as Frequency Ratio (FR) and Weight of Evidence (WOE).

A process diagram outlining the input factors utilized to determine the GRP for Savary Island is included in Figure 13. Each of these factors is assigned an appropriate weighting factor in the calculation of recharge potential. Weighting factors were determined based on previous studies and the main factors predicted to influence groundwater recharged across Savary Island.

5.2.1.1 *Preferential recharge/discharge areas (PRDA) (Value 0 and 1)*

Within the water cycle, a proportion of precipitation received at the ground surface will infiltrate into the ground creating groundwater recharge. Groundwater recharge typically occurs in upland areas where the unsaturated zone is thicker and the depth to the groundwater table is deeper, allowing water to percolate underground and replenish the aquifer. In contrast, groundwater discharge areas are typically located in topographic lows such as along streams, valleys and shorelines, providing seasonal or year-round baseflow to streams, wetlands and springs (Fetter, 2018).

The depth of the groundwater table or the thickness of the unsaturated zone has a significant role in controlling groundwater recharge rate across Savary Island. Despite surficial materials that are suitable for groundwater infiltration, a shallow water table limits the amount of water that can infiltrate into the ground.

The two factors “average interpreted groundwater elevation” and “depth to water” were used to estimate the potential for groundwater recharge to occur. For instance, if the groundwater level is above the ground surface, it indicates a groundwater discharge zone, in which groundwater recharge will be limited. The opposite condition is observed when the groundwater level is below ground and allows mostly groundwater recharge will occur.

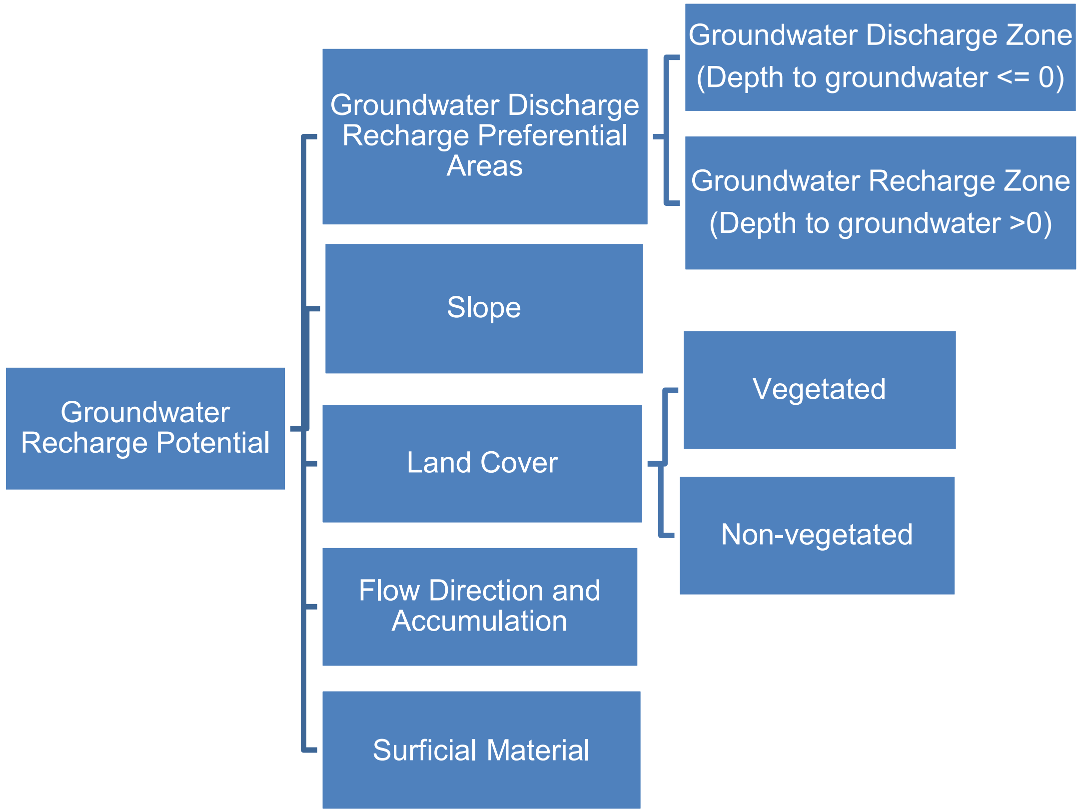


Figure 13: Flow chart illustrating the inputs used to estimate the groundwater recharge potential.

Groundwater depth measurements were obtained from GWELLS, additional well construction records provided by local companies, and field measurements collected in September 2024. Using the Leapfrog model a groundwater elevation surface was created (groundwater elevation grid in meters above sea level) and exported into QGIS as a raster file. The interpreted depth to water across the island was generated in QGIS by subtracting the average interpreted groundwater elevation from the gridded topographic elevation in the high-resolution Lidar DEM.

While field measurements of groundwater level were collected over many years and during different seasons the variability is not anticipated to introduce a significant error. According to Provincial Observation Well data (OW408, OW500 and OW511), the water table elevation fluctuates less than 1 m over the year, with shallower levels in late winter/early spring and deeper levels in late summer/early fall (see section 4.5 Groundwater monitoring). When considering the combined effects of seasonal fluctuation and tidal influence some areas may be associated with groundwater discharge in the winter and at high tide, yet they are groundwater recharge areas for the remainder of the year and during low tide. For this study, all areas identified with either permanent or seasonal groundwater discharge, where the average interpreted depth to water is zero 0 or a negative value (i.e. level above ground), were classified as groundwater discharge areas.

Maps of preferential recharge and discharge areas were developed for the island based on the average interpreted depth to water method. An attribute rating system was developed and assigned a value of "0" to a probable groundwater discharge area and "1" to a probable groundwater recharge area. Figure 14 illustrates the map of preferential recharge and discharge areas.

5.2.1.2 *Slope Coefficient (1%-45%)*

Topography greatly influences the potential for water infiltration to the subsurface. In groundwater recharge areas, a low slope promotes infiltration, whereas a steep slope promotes runoff and decreases infiltration. The high-resolution (1 m) LiDAR digital elevation model (GeoBC Branch, 2024) was processed to generate the topographic slope with 1 m resolution. The topographic slope (in degrees) was classified into seven categories representing high to low groundwater recharge potential. The resulting slope infiltration factors are summarized in Table 7 and shown in Figure 14.

Table 7: Slope infiltration factors and groundwater recharge potential based on the slope degree.

Groundwater recharge potential	Slope (°)	Infiltration factor
Lowest	> 24	0.01
Very poor	8.5 - 24	0.05
Poor	4.5 -8.5	0.10
Moderate	2.7 - 4.5	0.15
Good	1.8 - 2.7	0.25
Very good	0.2 - 1.8	0.35
High	< 0.2	0.45

5.2.1.3 *Land Cover Coefficient (20% and 30%)*

Vegetation affects groundwater recharge through the interception of precipitation by foliage and use of water for the plant growth. Greater foliage interception also leads to longer exposure to the atmosphere and increased evaporation. In comparison unpaved areas cleared for land development could promote water infiltration. Land cover across the island was categorized into two main types: vegetated (forested) areas and non-vegetated (cleared) areas.

The vegetated and non-vegetated land areas were generated using raw LiDAR with Tree Light - 1 m resolution (GeoBC Branch, 2024) which identifies areas of vegetation cover. An infiltration factor of 20% was assumed for vegetated areas and 30% for non-vegetated areas. The resulting map is shown in Figure 14.

5.2.1.4 *Wetness Coefficient*

The wetness coefficient is a measure of the probability of water drainage to a site, based on the slope and surficial geology (Nguyen Ngoc Thanh et al., 2022). Areas with a higher coefficient are more likely to capture runoff from a larger area, compared to areas where flow is unlikely to accumulate with a low wetness coefficient. To generate the wetness coefficient, a flow direction and accumulation layer was combined with surficial geology mapping of the island. The product is a map layer shown in Figure 14, showing the relative probability of accumulated flow percolating into the ground.

5.2.1.5 *Flow Direction and Accumulation (FDA)*

Flow Direction and Accumulation (FDA) is a function of the land slope and upgradient contributing area. Large values for FDA are typically associated with lowlands having a larger contributing (catchment) area. FDA was generated in QGIS using the LiDAR 1 m- resolution (GeoBC Branch, 2024) with a defined output grid size of 10 m. Figure 14 shows the generated map of FDA across the Savary Island where larger values indicate areas with a larger upstream area contributing to runoff and therefore likely higher potential for recharge.

Table 8: FDA infiltration factor and groundwater recharge potential based on the FDA range.

Groundwater Recharge Potential	Flow Direction Accumulation Range	Flow Direction Accumulation Coefficient
Low	<5	0.20
Moderate low	6-12	0.21
Moderate	13-22	0.22
Moderate high	23-76	0.23
High	76-300	0.24
Very High	300-1450	0.25

5.2.1.6 *Surficial geology*

Surficial geologic material refers to the unconsolidated (loose) sediments exposed at the ground surface. For unconsolidated surficial materials, the size of the particles, homogeneity, density of sediments and how the sediments are stratified defines the soil structure. These characteristics influence the ability of soil or surficial sediments to absorb and hold water during rainfall events (Christelle Basset et al., 2022).

Based on the main surficial geology material (Tetra Tech, 2023b), sediment infiltration factors were developed. The factors depended on the surficial material attributes such as texture, particle size, silt percentage, degree of sorting and rounding of particles, and level of compaction indicated by the terrain mapping code (Resources Inventory Committee, 1996). Table 9 summarizes the developed sediment infiltration factors. Areas with both a high Flow Direction Accumulation combined with suitable surficial soil materials such as sand suggest a higher possibility for groundwater recharge.

Table 9: Surficial geology and sediments infiltration factor based on the materials.

Surficial material code (terrain)	Main Surficial geology Material	Sediment Infiltration Coefficient
sWv/R	Rock	0.75
M	Till	0.85
Mv/sgFGb	Glacio-Fluvial	0.95
sWvw/sFGb	Marine	0.95
sErvb/M	Eolian	0.95
Mv/sgFGb	Glacio-Fluvial	0.95
sgWv/M	Till	0.9
sWvw/M	Marine	0.9
sErvb/sfFG	Eolian	1

Across Savary Island the composite groundwater recharge potential was determined using the equation:

$$\mathbf{RP = R_{PRDA}\,[(R_{slope}) + (R_{Wetness}) + (R_{landcover})]}$$

where:

RP = Recharge potential (0-100%)
R_{PRDA} Factor = Preferential Recharge/Discharge Areas Factor (1 and 0)
$R_{\text{Land cover}}$ Coefficient= Land Cover/ Vegetated and Non-vegetated Zone (20%-30%); Influence ranges up to 30%
R_{Wetness} Coefficient = Combined Flow Direction and Accumulation (15%– 0.25%) with Surficial Geology Material (0.75%-100%), Influence ranges up to 25%
R_{Slope} Coefficient = Slope Factor (1%-45%); Influence ranges up to 45%

5.2.2 Groundwater recharge potential results and discussion

The resulting groundwater recharge potential map for the Island is presented in Figure 14. A recharge potential of 1 suggests high potential of recharge, across a flat (zero slope) bare land (non-vegetated) with surficial geology material of sand found within areas with a high preferential of recharge (PRDA=1).

The lowest recharge potential values are typical for areas of preferential discharge (PRDA=0). Groundwater recharge potential across Savary Island varies depending on the location. Slope and land cover have the greatest influence on whether precipitation will infiltrate into the land surface. In general, diffuse recharge is anticipated to occur across most of the Island footprint. Cliffsides, beaches and lower elevation planes along the margins of the Island have a lower recharge potential and are considered discharge zones.

5.3 Groundwater recharge from surplus

The gridded water balance model surplus was combined with the groundwater recharge potential map to estimate the amount of recharge the aquifer will receive during different times of year. Figure 15 shows the monthly groundwater recharge expected based on the moisture surplus and the recharge potential of the landscape.

Figure 15 summarizes the monthly precipitation, actual evapotranspiration (AE), moisture surplus (S), and groundwater recharge estimated using the water balance model based on the 1990-2010 Climate Normal from 1991-2010. Historically the precipitation occurred year-round, while the wettest months allowed a moisture surplus to be generated and groundwater recharge to occur during the months from October to April.

Considering the current 2025 scenario (SSP 2.6), precipitation is expected to be higher from October to March, but lower from April to September. Temperatures are also higher increasing evapotranspiration, reducing soil moisture surplus. Consequently, groundwater recharge is reduced, and no recharge occurs from April through to September, the period of greatest water-use. The next step in generating the water balance was to determine water demand in comparison to the supply (recharge).

Additional tables showing the water balance per groundwater management region are provided in Appendix E (Figure E4 and E5).

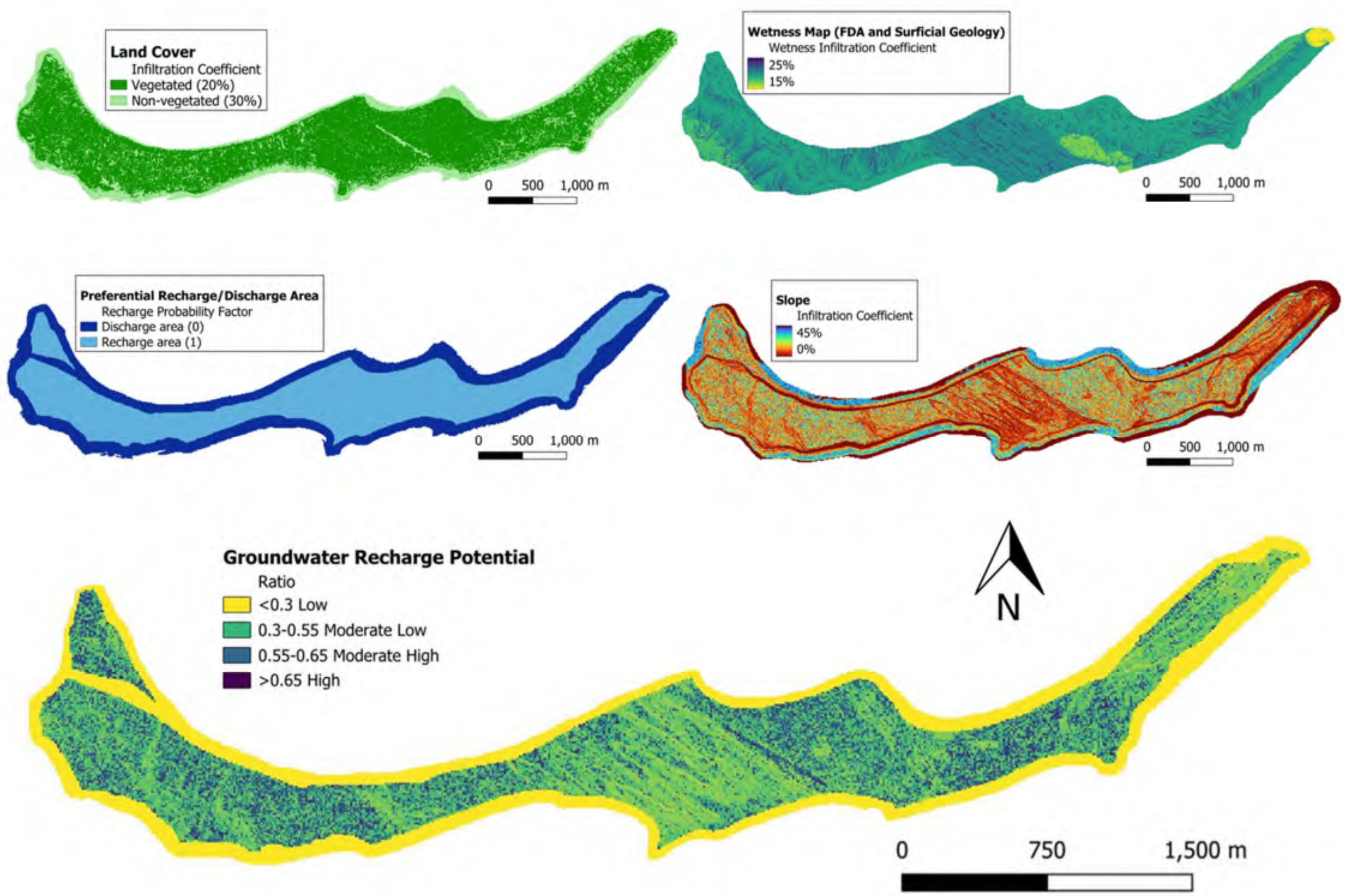


Figure 14: Land cover, preferential recharge/discharge areas, wetness coefficient and slope input factors and resulting groundwater recharge potential.

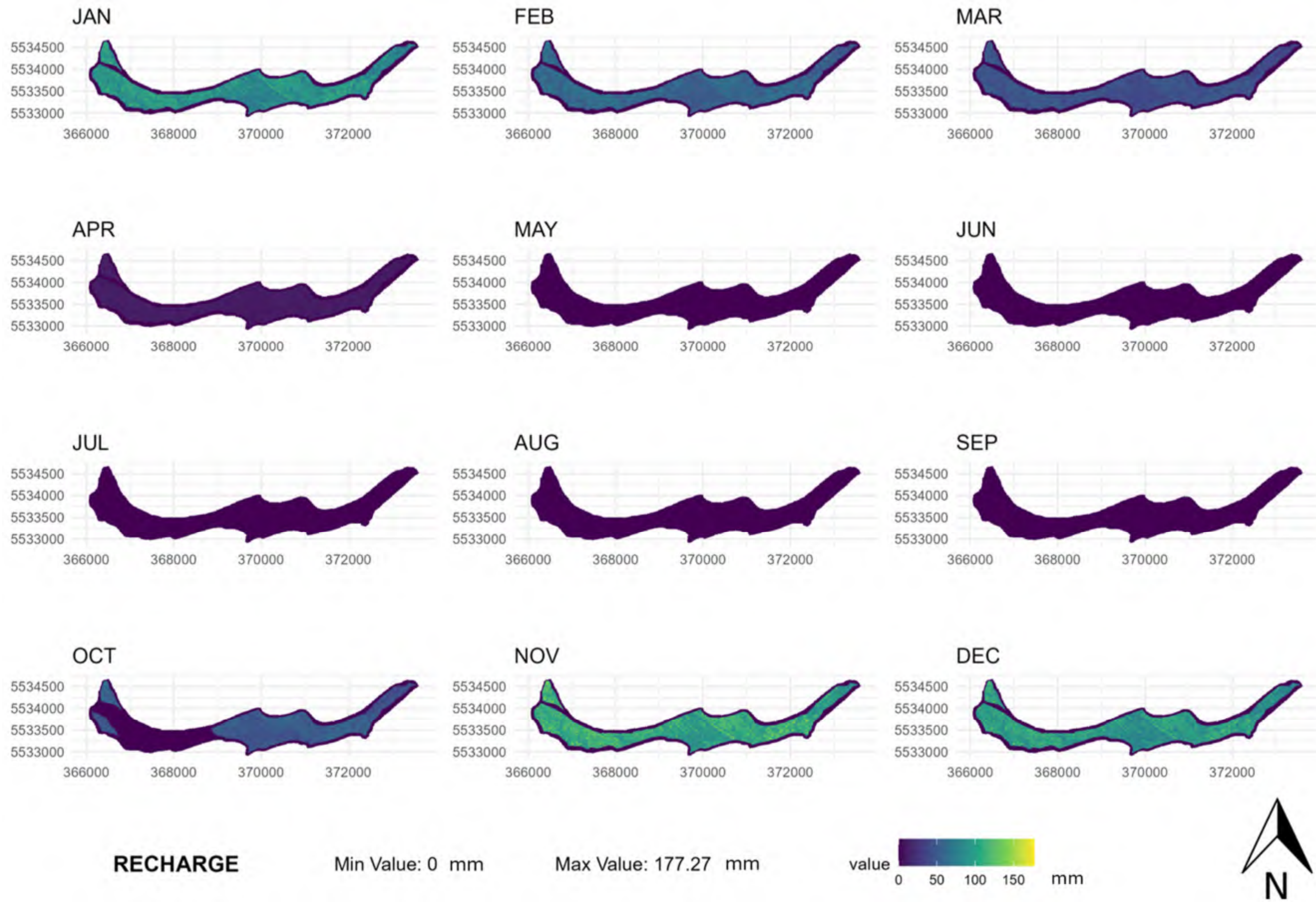


Figure 15. Groundwater recharge (mm) (Climate Normal 1981-2010) (water balance model output).

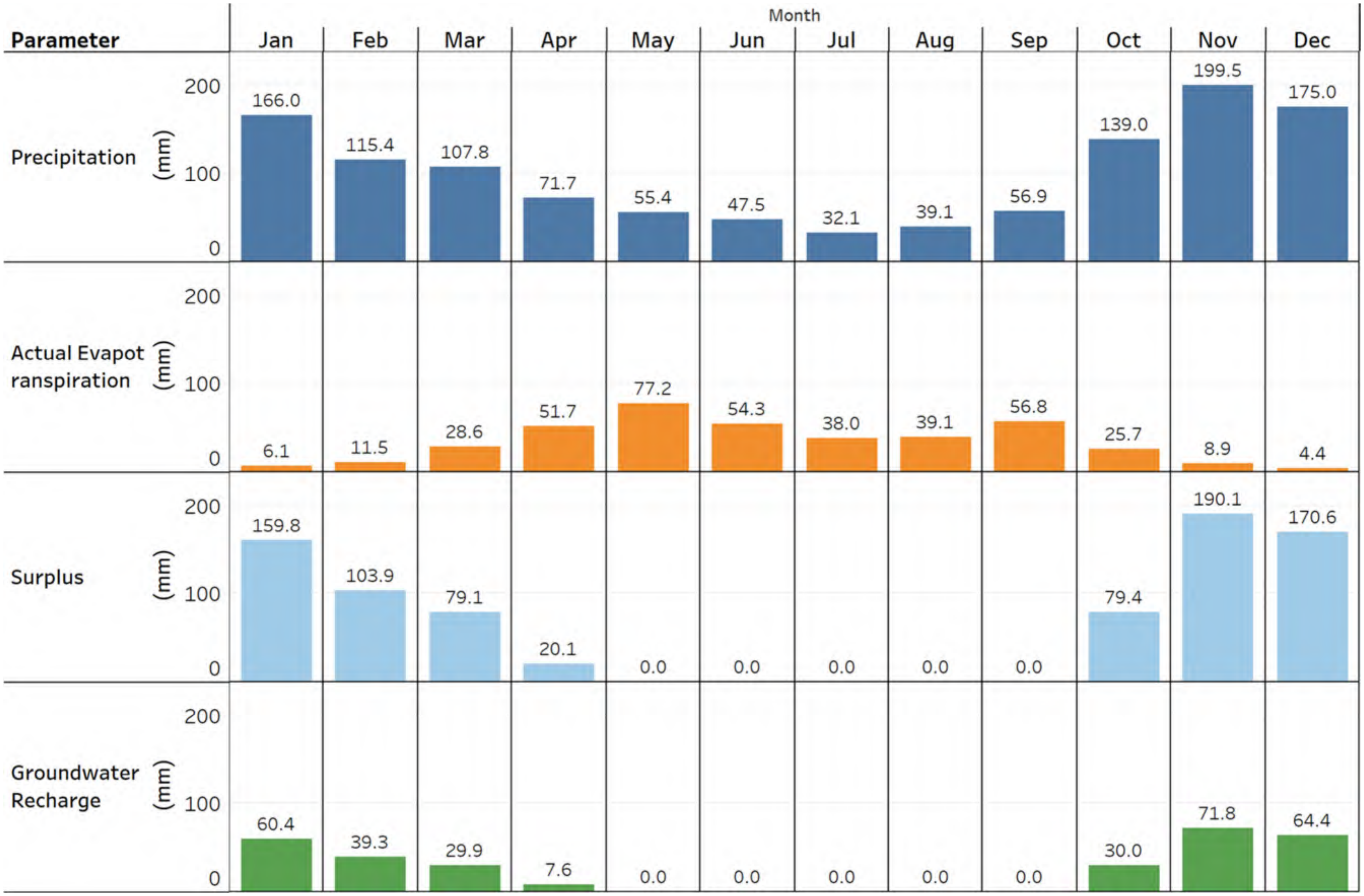


Figure 16. Water balance model results for Precipitation, Actual Evapotranspiration, Moisture Surplus and Groundwater Recharge (mm) based on Climate Normals 1981-2010.

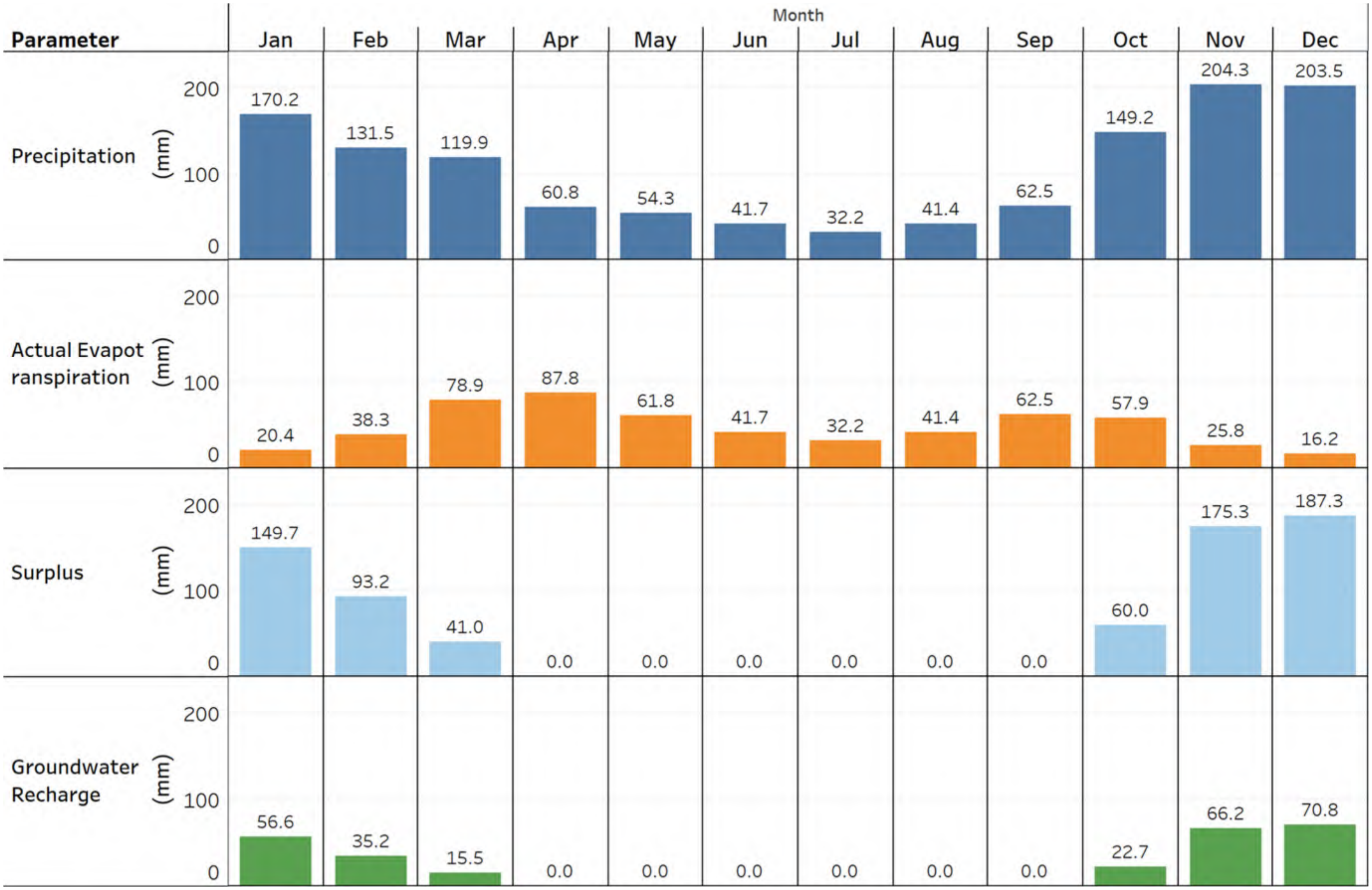


Figure 17. Water balance model results for Precipitation, Actual Evapotranspiration, Moisture Surplus and Groundwater Recharge (mm) for 2025 (SSP 2.6).

5.4 Water demand

The next step of the water balance determination was to estimate water demand in comparison to water availability. Accurate estimation of water use is particularly challenging in rural areas where water is supplied from independent, typically un-metered, water sources such as domestic wells, and on islands with significant seasonal differences in population.

This study used a range of different information sources to estimate water demand on Savary. The primary sources of data included information on land use and occupancy from BC Assessment Primary Actual Land Use categorization provided by the qRD GIS department (BC Assessment, 2024). An initial analysis was completed using data from the 2024 Assessment Roll Year. Subsequently, data from the 2025 Assessment Roll Year were obtained in January 2025, and considered more current, as they were updated following field verification by BC Assessment staff in September and October 2024. Savary Shores Improvement District provided exceptionally detailed data, including metered use for the period from 1996 to 2023, inclusive of active connections for the 2020-2023 which were used to derive estimates of per connection (per lot) water use, and proportions (percentage) of seasonal occupancy. The general approach for estimating water demand is outlined in Figure 18, while additional assumptions, methods and resulting estimates of water use on the Island are discussed in the sections below.

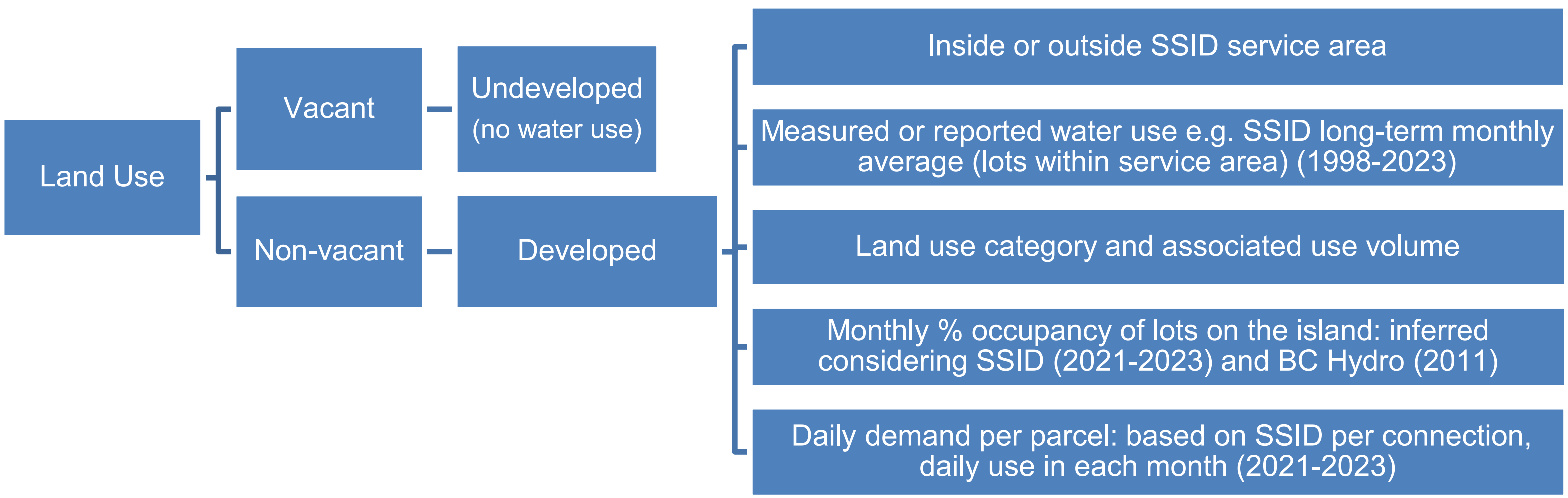


Figure 18. Water demand estimation approach.

5.4.1 Population and seasonal occupancy

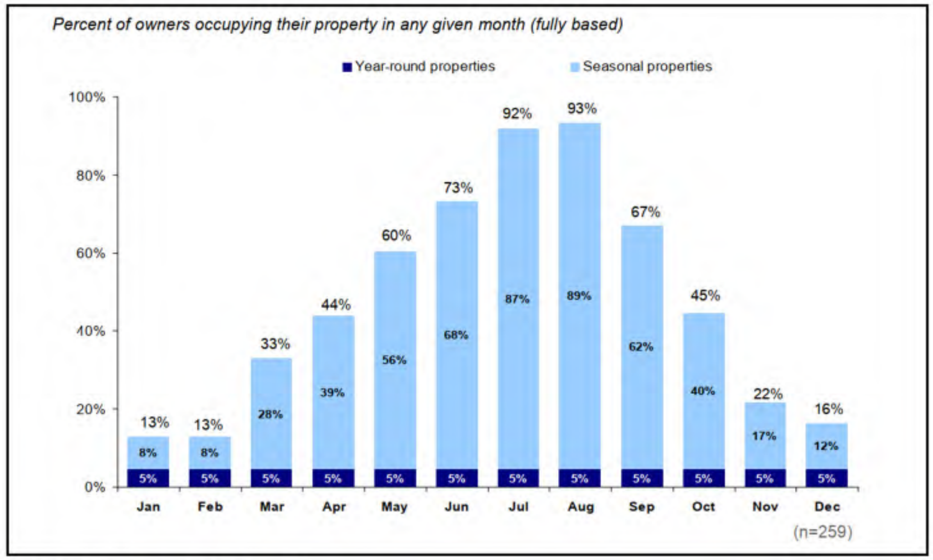
The population and occupancy per lot varies significantly depending on the time of year, with the greatest occupancy occurring during the months of July and August annually. Published population and occupancy estimates are shown in Table 10, based on 1) Tupper (1996), 2) BC Hydro (2012, 2011) 3) ASIC (2023), and 4) qRD Groundwater study survey (2024).

To calculate potential energy use needs, BC Hydro previously asked residents regarding the months they spent on the Island, which gives an idea of the percentage of permanent and seasonal residency, as summarized in Figure 19. The 2011 BC Hydro survey estimated that approximately 5% of islanders were full-time residents, compared to 95% who visited periodically or seasonally, with an average of 69 "season days" spent on the island per year; they further estimated that seasonal population could peak to up to 2,500 to 3,000 individuals during the summer period. More recent surveys, summarized in section 3.3, indicated a similar pattern of seasonal occupancy.

Table 10. Savary Island population and occupancy estimates.

	Reference or data source			
	1	**2**	**3**	**4**
Population				
Year-round	70	100		
Seasonal	1000	3000		
Occupancy (per parcel)				
Year-round average		1.9	2	2
Seasonal average		3.4	3-6	3
Seasonal range		1-6+	3-10	0-15

Source: 1) Tupper (1996), 2) BC Hydro (2012, 2011) 3) ASIC (2023), 4) qRD Groundwater study survey (2024).



Note: Totals may not reconcile due to rounding.

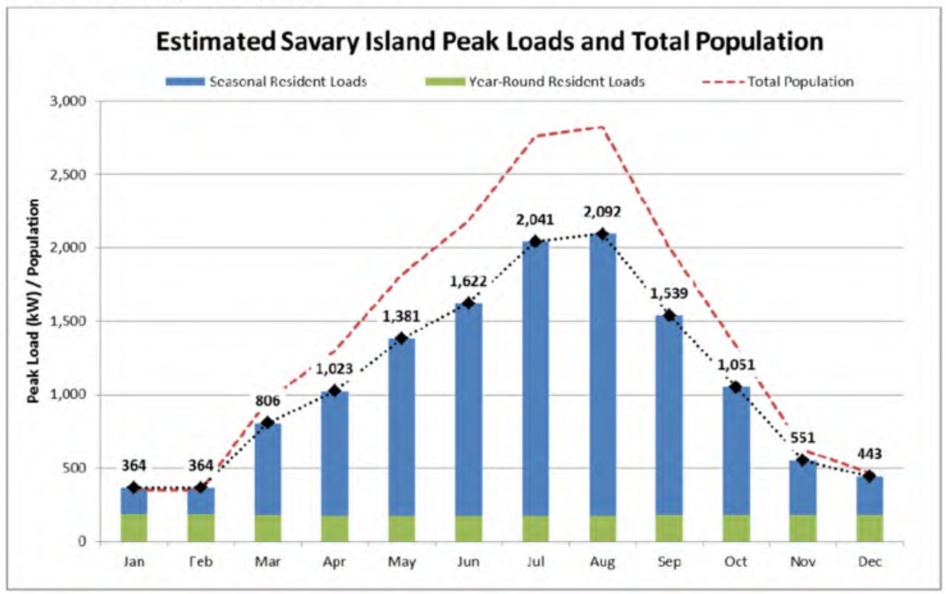


Figure 19. Percentage of lots per month occupied by year-round or seasonal residents and estimated monthly population. Reproduced from BC Hydro (2011, 2012).

5.4.2 Land use

Using the BC Assessment spatial dataset, statistics were calculated on the number of cadastral (land) parcels within each primary actual use category (island-wide and within each groundwater management area). The Primary Actual Land Use Codes were defined within the BC Assessment data advice (BC Assessment Authority, 2022).

- Land use categories were identified as either vacant (undeveloped and therefore unlikely to have onsite water use) or non-vacant (lots assumed to be developed and utilizing a water source). For example, the large conservation land parcel in the centre of the island was included within the category 061 “2 Acres or More (Vacant)”. Most lots were within a residential category (e.g. single-family dwelling). The category “Residential, outbuilding only” was also assumed to be occupied by a residence or building that utilized water. Unless specified within the land use category (e.g. residential dwelling with suite), only one residence was assumed per parcel, although it is known that some parcels have multiple dwellings.
- Lots were further identified as being within or outside of the SSID service area. If inside the service area, the water source was assumed to come from the local water provider. An exception was the Savay Island General Store which uses its own onsite well.

5.4.3 Measured water use

Water demand on Savary Island is likely to differ from many other urban and rural communities, due to the lack of centralized services. Apart from the water supplied within the SSID service area, the island is off grid, forcing an overall conservation mind-set for energy and water usage. The data from the SSID long-term operations was thus essential for analyzing local water use patterns.

Within the SSID service area, there are a total of 213 serviceable lots, 172 of which are connected to the water system (SSID, 2024). Metered pumping volumes have been recorded by the water system since 1998. The reported volumes are assumed to include water used for main flushing and maintenance. To reduce the risk of uncontrolled leaks, distribution valves to each property are generally closed during periods of disuse. Therefore, the purveyor is able to track how many lots are connected for a given period, and detailed data on the number of lots connected per month were collected since 2021.

SSID monthly water use for the years from 1998 to 2023 is shown in Figure 20. During the year, roughly 50% of all annual usage occurs within the months of July and August. Potential outliers possibly associated with leaks or extended maintenance periods were observed in April 2013 and December 2022. Annual water use from 1998-2023 is shown in Figure 21 and shows an increasing trend, with 2021 demonstrating the highest recorded use of 8,200 m^3. The number of serviced properties with active connections in each year has increased by 55% from 106 in 1998 to 164 in 2023, and the annual water use has increased by the same percentage (55%) during that time. There was a notable increase in water use observed in spring and summer 2021 (observed in both Figure 20 and Figure 21 which was believed to be due to the 2021 heat dome which resulted in much higher than average air temperatures during the summer, and the effect of Covid-19 on island residency patterns. Subsequent years have shown a slight decline with annual use of 7,200 m^3 in 2022, down to 6,800 m^3 in 2023. Additional water use data from SSID are summarized in Appendix D.

Daily demand per connection in SSID was calculated using data from 2021-2023, a period when number of active connections was recorded monthly (Figure 22). From 2021-2023 the average daily water demand per connection ranged from a low of 84 L/d in November up to a maximum of 414 L/day in July. It was assumed that there was one dwelling per parcel or connection (i.e. number of occupied dwellings equivalent to number of connections serviced). The occupancy of each dwelling was considered variable and assumed to be highest in July and August based on resident surveys. Some increased water use during the summer (June-August) is also considered due to outdoor use such as irrigation of domestic gardens, more likely for full-time residents or those residing for a longer period during the year. The calculated daily use was also likely lower in winter and shoulder season months in the spring and fall, as many residents visit or stay on the island for shorter periods, such as weekends only.

Per capita water use on Savary is much lower than for other communities in southern BC. For example, on Salt Spring Island in the Capital Regional District, water use reported by community water systems averaged from 93 L/d/connection up to 630 L/d/connection, while groundwater sourced systems using typically in the lower range (average 229 L/day/connection for ten reporting water groundwater systems) (Cowan, S., 2021). In the Regional District of Nanaimo, which operates nine local water services, water demand is typically higher in communities with larger property areas and dwelling sizes. The lower end ranges from 380 L/d/connection in winter up to 500 L/d/connection in summer for the Melrose Terrace Water Service Area, a small rural neighbourhood within mainly modular or small homes. This compares to 740 L/d/connection in winter and 1940 L/d/connection in summer for the River's Edge subdivision, a suburban community with acreages and large homes (Regional District of Nanaimo, 2024a, 2024b).

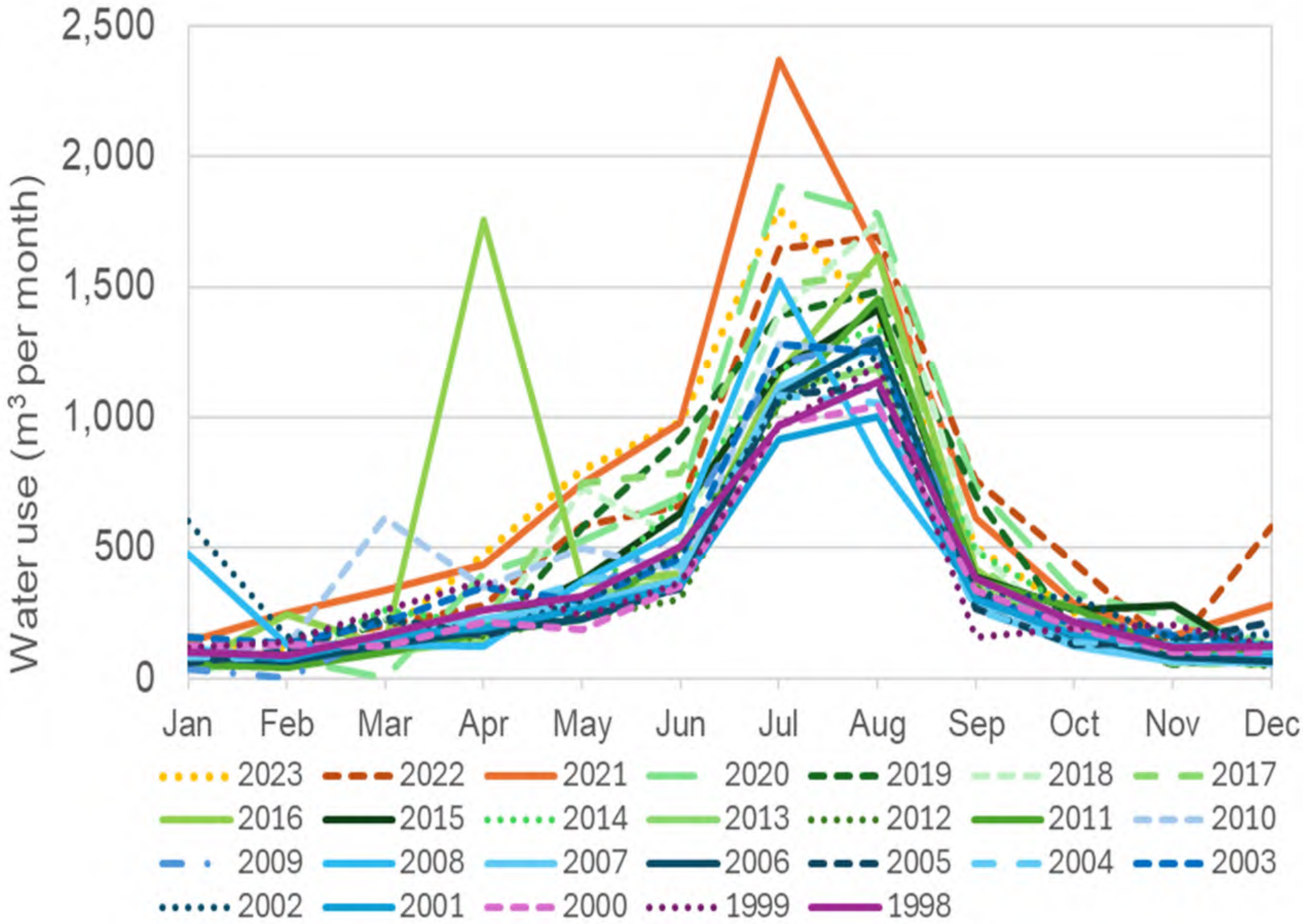


Figure 20. Savary Shores Improvement District (SSID) Monthly Water Use 1998-2023.

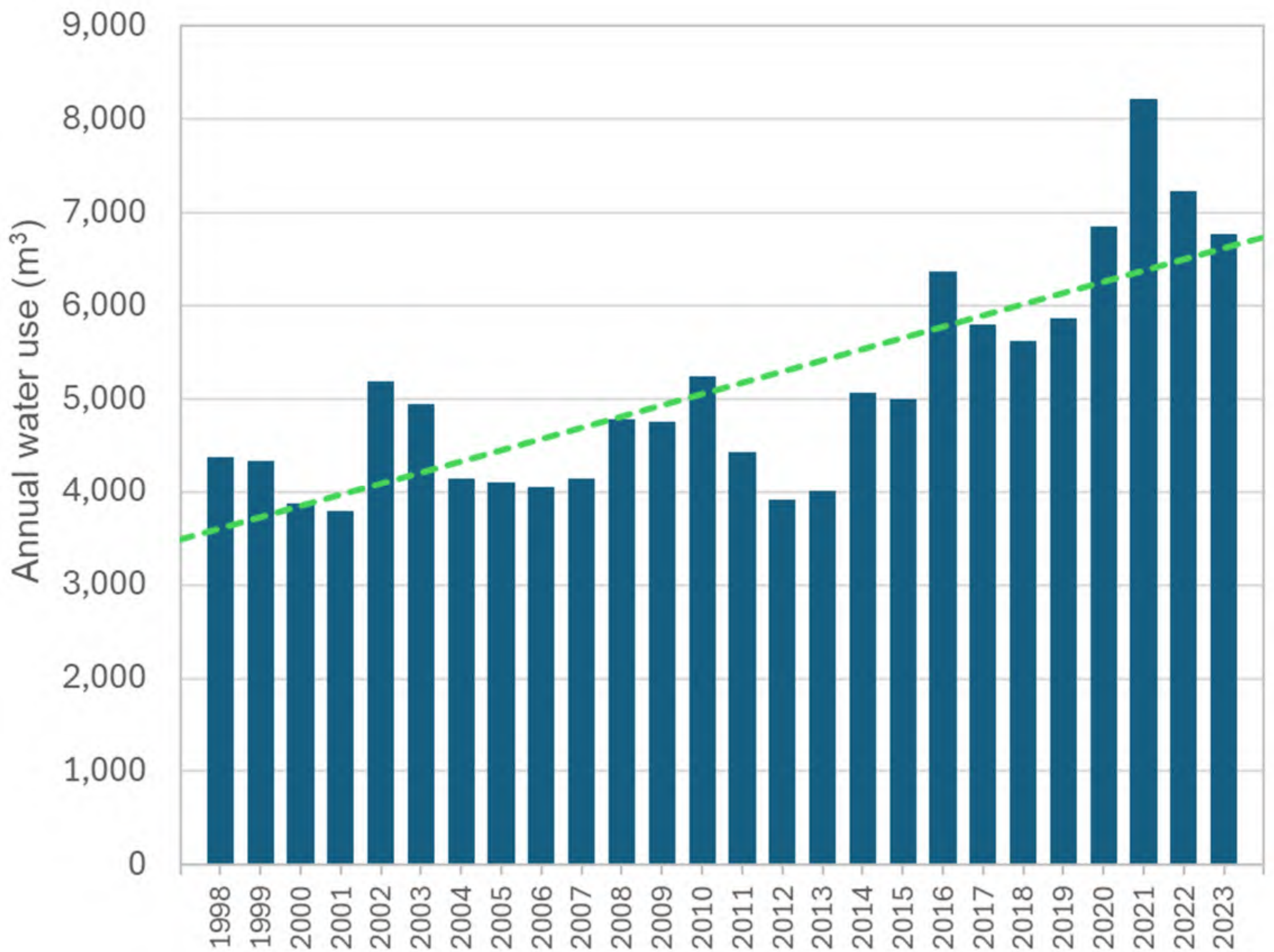


Figure 21. Savary Shores Improvement District (SSID) Annual Water Use (1998-2023). Green line indicates long-term trend.

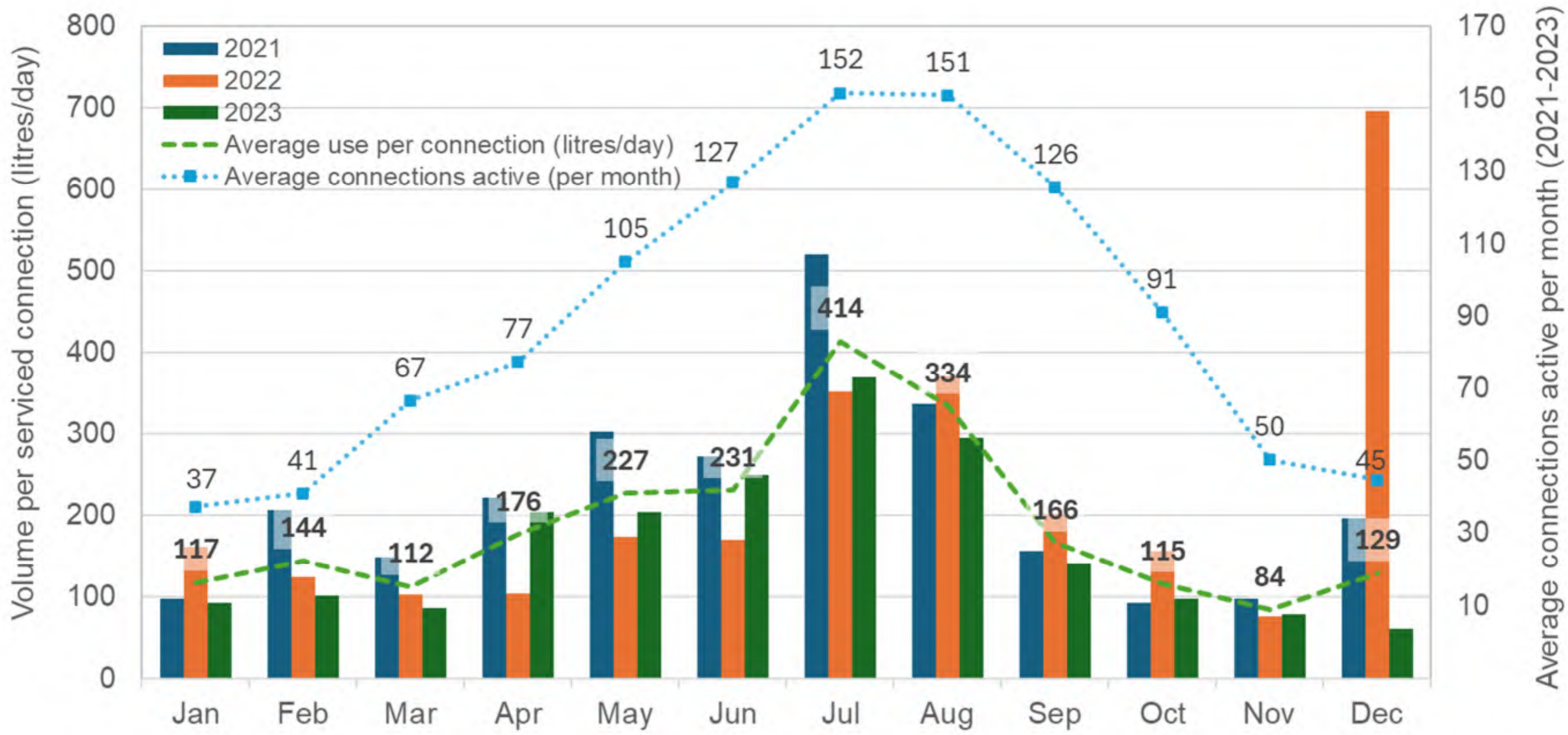


Figure 22. Savary Shores Improvement District average daily water use per connection and number active connections per month (2021-2023).

5.4.4 Estimated water use

Outside of the SSID service area, water use is unmetered, and therefore usage was estimated using the following assumptions and methods.

- **Developed lots and water sources:** All lots with a reported land use that was non-vacant were assumed to be developed and utilizing water from a groundwater source. Although some developed parcels use a shared well on an adjacent property rather than on the property itself (e.g. a shared domestic well), the water demand per parcel depends on land use type rather than physical presence of a well. Although rainwater collection may be used to augment supplies, it is not considered a major source based on survey responses and field observations.

- **Water demand categories:** The average daily water use per parcel and per month was estimated depending on the type of land use. Most parcels had a residential categorization, e.g. single-family dwelling. The seasonal pattern of residential water use (average daily volume per parcel during different periods of the year) was assumed to be similar to the average values calculated from metered use within SSID. This approach was considered reasonable, while acknowledging that water use will vary depending on the type of occupancy (i.e. long-term residents vs short term visitors, or vacation renters), and characteristics of the water supply and wastewater infrastructure (well type, whether hauled, connected to a hand pump, or electrical pump plumbed to the home, number of kitchens and bathrooms in the home or property, laundry facilities, use of flush toilet vs composting toilet, etc.).
- **Residential multiplier:** For residential-related categories which suggested a potentially higher use a proportional multiplier was applied to residential water use estimate e.g. a multiplier of 1.5 was applied to lots designated as "residential dwelling with suite."
- **Percent occupancy of lots:** Outside of the SSID service area, it was assumed that the monthly occupancy pattern for non-vacant residential lots would be similar to that in the service area. The percentage of residential lots likely to be occupied within a given month across the island was estimated quantitatively. Monthly occupancy patterns in SSID (from the 2021-2023 active connections dataset) were considered, along with the relative (%) monthly residency estimated by the BC Hydro community survey and energy needs assessment (2012, 2011). The monthly percent occupancy was further adjusted, typically rounding down to the nearest 10th or 5th percentage in comparison to referenced empirical values to provide a conservative estimate.
- **Non-residential use:** The non-residential land use category included Government Buildings (e.g. firehalls). The fire department use is the largest individual water user on the island by volume. The Savary Island Volunteer Fire Department (SIVFD) reported using from 20,000 to 30,000 US gallons per year for practice purposes (Chris Philpott, personal communication, September 2024). Fire department storage tanks distributed around the island are filled by tanker truck from the main firehall well supply. The qathet (Powell River) Regional District has an active water license application for 67 m^3/year (roughly 25,000 US gallons per year) for fire protection purpose by the SIVFD, and 0.500 m^3/d for facility usage. For the water use estimate, the license application volume was used, including the daily demand for facility use (year-round) and the water for firefighting practice assumed to be used from May-September annually (67,000 litres/5 months). The actual water demand for facility use (bathrooms and kitchen) is likely less than the license application quantity during much of the year. The volunteer first responders typically attend the main fire hall for a few hours ~2 days/week year-round, while fire practice activities are seasonal, mainly in the spring to fall period (Ruth White, personal communication, January 2025).

- **Independent use in SSID Service Area**: The Savary Island General Store is located within SSID service area but operates its own well. The store land use was classified by BC Assessment as "residential" and "residential-outbuilding only" and water use was considered equivalent to residential use (per parcel). No other wells were considered active in the SSID service area.
- **Resorts and vacation rentals:** With the exception of the Savary Island Resort, which has a different land use category (seasonal resort), water use for vacation rentals were not accounted for separately from other residential uses. A qualitative review was completed of public vacation rentals on the island from which approximately 55 listings were noted on AirBnB and 25 listings were noted on VRBO, many cross-listed on these platforms and on the Savary Island Rentals page on the ASIC website. Island-wide, 55 listings represent roughly 7% of non-vacant lots. Approximately 11 vacation rental properties (20%) were located within the SSID service area, and therefore water use on these properties would be incorporated within the metered use estimates. It is likely that additional properties on the island are rented through informal means including word or mouth or other advertising platforms, however there is no easy method to track vacation rentals using existing data.

  Vacation rentals may increase overall occupancy (number of persons staying on each parcel) mostly concentrated in the summer months and shoulder season (late spring and early fall). While occasional visitors may bring more urban (i.e., less conservation conscious) water use patterns, many vacation rentals incorporate measures to reduce water use, such as requiring guests to provide their own linens. Not accounting separately for vacation rental use was not anticipated to significantly affect the accuracy of the water use estimates. From a planning perspective, the qRD and community might consider ways to better quantify vacation rental water use in future. Non-domestic (commercial) groundwater use (e.g. for water purveyors, resorts, restaurants and public facilities) requires a groundwater license under the *Water Sustainability Act* (Province of BC, 2014; Ministry of Water, Land and Resource Stewardship, 2024a). However, under current policies a groundwater license is generally not required for bed and breakfast use (Evan Rankin, Ministry of Water, Land and Resource Stewardship, Water Authorizations, personal communication, April 2024).
- **Irrigation and agricultural water use:** There are no designated agricultural land parcels on the island. Irrigation for domestic gardens or moderate sized market gardens was therefore integrated within the residential category (relative percent increase in summer versus winter water use). Water use for irrigation is likely not a significant component of overall water use given the residency patterns on Savary.
- **Water Rights/Licensed Use:** Water license volumes from the BC Water Rights Database were reviewed for licensed surface water Points of Diversion (POD's) including springs, Points of Well Diversion (PWD's for groundwater diverted from wells) and Points of Groundwater Diversion (PG's for groundwater connected sources where diversion is not from a well, such ditches, quarries and dugouts). There are eleven current (active) surface water licenses, six for Qaye qun Springs on the north side of the island, three for Nielsen Spring, one for Neilsen Brook and one for "Shallow Spring" on

the south side of the Island. Based on information gathered during the field survey, surface water licenses for surface sources on the south side of the island (e.g. Neilsen Spring), are no longer in use and have been replaced by other water sources due to diminished quantity or unsuitability of the supply. Active use of water from Qaye qun Spring on the north side of the island was reported anecdotally during the field survey and the online water use survey, but the actual volume of use is likely small, as people typically haul the water using buckets for drinking water use only (i.e. water from the spring is likely not used for sanitation). For the above reasons, no water demand was assigned to surface water sources. There are four active applications for groundwater diversion from AQ834, for Savary Shores Improvement District (incorporated within metered use values), and for qathet (Powell River) Regional District, for the firehall (included under government buildings category).

5.4.5 Water demand calculation

Water demand calculation for unmetered/unreported use: Considering data sources and assumptions discussed above, the water demand was calculated for each land use category in the groundwater management areas using the formula:

Monthy water use (litres/month) = Daily use volume per land-use category (litres/day) X Residential use multiplier (if applicable) X % Occupancy per month X Days per month X Number of lots

Metered use: Water use within Groundwater Management Area E for residential categories was based on the long-term metered use in SSID.

Water use scenarios

Three water demand scenarios were considered:

- Scenario 1. Current water demand based on 2025 land use and seasonal residency patterns;
- Scenario 2. Potential water demand based on 2025 land use and full-time residency (current licenced use for fire suppression);
- Scenario 3. Potential water demand based on development of all residential lots, excluding current conservation parcels, and full-time residency (current licensed fire suppression use).

5.4.6 Accuracy and validation

- For Scenario 1, the accuracy of the % Occupancy factor was validated by estimating the island population in each month, assuming an average number of persons per non-vacant residential parcel as 2 per parcel in fall and winter (October to April), 2.5 residents per parcel in shoulder season (May, June and September) and 3 persons per non-vacant residential parcel in summer (July-August). The resulting population estimates were consistent with the population estimates from community surveys and other sources. It is noted that the population estimated does not represent persons residing on the island for the whole month but rather present at some period during the month. Because the water use per parcel is low (200 L/day in winter up to 400 L/day in summer), variations in the % Occupancy do not make a significant difference in the final water demand calculated.
- The peak season population estimates for this study were lower than predicted by BC Hydro (BC Hydro, 2012), however our analysis considered only non-vacant lots on the Island (excluding lots designated as undeveloped), whereas BC Hydro considered a larger number of parcels (1020) as potentially inhabitable.
- For lots within SSID, the water use estimated (modelled) was compared to the long-term measured average and percentiles, resulting in volumes within ±20%.

5.4.7 Estimated annual water demand results

The estimated water use for per region is shown in Table 12. For Scenario 1, considering current (2025) land use and seasonal occupancy, the total current water use for Savary Island is estimated as 30,600 m^3/year. Nearly all water use is for residential purposes (99%) within different land use categories. The highest water demand occurs during the months from June-September annually, with July being the peak month. The estimated monthly water demand (2025), seasonal occupancy and monthly per connection water use is shown in Figure 23.

For the different groundwater regions, because it is the largest, Area B has the highest demand of 15,100 m^3/year or roughly half of total water use on the island. Use in Area E (Savary Shores) and Area F (east island) are roughly equivalent at 5,200 m^3/year followed by Area A (Thah teq, Indian Point) 4,200 m^3/year. Because it has the largest average lot size of all groundwater regions, Area D has the lowest demand of roughly 800 m^3/year.

Scenario 2 considered the water demand if all currently developed (non-vacant) lots were occupied full-time, but while maintaining a relatively low water use (due to high conservation) of 240 L/d. This scenario would more than double water demand up to 73,400 m^3/year. In Scenario 3, the estimated water demand assumes all developable lots are occupied full time, excluding currently protected conservation areas. This results in an annual water demand up to 116,700 m^3/y.

The water use values for all scenarios were compared to estimated monthly and annual recharge to develop the aquifer water balance. None of the scenarios considered available drawdown or other limits to pumping such as water quality impacts (i.e. seawater intrusion). In addition, all water use was considered consumptive (i.e. the potential contribution of septic effluent to groundwater recharge was ignored. This assumption is considered reasonable, as the majority of septic discharge would be during the summer, when there is a soil moisture deficit and shallow discharge is likely to be used by evapotranspiration.

Table 11. Lots within primary land use categories for Savary Island (2025 Assessment Year).

					GW Use / Water System						
					NO	YES	YES	YES			
Region	Actual Use Code	Primary Actual Use Category	Number of lots in category (Note 1)	Conservation lots (vacant category)	Outside SSID (No Water Use)	Outside SSID (Water Use)	In SSID (Water from SSID)	In SSID (Do not receive water from SSID)	Water use category (Note 2)	Residential use multiplier (if applicable)	Note
A	000	Single Family Dwelling	101			101			R	1	
	001	Vacant Residential < 2 Acres	48	7	48				NW		
	020	Residential Outbuilding Only	6			6			R	1	
	032	Residential Dwelling with Suite	1			1			RM	1.5	
	040	Seasonal Dwelling	3			3			R	1	
	060	2 Acres Or More (Single Family Dwelling, Duplex)	1			1			R	1	
B	000	Single Family Dwelling	294			294			R	1	
	001	Vacant Residential < 2 Acres	282	11	282				NW		
	020	Residential Outbuilding Only	27			27			R	1	
	038	Manufactured Home (Not In Manufactured Home Park)	2			2			R	1	
	040	Seasonal Dwelling	59			59			R	1	
	060	2 Acres Or More (Single Family Dwelling, Duplex)	6			6			R	1	
	061	2 Acres Or More (Vacant)	4	1	4				NW		
	062	2 Acres Or More (Seasonal Dwelling)	1			1			R	1	
	238	Seasonal Resort	1			1			RM	7	
	601	Civic, Institutional & Recreational (Vacant)	14		14				NW		
	620	Government Buildings	2			2			G		(5)
C	061	2 Acres Or More (Vacant)	1	1	1				NW		

Region	Actual Use Code	Primary Actual Use Category	Number of lots in category (Note 1)	Conservation lots (vacant category)	GW Use / Water System: NO – Outside SSID (No Water Use)	GW Use / Water System: YES – Outside SSID (Water Use)	GW Use / Water System: YES – In SSID (Water from SSID)	GW Use / Water System: YES – In SSID (Do not receive water from SSID)	Water use category (Note 2)	Residential use multiplier (if applicable)	Note
D	000	Single Family Dwelling	16			16			R	1	
	001	Vacant Residential < 2 Acres	3	1	3				NW		
	020	Residential Outbuilding Only	2			2			R	1	
	032	Residential Dwelling with Suite	1			1			RM	1.5	
	060	2 Acres Or More (Single Family Dwelling, Duplex)	2			2			R	1	
	061	2 Acres Or More (Vacant)	3	3	3				NW		
E	000	Single Family Dwelling	1					1	R	1	(6)
			153				153		SS	1	
	001	Vacant Residential < 2 Acres	41		41				NW	0	
	020	Residential Outbuilding Only	1					1	R	1	
			8				8		SS	0	
	040	Seasonal Dwelling	6				6		SS	0	
	236	Campground (Commercial)	2				2		SS	0	
	272	Storage & Warehousing (Open)	1				1		SS	0	
	273	Storage & Warehousing (Closed)	1		1				NW		
	560	Water Distribution Systems	1				1		NW		
	620	Government Buildings (Includes Courthouse, Post Office	2				2		SS		
	652	Churches & Bible Schools	1				1		SS		
	-	Savary Shores Improvement District (SSID) metered use							SSID		(7)
F	000	Single Family Dwelling	118			118			R	1	
	001	Vacant Residential < 2 Acres	2	2	2				NW		
			120		120				NW		
	020	Residential Outbuilding Only	8			8	126		R	1	

Region	Actual Use Code	Primary Actual Use Category	Number of lots in category (Note 1)	Conservation lots (vacant category)	GW Use / Water System: NO Outside SSID (No Water Use)	YES Outside SSID (Water Use)	YES In SSID (Water from SSID)	YES In SSID (Do not receive water from SSID)	Water use category (Note 2)	Residential use multiplier (if applicable)	Note
	032	Residential Dwelling with Suite	1			1			RM	1.5	
	040	Seasonal Dwelling	9			9			R	1	
	062	2 Acres Or More (Seasonal Dwelling)	1			1			R	1	
	070	2 Acres Or More (Outbuilding)	1			1			R	1	
	601	Civic, Institutional & Recreational (Vacant)	4		4				NW		
	654	Recreational Clubs (tennis court)	1		1				NW		

Notes

(1) Land use categories and lot estimates from BC Assessment Authority (2025) Assessment Roll updated following Sept 2024 field audit.

(2) Water use categories: R=Residential RM=Residential use with multiplier NW=No water use G=Government use (e.g. firehall) SSID=Savary Shores Improvement District measured data SS=Usage accounted for in SSID total.

(3) Seasonal occupancy factor (% developed lots occupied per month) based on SSID average (2021-2023), BC Hydro (2011) estimated monthly percent occupancy, and community surveys (ASIC (2023), qRD (2024).

(4) Water use per residential category lot based on long-term monthly average in SSID (1998-2023).

(5) Water for practicing firefighting reported from Savary Island Fire Department as 20,000 - 30,000 US Gallons/year. Active groundwater license applications for 0.5 m^3/d (facility usage) and 67 $m^3/year$ for firefighting including practice (equivalent to ~25,000 USgallons/year). Licensed volume was converted to litres. Water use for firefighting practice divided between months of May to September.

(6) Savary Island Store lots are categorized by BC Assessment as residential and residential outbuilding. Assume use equivalent to one residence per parcel. There are no formal public washrooms at the store. Actual water use may be slightly higher but generally similar to residential parcels (for washing equipment, fixtures and products, etc. Store closed in winter season.)

(7) Water use for lots inside SSID incorporated within average water use data from purveyor (except General Store).

Table 12. Savary Island water demand per groundwater region (2025 Assessment Year)

	(Note	January	February	March	April	May	June	July	August	September	October	November	December	Year	
		31	28	31	30	31	30	31	31	30	31	30	31	365	Days per month
Seasonal occupancy factor (% developed lots occupied per month)	(3)	10%	10%	20%	35%	40%	50%	80%	80%	50%	25%	15%	15%		
Residential use (daily volume per lot, litres)	(4)	200	200	200	200	250	250	400	400	200	200	200	200	240	% Occupancy Average (L/d)

Scenario 1: Savary Island Water Demand by Area (2025 land use, seasonal occupancy)

Total estimated demand (m³/month)														Lots with water use (2025)
A	70	63	140	236	349	422	1,116	1,116	338	174	101	105	4,229	112
B	261	236	507	847	1,257	1,513	3,957	3,957	1,216	629	371	384	15,135	392
C	-	-	-	-	-	-	-	-	-	-	-	-	-	0
D	13	12	27	45	67	81	213	213	65	33	19	20	808	21
E	122	104	196	304	407	547	1,300	1,349	412	212	125	129	5,206	173
F	86	78	172	291	429	519	1,374	1,374	416	215	125	129	5,206	138
All	552	493	1,040	1,722	2,509	3,083	7,960	8,010	2,446	1,264	741	766	**30,585**	836

Scenario 2: Savary Island Water Demand, Cubic Meters Per Month (Projected, full time occupancy all 2025 non-vacant lots, 240 L/d average use, current fire protection use)

Total estimated demand (m³/month)														Lots with water use (2025)
A	833	753	833	806	833	806	833	833	806	833	806	833	9,811	112
B	2,925	2,642	2,925	2,830	2,938	2,844	2,938	2,938	2,844	2,925	2,830	2,925	34,501	392
C	-	-	-	-	-	-	-	-	-	-	-	-	-	0
D	156	141	156	151	156	151	156	156	151	156	151	156	1,840	21
E	1,287	1,163	1,287	1,246	1,287	1,246	1,287	1,287	1,246	1,287	1,246	1,287	15,155	173
F	1,027	927	1,027	994	1,027	994	1,027	1,027	994	1,027	994	1,027	12,089	138
All	6,228	5,625	6,228	6,027	6,241	6,040	6,241	6,241	6,040	6,228	6,027	6,228	**73,396**	836

Scenario 3: Savary Island Water Demand, Cubic Meters Per Month (Projected, Full time occupancy all residential habitable lots, 240 L/d average use, current fire protection use

Total estimated demand (m³/month)														Lots with water use (projected)
A	1,138	1,028	1,138	1,102	1,138	1,102	1,138	1,138	1,102	1,138	1,102	1,138	13,403	153
B	5,067	4,577	5,067	4,904	5,081	4,917	5,081	5,081	4,917	5,067	4,904	5,067	59,730	680
C	-	-	-	-	-	-	-	-	-	-	-	-	-	0
D	171	155	171	166	171	166	171	171	166	171	166	171	2,015	23
E	1,607	1,452	1,607	1,555	1,607	1,555	1,607	1,607	1,555	1,607	1,555	1,607	18,922	216
F	1,920	1,734	1,920	1,858	1,920	1,858	1,920	1,920	1,858	1,920	1,858	1,920	22,601	258
All	9,903	8,945	9,903	9,584	9,917	9,597	9,917	9,917	9,597	9,903	9,584	9,903	**116,670**	1330

(3): Seasonal occupancy factor (% developed lots occupied per month) based on SSID average (2021-2023), BC Hydro (2011) estimated monthly percent occupancy, and community surveys (ASIC (2023), qRD (2024).
(4): Water use per residential category lot based on long-term monthly average in SSID (1998-2023).

Tupper (1996) estimated annual water use as 12,600 m^3/year for the entire Island when his survey was completed in 1995. Based on SSID operational data, the number of connected lots and the volume of water use within the service area have increased 55% since 1998. Therefore, if a similar growth pattern was applied to the historical water use estimate, it would project an increase in annual water demand up to 19,530 m^3/year for the present day. Current use is likely to be higher than in the past as it is expected that there is much greater use and reliance on drilled wells in comparison to sand points and shallow dug wells within recent decades. Also, there is a trend of increasing residence size and increased household amenities such as flush toilets, resulting in an overall higher usage expected per parcel. In a more recent study, Chesnaux (2021) used a simplified method to estimate water use on the Island as 12,780 m^3/year, assuming 100 full-time inhabitants using 350 litres per day year-round. In comparison, the estimate from this (current) study is founded on reported data, and well-defined assumptions, including local usage patterns.

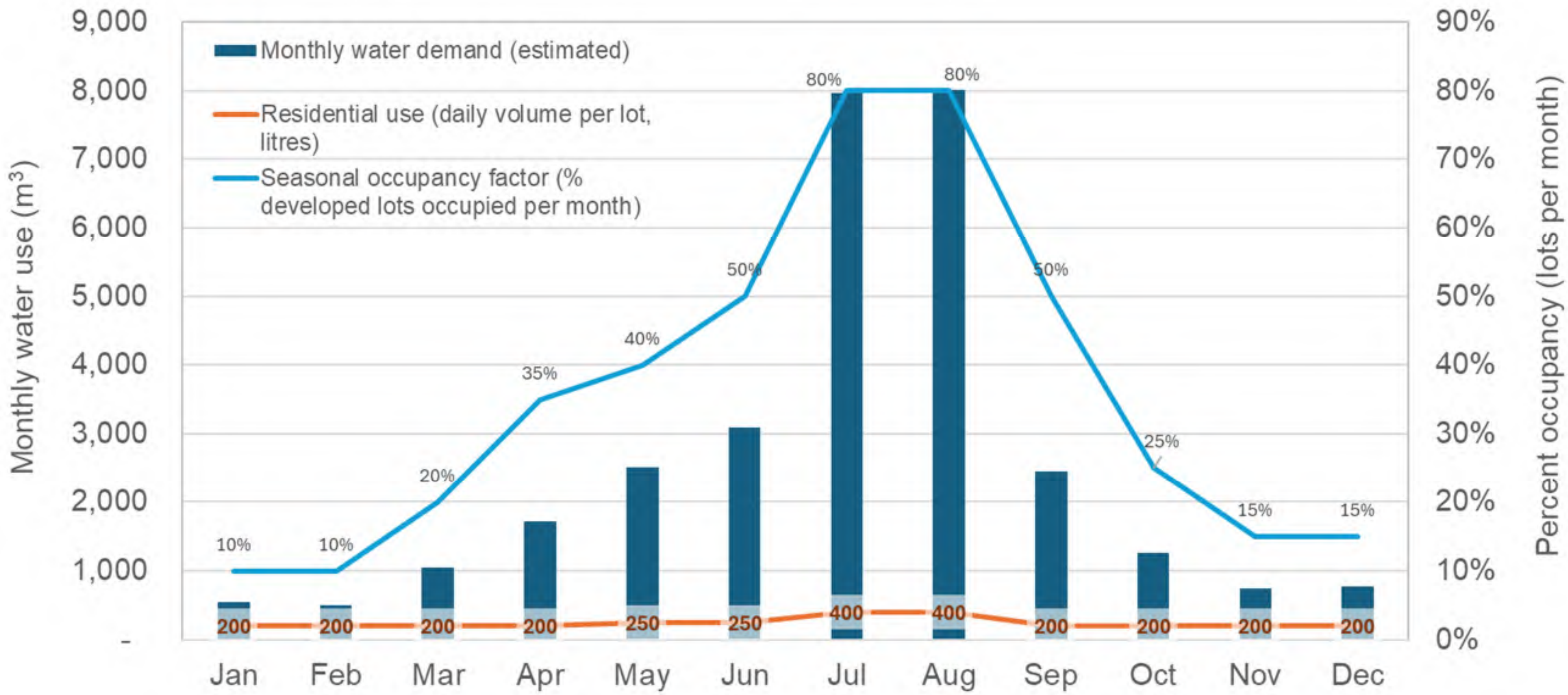


Figure 23. Savary Island 2025 estimated monthly water demand, average residential use per lot and seasonal occupancy (%).

5.5 Water balance results

The final step in calculating the water balance was to compare water outputs (water use or demand) to water inputs (groundwater recharge). Figure 24 shows the annual water balance of water use compared to recharge for the management regions on Savary Island.

The water balance considered water availability based on the 2025 climate, and three water demand scenarios: seasonal occupancy of currently developed lots (i.e. status quo), full-time occupancy of existing developed lots, and full-time occupancy of all developable lots excluding existing conservation parcels.

The water stress category indicates the relative amount of water use compared to available groundwater recharge, based on the United Nations Renewable Stress Scale (Richey et al., 2015). If less than 10% of available recharge is used for water demand, the aquifer stress level is considered low, while using 10 to 20% of groundwater recharge would be considered a moderate level of stress, and greater than 20% would be considered a high stress level.

Based on current water use and occupancy, water demand is less than 10% of groundwater recharge in all Savary Island areas. The highest percentage of use is in groundwater management region A (7%), while all other regions use less than 5% of recharge. Under the buildout scenario 2 (currently developed lots occupied full time), the proportion of water use to recharge increases to a moderate level of aquifer stress. Under the full buildout scenario both area A and F would reach or approach a high aquifer stress.

The seasonal variation in demand vs availability was also considered. Graphed values of demand vs recharge by month are included in Figure 25 (by area) and Figure 26 (island-wide). Because the spring and summer have low precipitation, high temperatures, high rates of evapotranspiration and a soil moisture deficit, even under the current (2025) climate, water use and land use scenario, the water demand will exceed recharge in all months from April to September, coinciding with the period of greatest water use. During this period, water must be pumped from storage in the aquifer.

While many potential scenarios could be evaluated, three scenarios were chosen to consider the potential effects if Savary Island were to transition from a mainly recreational community, inhabited seasonally, to a community of more full-time residents. The findings confirm that there is likely to be increased water stress if occupancy increases. Moreover, the anticipated volumes of water use per connection were conservative and reflective of water demand in the lowest range, consistent with smaller cabins, self-supply of power and sanitary services, and minimal irrigation use. Higher rates of water demand, in the range used in moderate sized or larger homes in rural or semi-rural communities in BC would further increase water stress. Additional factors including climate change (higher temperatures and changing precipitation patterns), sea water intrusion and aquifer intrinsic vulnerability to contamination will also affect water sustainability on the Island.

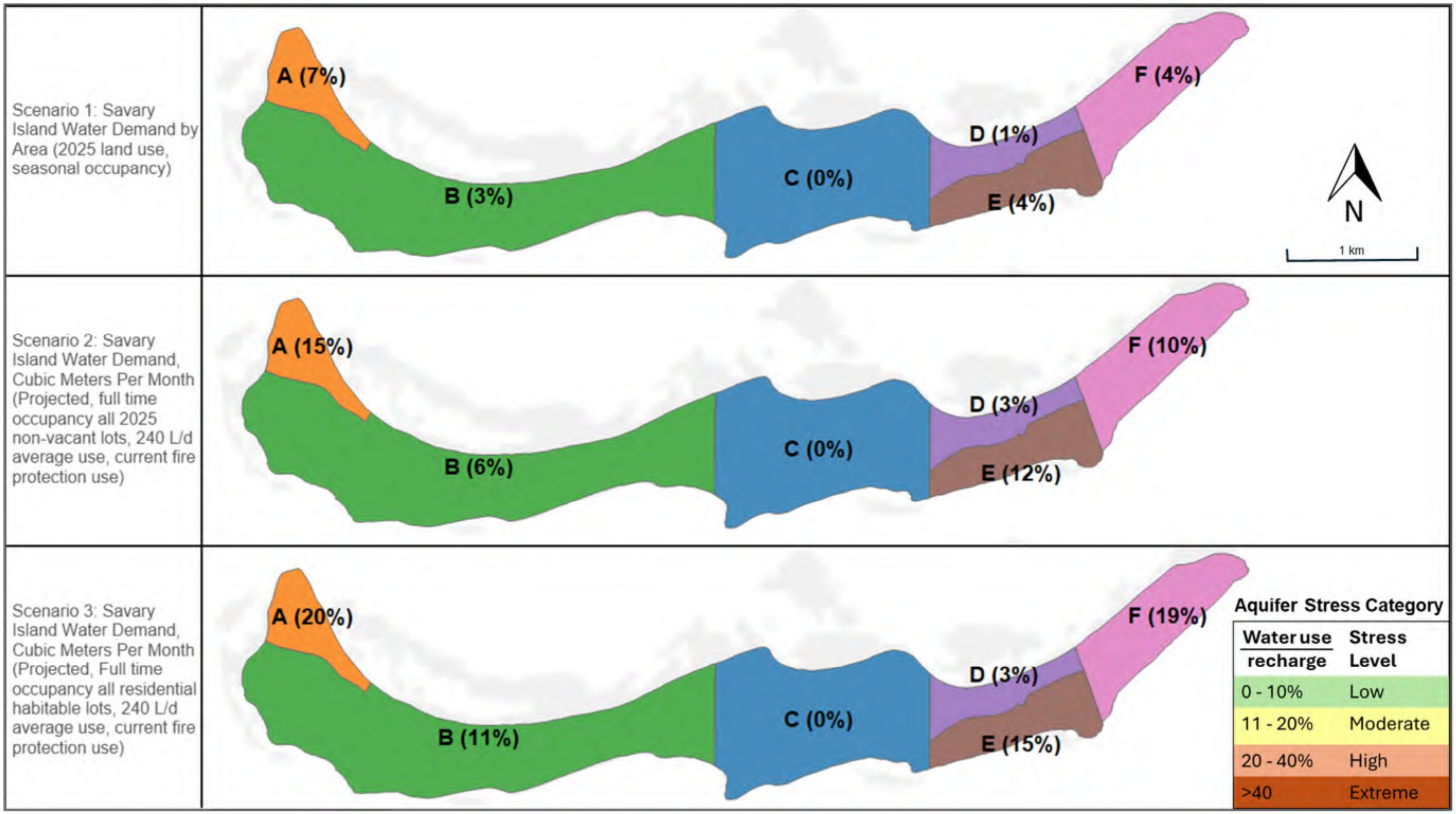


Figure 24. Savary Island annual water demand vs recharge by management area for different water use scenarios.

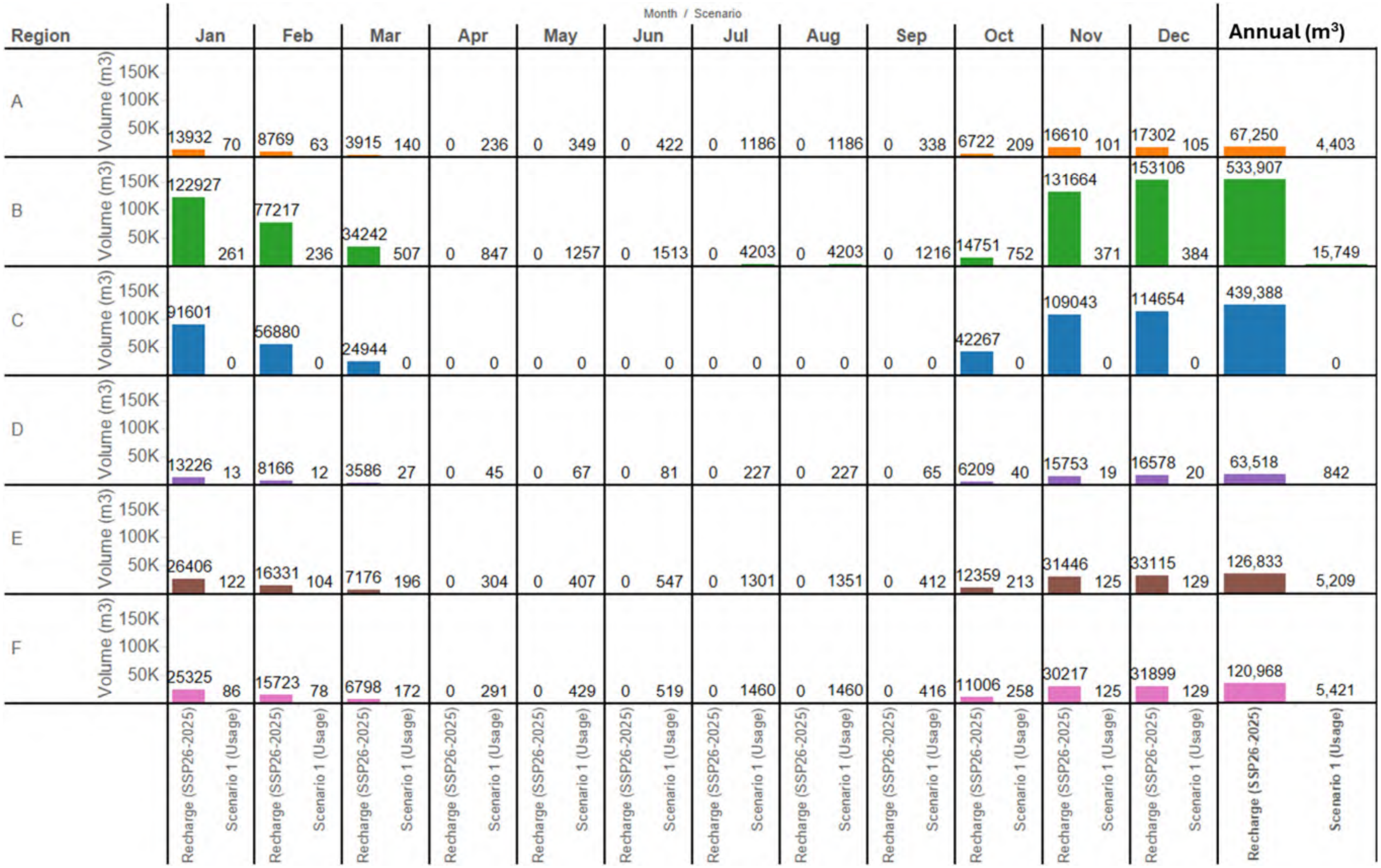


Figure 25. Savary Island monthly water use versus groundwater recharge by region (current 2025 climate, land use and water demand).

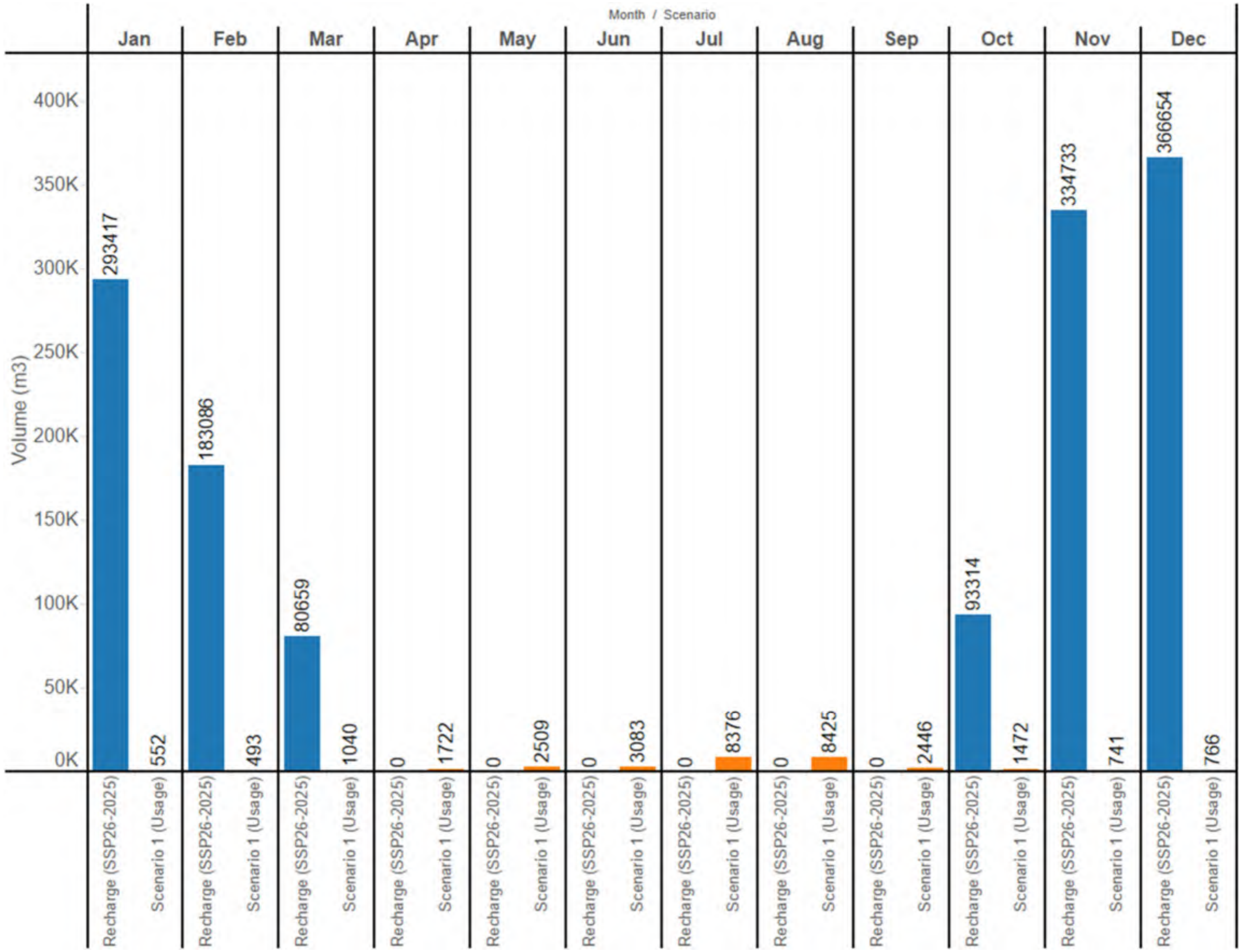


Figure 26. Savary Island (whole island) monthly groundwater recharge and water demand (current 2025 climate, land use and water demand).

6 IMPACTS OF CLIMATE CHANGE ON FRESHWATER RESOURCES

Climate change is one of the most challenging pressures facing humanity today. A key change associated with climate change is an increase in near-surface air and ocean temperatures which has profound impacts on the global water cycle affecting both the quality and quantity of freshwater systems (Bates et al., 2008).

A 2017 report Climate Projections for the Capital Regional District (CRD) used current climate models to predict how climate change will alter environmental conditions in south coastal BC over the coming decades (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). All of the climate models projected daytime high and nighttime low temperatures to rise. While temperatures are expected to increase year-round, the greatest increases will occur in the summer months. Monthly high and low temperatures show that the "new normal" for the region may be very unlike the past. Rising temperatures will lead to hotter summer days and nights, milder winters with the near loss of frost days and snowpack in all but the highest elevations. There may be a modest increase in annual precipitation by the 2050s, though the increase in precipitation will be distributed unevenly over the seasons. The largest increase is likely to occur in the fall season, while rain will decrease significantly in summer months. This region can expect stronger and more frequent extreme rainfall events, longer summer dry spells, and an extension of the dry season into September and October. In this context, some ways that climate change could affect freshwater resources on Savary Island and in the qathet Region are summarized below.

Wetter Winters: Climate change is affecting how much and when rain and snowfall occurs, and how long winters last. In coastal BC, winter precipitation is expected to increase, mainly occurring as rain due to higher temperatures (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). Reduced snowpack accumulated at the end of the winter season will limit water storage, reducing the delayed release critical to groundwater recharge and needed for baseflow in river systems (Gullacher et al., 2023). Increased rainfall may lead to higher aquifer recharge, but this will be received over a shorter period, affecting the seasonal patterns of groundwater level response (Green et al., 2011). For example, groundwater levels may begin to decline sooner in spring, affecting water availability later in the summer.

Higher Intensity Rainfall Events: When the atmospheric temperature is warmer, it can evaporate and hold more moisture. Consequently, an increase in high-volume, high-intensity precipitation events is expected, especially during winter months (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). Sporadic, high intensity rainfall – rather than low-volume, temporally distributed rainfall – tends to produce a large amount of surface runoff (soil erosion, flooding) but reduces groundwater recharge as there is a limit to the amount of water that can infiltrate into most soils at any given time (Green et al., 2011).

Increased Evapotranspiration: Higher evaporation (from all surfaces, soils, and water bodies) and higher transpiration from vegetation is expected, due to an increase in temperature, leaving less water to infiltrate into the soil and causing a reduction in groundwater recharge (Bates et al., 2008).

Droughts: Longer, drier summers will increase the risk of drought and reduce water availability during the dry season (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). On Savary, as in other communities, peak water use also coincides with the period of lowest water availability, which will necessitate careful management of water supplies (Ministry of Water, Land and Resource Stewardship, 2024b).

Degradation of Water Quality: Decreased groundwater recharge or increasingly sporadic timing of recharge can lead to a reduced dilution by freshwater of natural minerals (iron, manganese, arsenic) and water contaminants from human activities (nitrogen/phosphorous from septic systems), especially during the dry summer months (Green et al., 2011). This can result in increased concentrations of harmful substances in the water (water pollution), negatively affecting aquatic environments, and undermining the health and sustainability of groundwater and groundwater-dependent ecosystems.

Seawater intrusion: Island aquifers are particularly vulnerable to the effects of sea water intrusion (Werner et al., 2013). Climate change will result in long-term sea level rise; while, during periods of storm surge sea levels may further increase temporally, and lowland areas may be overtopped by waves (Thissen et al., 2024). High densities of wells, intensive groundwater use and over pumping during dry seasons can increase stress on limited freshwater resources in coastal areas (Sivak and Wei, 2021; Werner et al., 2013). Seawater intrusion, exacerbated by climate change impacts is one of the most significant factors likely to affect the quantity and quality of freshwater available on Savary Island. Seawater intrusion processes, impacts and management are discussed further in section 9.1.

Increased Fire Risk: Hotter temperatures contribute to higher rates of evaporation, lower atmospheric humidity and drying of vegetation and soil, increasing fire risk in a warming climate (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). Rural communities in forested areas face an increasing hazard of forest fire related impacts. Fires can directly affect water resources by damaging water related infrastructure (distribution and treatment plants, pump systems, piping). Loss of vegetation, and alteration of soil structure reduces the ability of the soil to absorb water in fire damaged areas, increasing runoff and risk of landslides and flooding (Moazeni and Cerda, 2024). Changes in groundwater and surface water quality can also occur over a longer-term following a fire, including increasing water turbidity and the concentration of nutrients and other minerals (i.e. arsenic, nitrate, potassium, phosphorus, and dissolved organic carbon) (Emelko et al., 2011; Moazeni and Cerda, 2024).

6.1 Model-Predicted Climate Conditions for the Next Decades

The impact of climate change to the water resources of the study area was analyzed using data from the ClimateBC/ClimateNA data project (Wang et al., 2016) which provides statistically downscaled climate projection data across BC, based on a selection of models from the IPCC's Coupled Model Intercomparison Project (CMIP6). The CMIP6 Global Climate Models (GCMs) aim to estimate the patterns of future climate change under different scenarios of climate "forcing." These scenarios are called "shared socio-economic pathways" (SSPs) meant to represent various possible socio-economic pathways that society could take to respond to climate change in the coming years (Riahi et al., 2017). In the present analysis, four SSP scenarios have been considered, SSP 2.6, 4.5, 7.0 and 8.5 spanning the range from most optimistic (high rates of emission reduction and mitigation policies over the coming decade) to pessimistic (little to no climate change mitigation, leading to runaway climate change). Future climate change under each of these scenarios was predicted for three time-periods – 2025, 2055, and 2085.

Using the projected climate change for the four SSPs in the three future periods, monthly groundwater recharge was calculated for each scenario and compared the results to the historical "normal" values (1981-2010). For the 2025 and 2055 scenarios, shown in Figure 27 and Figure 28 respectively, groundwater recharge is expected to decrease in all months except December. The greatest difference is anticipated in March, April and October, indicating that the dry season is likely to lengthen significantly compared to present, causing groundwater levels to decline earlier in the spring, and aquifer replenishment to begin later in the fall. These patterns are consistent across all the SSP scenarios, while the magnitude of these changes is higher for the more pessimistic SSPs. The third (2085) scenario is included in Appendix E, Figure E6.

The results are consistent with changes expected under climate change globally. Increasing temperatures, particularly during the summer months, combined with higher solar radiation and lower summer precipitation will mean no groundwater recharge in summer, and a reduced potential for groundwater recharge in the spring and early fall. The current hydrological regime, however, already operates within a pattern of excess water during the winter and low precipitation during the summer. The impact of climate change on this system will reduce the available window or annual time-period for groundwater recharge, and increase the water deficit during the dry season, when water usage is highest. The longer dry season will also increase soil and plant moisture stress, increasing fire risk in vegetated areas.

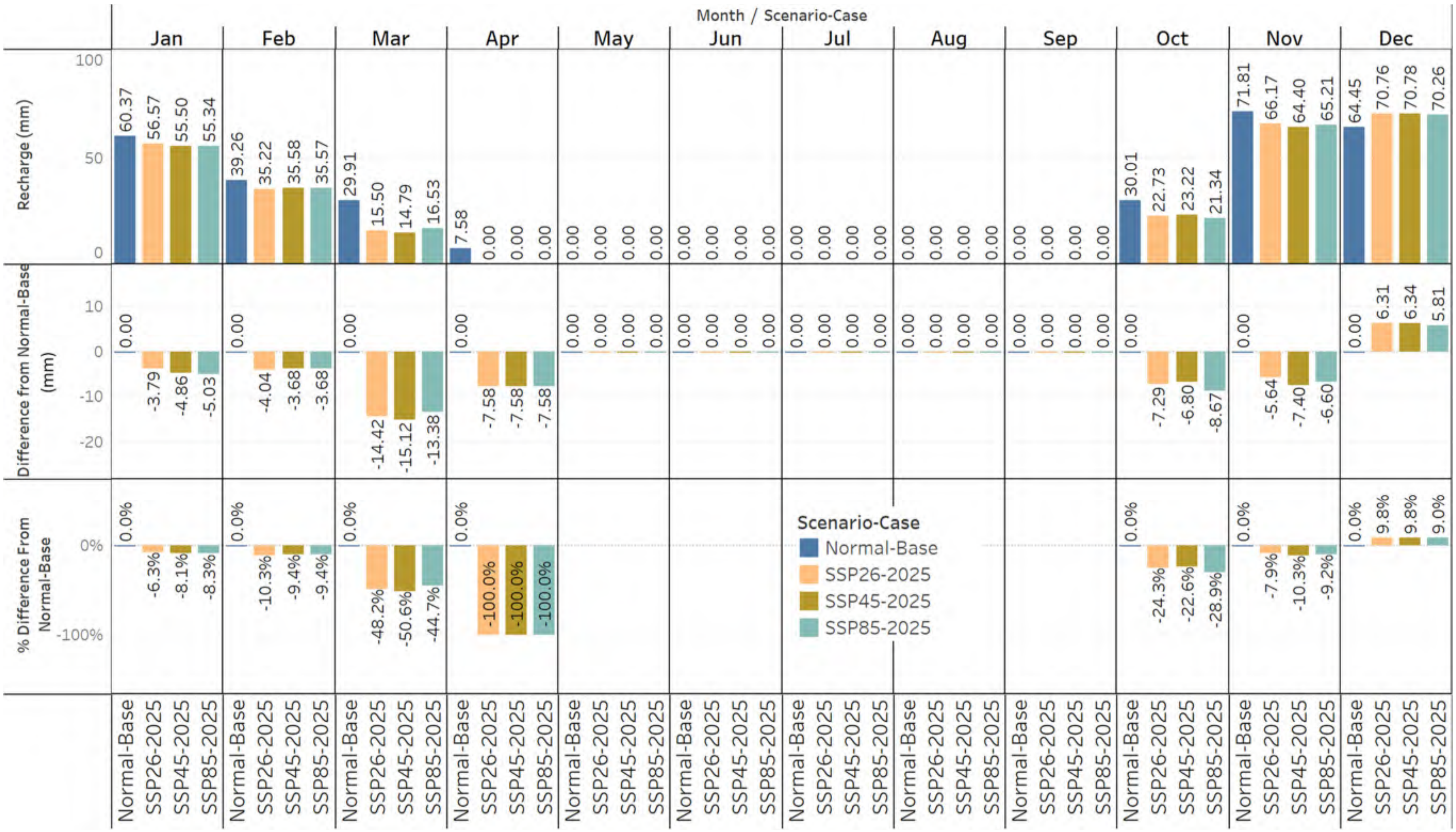


Figure 27. Estimated recharge and change in 2025 (current year) relative to 1981-2010 climate normals, summarized by month for Savary Island, SSP 2.6, 4.5 and 8.5.

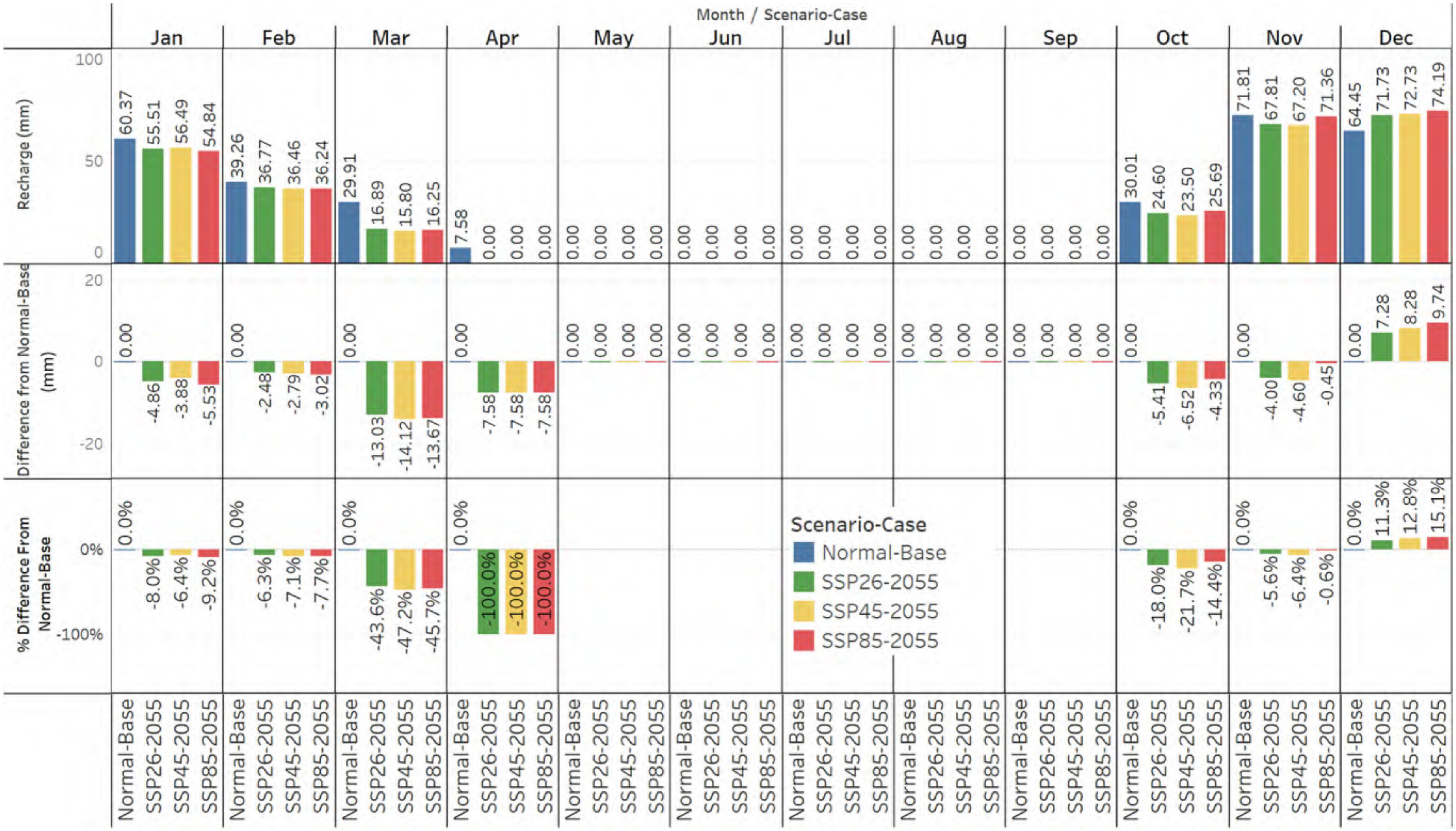


Figure 28. Estimated recharge and change in 2055 relative to 1981-2010 climate normals, summarized by month for Savary Island, SSP 2.6, 4.5 and 8.5.

7 GROUNDWATER PROTECTION, WELL CONSTRUCTION & MAINTENANCE

Proper well construction, maintenance and operation are critical for the protection and sustainability of groundwater resources. The *Water Sustainability Act*, Groundwater Protection Regulation (GPR) outlines the requirements to ensure wells are constructed and maintained properly, such installing and maintaining well caps and surface seals, grading, flood protection, and keeping the area around a well free of foreign matter which could contaminate the groundwater supply. These standards must be followed by well drillers, pump installers and homeowners.

During the September 2024 field assessment, information was collected at each surveyed site on well construction aspects. The majority of inspected wells (40 wells, 74%) were drilled wells, 12 wells (22%) were driven sand point wells, while 2 (4%) were excavated or dug. Most wells observed were compliant with GPR well construction standards, including use of a secure well cap (96% of wells). A summary table of observations in comparison to the GPR requirements is included in Appendix F. In addition to the documented well inspections, an additional 12 wells were observed in the field along roadways some of which have protection concerns, such as unfilled water line trenches, or proximity to foreign matter (i.e. garbage or waste around the well).

Key practices that are important for well and aquifer protection on Savary Island are described below. Some observed well construction and maintenance practices that could be improved are shown in Figure 29. Diagrams showing construction characteristics of excavated, sand point (driven) and drilled wells that meet GPR standards are shown in Figure 30 to Figure 32.

Well inventory: There are many unregistered wells on the island which leads to an incomplete understanding of where and how many residents are using groundwater. It also limits the ability to understand well construction characteristics (such as depth of wells drilled) and where groundwater development pressures may be occurring from drilling of new wells. Efforts could be made to continue field inventory of wells and to register more wells in the GWELLS database. The Ministry of Water, Land and Resource Stewardship could also more strongly enforce compliance of well record submission by well drillers.

Surface seals: The Savary Island aquifer(s) are made of highly permeable sand, with a very shallow soil layer in most areas. During well construction, the area of drilling is disturbed and loosened, creating subsidence or voids around the well casing. Installation of a bentonite clay surface seal during well construction is essential. The surface seal around the well casing must also be restored after installation of the well pump and below ground water lines which connect to piping down through a hole in the side of the casing, connected by a water-tight coupling (pitless adapter). Trenching for water lines can act as a preferential pathway for surface water runoff to concentrate and flow toward the well. These must also be refilled and material re-compacted after water line installation. The land surface around the well should be graded and sloped so that surface water flows away from it.

Hand pump installations: Many sandpoint wells were equipped with hand pumps. While convenient for seasonal use, water discharge from the hand pump at the well head could cause erosion of soil and surficial materials. Similarly, if people do activities such as washing in this area, it could introduce contaminants to the well and aquifer. A splash pad such as a cement paving stone under the discharge point could help prevent erosion, however all washing should be done away from the well itself.

Foreign matter: Keeping the area around the well clean and accessible protects it from contamination. Foreign matter must be kept a minimum of 3 m away from the well. Foreign matter includes garbage, waste, pesticides/fertilizers, materials from construction or demolition, fuel or other potential contaminants. Vehicle parking or other sources of hydrocarbon contaminants such as generators should be kept a minimum of 3 m from the well, and ideally further away. Generators should be place on an impermeable surface or spill tray to avoid accidental spills.

Well to well setbacks: In areas with a high density of small lots, ensuring adequate setbacks for well construction can be a challenge. The GPR requires a minimum 15 m setback between water supply wells on adjacent properties. Some sites were observed with adjacent wells closer than 15 m.

Proximity of septic systems: A well should be sited a minimum of 30 m from any probable source of contamination such as a septic field, septic tank, or outhouse. Well siting setbacks are included in the *Public Health Act*, Health Hazards Regulation (Province of BC, 2011). Sewerage and septic system setbacks are specified in the *Public Health Act*, Sewerage System Regulation (Province of BC, 2004). This study did not complete detailed measurements or inspections of the well to septic setbacks, however some locations were noted where contaminant sources such as outhouses were sited too close to a drinking water well. In areas of high lot density and small lot size, it may be challenging to find a well site that is a sufficient distance from a septic system including those on adjacent parcels, especially for lots developed later than the neighbouring lots.

Figure 29. Savary Island well protection observations. A. New well with subsidence and unfilled annular space surrounding the casing after drilling (must be filled in with sealant and regraded). B. An unfilled trench where water lines were installed or C. annular space left open after installation of pitless adapter (water line) below ground. Both provide a preferentially pathway for contaminants to infiltrate toward the well and into the aquifer. Surface seal should be restored, trenches filled and area around well regraded to protect the well. D. Gas generator with no spill pan less than 3 m from well. An accidental spill could contaminate the well and aquifer. E. A low casing stickup (<0.3 m) increases risk of flooding, vermin or contaminant entry into a well. F. A well that is located close to a sewage source is at higher risk of contamination.

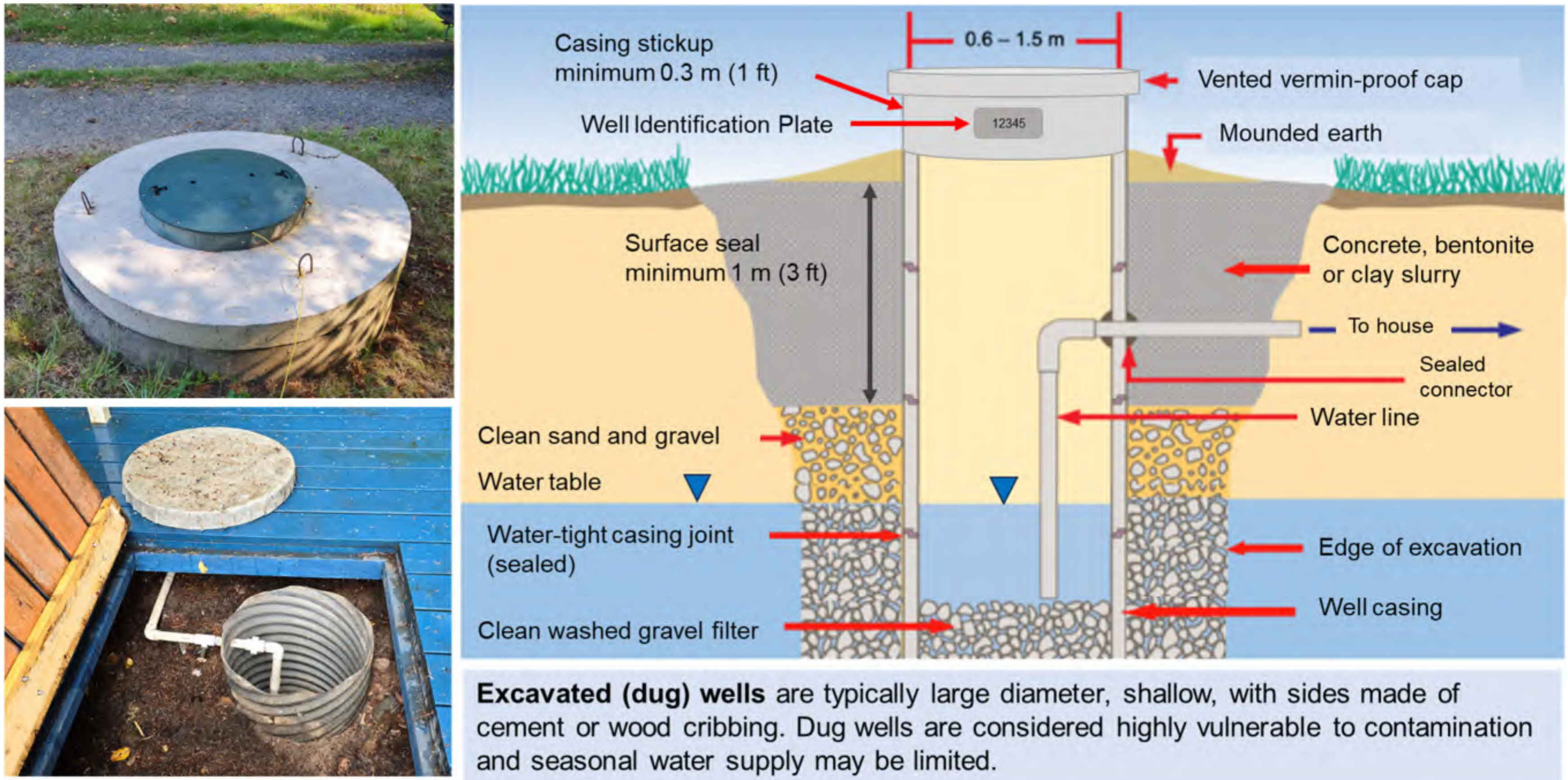
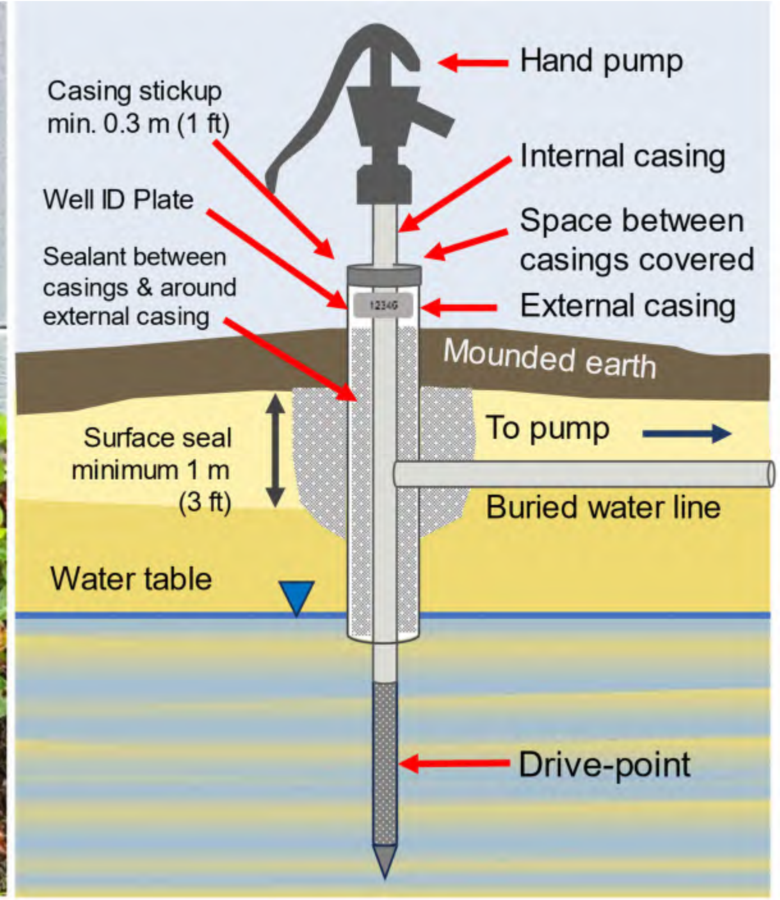
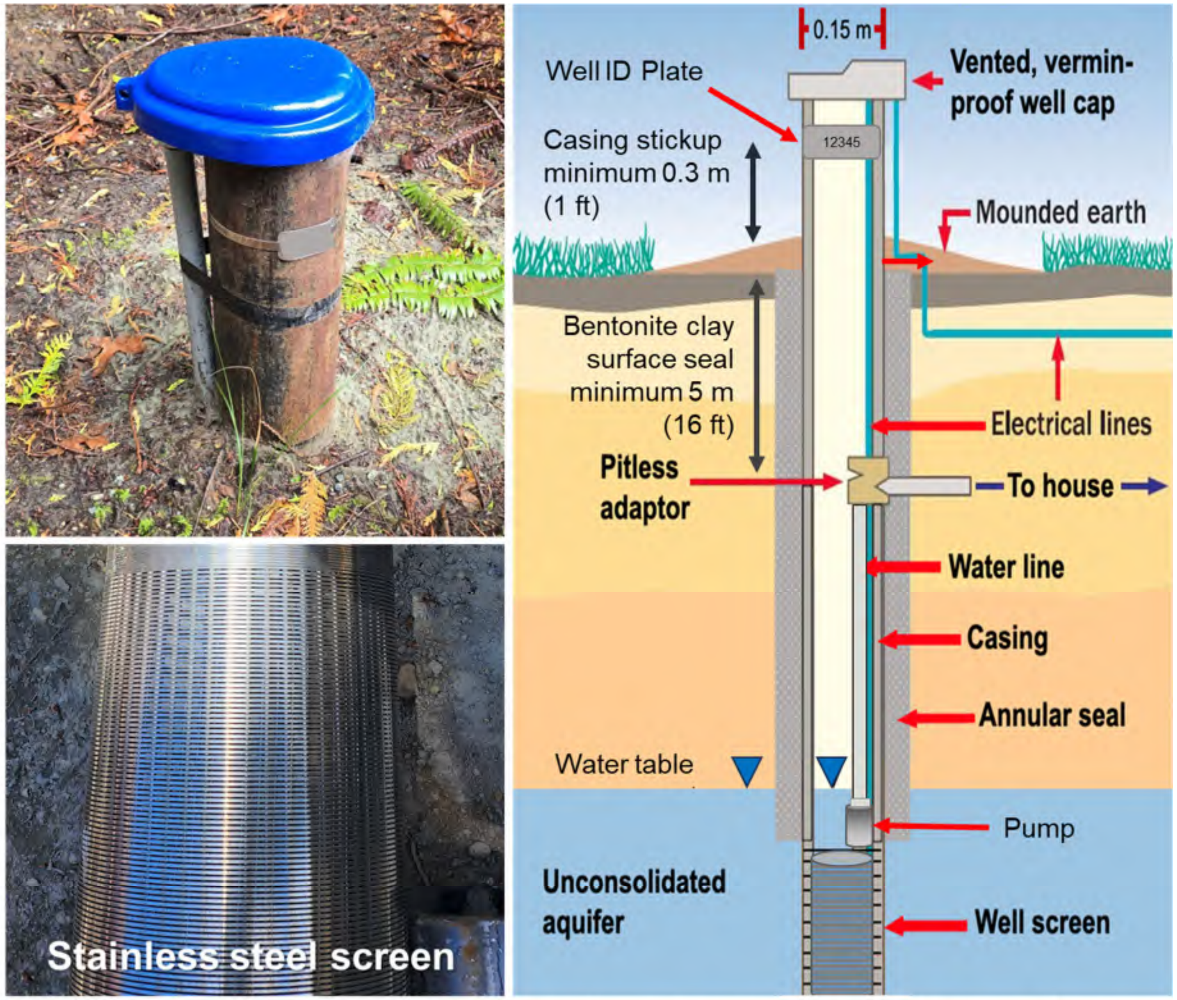


Figure 30. Excavated (dug) well construction and photo examples. Diagram modified from (Drage, 2022).



Sand point (driven) wells are constructed using a cylindrical pipe with a screen and pointed end which is hammered into the ground. They are usually shallower than drilled wells, with a smaller diameter (e.g. 2") stainless steel or galvanized aluminum screen. Sand points are considered vulnerable to contamination and water supply may be limited in the dry season.

Figure 31. Sand point (driven) well construction.



Domestic drilled wells in unconsolidated (sand and gravel) aquifers are often 0.15 m (6”) in diameter with steel casing and stainless steel well screen (bottom left). The wells vary in depth, water production and vulnerability depending on the aquifer characteristics.

Figure 32. Drilled well construction in an unconsolidated (sand and gravel) aquifer. (Diagram modified from (Drage, 2022))

8 GROUNDWATER QUALITY

Groundwater quality is a key indicator of aquifer health and vulnerability. Assessment of groundwater quality on Savary Island consisted of:

a) Compilation of all available existing groundwater quality data, including long-term sample results from Savary Shores Improvement District, historical studies, e.g. (Pacific Hydrogeology Consultants, 1987; Tupper, 1996), and sample data from Provincial observation wells.

b) A point-in-time evaluation of current groundwater conditions was conducted in September 2024. The field assessment included the measurement of field parameters (e.g. temperature, specific electrical conductivity, pH, and oxidation reduction potential) and the collection of groundwater samples for laboratory analysis at sites distributed across the island. This aspect of the project was considered essential to the understanding of current conditions on the Island. The work was completed in the autumn, during a period of low groundwater levels and therefore was considered representative of dry season conditions. Some rainfall occurred in the week prior to and sporadically during the field program. A summary of the type of locations sampled is included in Table 13.

Table 13. Summary of sample locations.

Water-related field observations	Sites	Field water quality	Lab sample (geochemistry)	Lab sample (bacteria)
Wells (inspected)	54	47	27	7
Springs	3	1	1	1
Ocean (sea water)	6	2	2	0
Rain	1	1	1	0
Total		51	31	8

8.1 Sample methods

Field parameters: Field water quality (temperature, conductivity, total dissolved solids, pH and oxidation reduction potential) was measured using a calibrated handheld YSI multimeter. For dug and sand point wells connected to a hand pump, the hand pump was used to fill a bucket while purging multiple times and collecting repeated measurements. Most wells had either a submersible (internal) or jet (external) pump. In that case, a point of discharge such as a hose bib was selected as close as possible to the well and prior to any water treatment system or storage tanks and connected to a discharge hose assembly (rated for potable use). The connection point was sterilized using a 10% bleach solution prior to connection of the hose assembly which directed water flow through a closed flow cell, allowing measurement of water quality parameters while limiting alteration of readings that could result from exposure to the atmosphere. Water quality was monitored continuously until the parameters had stabilized (<10% change in successive measurements).

Laboratory samples: At selected sites, water samples were collected for laboratory analysis of geochemical parameters following standard purging and sampling protocols (2013; Province of BC, 2020). For groundwater sample sites, water was purged until field parameters had stabilized, typically within 10 to 20 minutes. Wells in active use stabilized more quickly, while purging duration was longer for inactive wells (residents not in the home). Samples for analysis of metals and nutrient concentrations were filtered and preserved in the field and all samples were maintained at <4°C (kept refrigerated while on island and transported in ice-filled coolers to the lab at the end of the field program). In total, groundwater samples were collected from 27 wells for geochemical analysis. In addition, one sample was collected using a grab technique from qɛyɛ qʷən (Qaye qwun) Spring on the north side of the Island, two grab samples were collected from the ocean (north and south sides of the island), and one composite rainwater sample was collected in a clean sample bottle left open to collect rainfall over a 3-day period. Geochemical samples were analyzed by the accredited Bureau Veritas Laboratory in Burnaby, BC. Samples for analysis of bacteriological water quality were collected at a subset of 8 sites (7 wells and 1 spring) and analyzed at the Vancouver Coastal Health Office (Powell River) or Centres for Disease Control Laboratory (Vancouver). All participants were provided with copies of their field assessment and laboratory results following receipt from the lab. A list of sample parameters is included in Table 14. Example photos from the field assessment are shown in Figure 33.

Table 14. Sample parameters.

Field parameters (YSI)	Temperature, dissolved oxygen, specific conductivity, conductivity, total dissolved solids, pH and oxidation reduction potential
Inorganics (Lab)	Conductivity, dissolved organic carbon (DOC), pH, total dissolved solids (TDS), turbidity
Nutrients and anions (Lab)	Alkalinity, bicarbonate, carbonate, hydroxide, hardness chloride, sulphate, nitrite, nitrate, total ammonia, orthophosphate, phosphorus
Dissolved metals (Lab)	Aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silicon, silver, strontium, sulphur, thallium, tin, titanium, uranium, vanadium, zinc
Bacteria (Lab)	Total coliforms, *Escherichia coli* (*E.coli*)

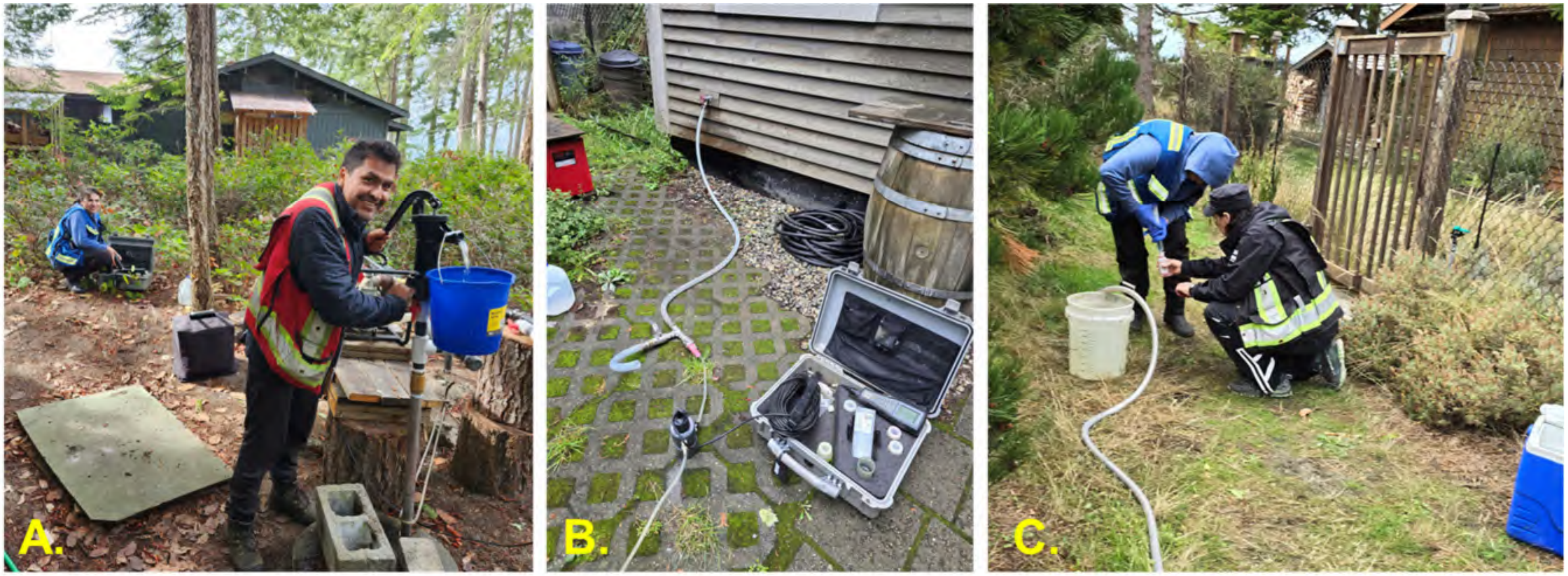


Figure 33. Field water quality assessment included A.-B. Purging and measuring field parameters, and C. Collecting samples for lab analysis.

8.2 Savary Island groundwater quality results

The results of the field sampling and geochemical data compilation are presented below, focusing on parameters related to potability and human health, environmental quality, and aquifer conditions (e.g. salinity). Locations where water quality data were collected or available from existing studies are shown in Figure 34. Groundwater sample results from September 2024 field survey are summarized in Table 15. Stations with longer term data compiled for the review included SSID Well 1 and 2.

8.2.1 Water type

A Piper diagram showing the relative concentration of major ions in water samples from Savary Island is shown in Figure 35. The different symbols represent the water sources i.e., drilled well, sand point well, spring, ocean or rainfall, while the colours represent the sample location within each groundwater management region. The water type indicates the relative proportion of major elements in the water sample, based on the position of the sample point in a representative quadrant of the diagram. The composition of the water samples identifies water originating from different sources, or that has undergone different geochemical processes, such as mixing, geochemical dissolution, or cation exchange.

Rainwater: The rain sample plots near the centre of the Piper diagram, with a sodium-bicarbonate (Na-HCO3) water type. The sample location was on the southwestern bluff of the island, and the rain composition indicates that ocean spray contributed to the dissolved mineral composition. Rainwater quality can vary seasonally, as wind born soil and other particulates are captured in the rain drops. Rain sampled at coastal and lower elevation locations in the southern Gulf Islands also demonstrates the influence of marine sources on its composition (Allen and Suchy, 2001). For comparison, the composition of rainwater chemistry data from long-term monitoring on Saturna Island is presented in Figure 42.

Ocean: Two samples were collected from shore locations at Savary, one on the southwest side of the island (along Sunset Trail) and the other on the northeast side of the island along Malaspina Promenade (near the barge ferry launch). On the Piper plot, ocean samples fall on the far right side of the diagram indicating a dominant sodium-chloride water type.

Groundwater: The groundwater type varies according to the location and well type. Groundwater from shallow sand point wells in area A are mainly calcium-bicarbonate (Ca-HCO_3) water type indicative of a fresh, recently recharged source. Drilled wells range from calcium-bicarbonate (Ca-HCO_3) to calcium-magnesium-bicarbonate (Ca-Mg-HCO_3) and sodium-chloride (Na-Cl) water type. Within the aquifer, more recently recharged groundwater is calcium-bicarbonate type (Ca-HCO_3) which undergoes a reaction in which the calcium is replaced by magnesium present in minerals within sand and gravel grains causing the water composition to evolve or mature toward a magnesium-bicarbonate water type (Ca-Mg-HCO_3). This effect is seen in samples from Area B and Area E (Savary Shores) where the unsaturated zone is thicker and the aquifer is deeper. Groundwater samples with a composition closer to sea water, sodium-chloride water type (Na-Cl), represent a mix between ambient groundwater and water from a marine source (salination pathway) indicating the potential impact of seawater intrusion, for example in groundwater sampled from some wells in Area F.

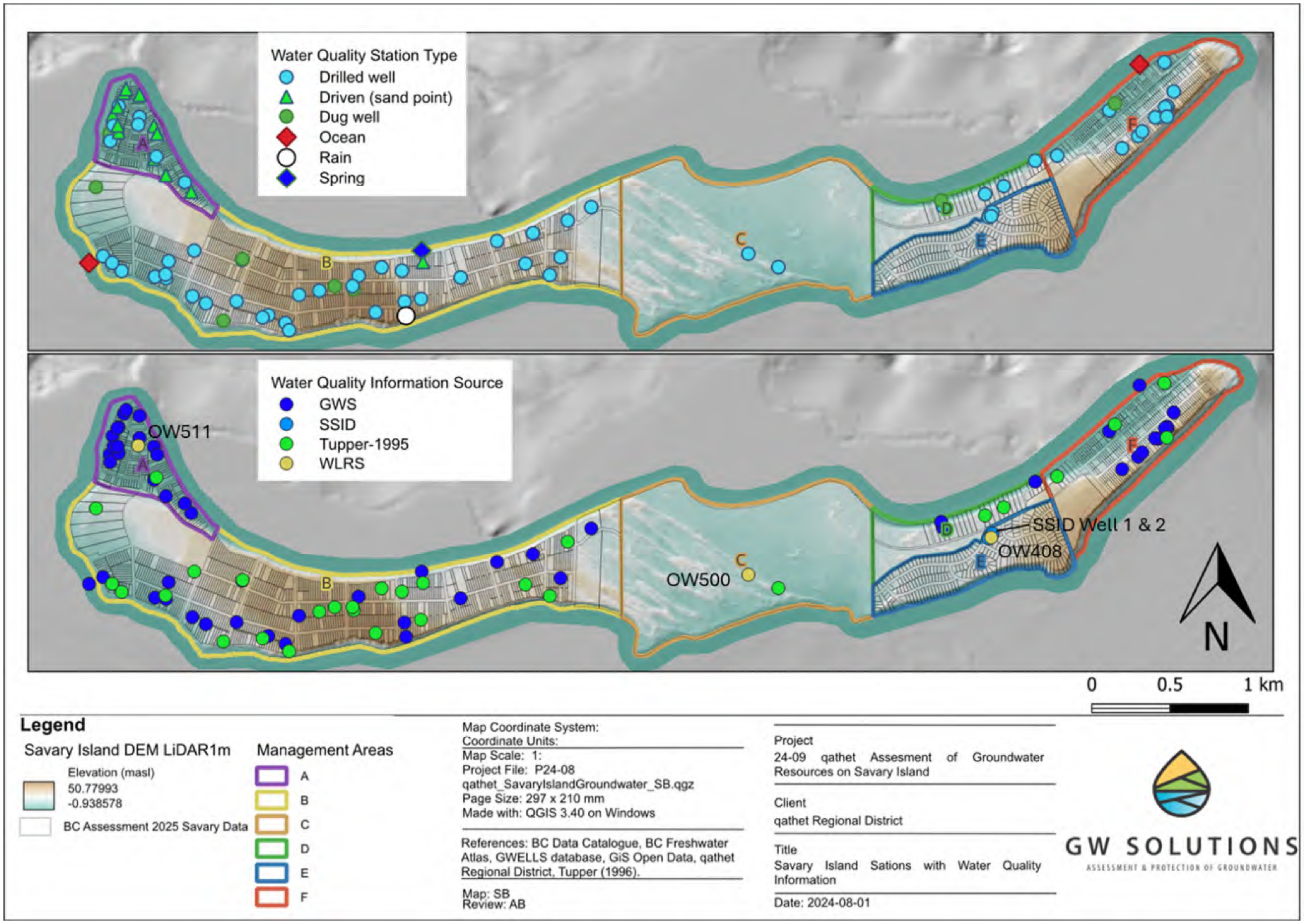


Figure 34. Savary Island water quality data and sample locations.

Table 15. Sample results range, median and guideline exceedances.

Parameter	Result Unit STD	Range concentration (Min-Max)	Median	MAC	AO	OG	Samples within guideline	Number of sample exceedencing guidelines		
								MAC	AO	MAC & AO
Chloride (Cl)	mg/L	11 - 92	36		250		27			
		340 - 340	340		250				1	
Dissolved Aluminum (Al)	mg/L	<0.003 - 0.06	0.003			0.1	28			
Dissolved Antimony (Sb)	mg/L	<0.0005 - <0.0005	0.0005	0.006			28			
Dissolved Arsenic (As)	mg/L	<0.0001 - 0.001	0.0001	0.01			28			
Dissolved Barium (Ba)	mg/L	<0.001 - 0.059	0.009	1			28			
Dissolved Boron (B)	mg/L	<0.05 - 0.1	0.05	5			28			
Dissolved Cadmium (Cd)	mg/L	<0.00001 - 0	1.00E-05	0.005			28			
Dissolved Chromium (Cr)	mg/L	<0.001 - 0.003	0.001	0.05			28			
Dissolved Copper (Cu)	mg/L	0 - 0.016	0.002		1		28			
Dissolved Iron (Fe)	mg/L	<0.005 - 0.28	0.018		0.3		26			
		0.896 - 3.21	2.053		0.3				2	
Dissolved Lead (Pb)	mg/L	<0.0002 - 0.001	0.0002	0.005			28			
Dissolved Manganese (Mn)	mg/L	<0.001 - 0.015	0.002	0.12	0.02		20			
		0.029 - 0.08	0.0325	0.12	0.02				6	
		0.137 - 0.191	0.164	0.12	0.02					2
Dissolved Selenium (Se)	mg/L	<0.0001 - 0.001	0.0001	0.05			28			
Dissolved Sodium (Na)	mg/L	11.7 - 75.5	21.6		200		27			
		214 - 214	214		200				1	
Dissolved Uranium (U)	mg/L	<0.0001 - 0.001	0.0001	0.02			28			
Dissolved Zinc (Zn)	mg/L	<0.005 - 4.46	0.0055		5		28			
Nitrate (N)	mg/L	<0.020 - 5.32	0.381	10			28			
Nitrite (N)	mg/L	<0.0050 - 0.0195	0.005	1			28			
pH	pH	6.66 - 6.97	6.715	7-10.5				8		
		7.01 - 8.1	7.53	7-10.5			20			
Sulphate (SO4)	mg/L	12 - 9.6	9.5		500		28			
Total Dissolved Solids	mg/L	100 - 94	155		500		26			
		530 - 720	625		500				2	

MAC=Maximum Acceptible Concentration, AO=Aesthetic Objective, OG=Operational Guideline. <Value indicates concentration below lab reportable detection limit.

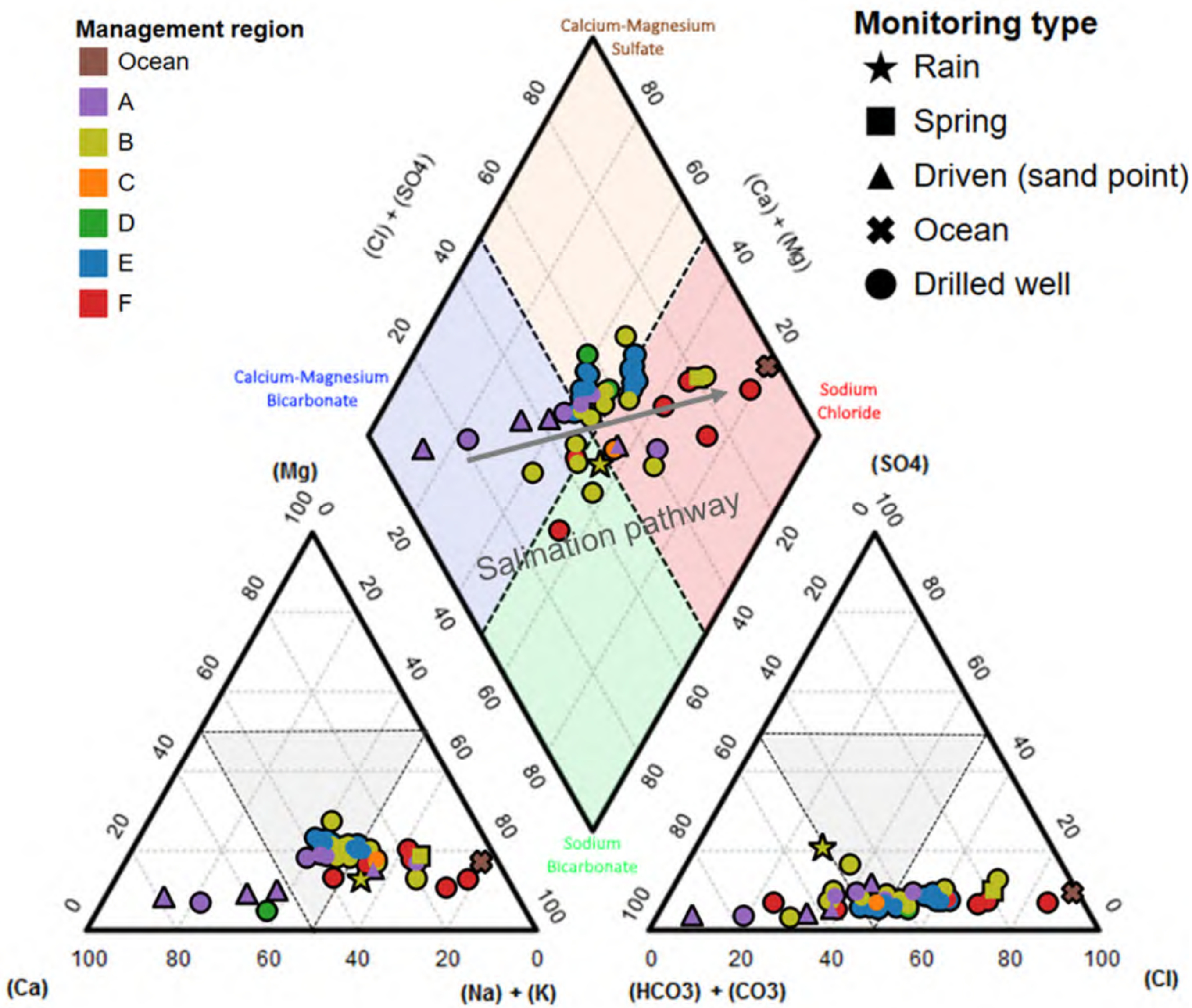


Figure 35. Piper plot of water samples from Savary Island water sources.

8.2.2 Natural contaminants

Elements such as arsenic, iron and manganese are commonly present in groundwater in this region, due to the weathering and dissolution of rocks in contact with the groundwater (McGuigan et al., 2010).

Arsenic in drinking water has no apparent smell or taste. It has been linked to both acute (toxic) and chronic health impacts including skin ailments, cardiological and neurological impacts and increased risk of some internal cancers (Health Canada, 2006). The guideline for Canadian drinking water quality for arsenic is a Maximum Allowable Concentration (MAC) of 10 µg/L (Health Canada, 2024a). However, due to potential long-term health impacts of arsenic in drinking water, Health Canada has recommended that arsenic concentrations be maintained as low as reasonably achievable, i.e. below 0.3 µg/L. Arsenic can be removed using treatment technologies such as ion exchange, adsorption, coagulation/filtration, greensand filters or reverse osmosis (Health Canada, 2006).

Iron and manganese are two metals often naturally present in groundwater, that can affect the aesthetic quality or pleasantness of water for drinking. The Health Canada Aesthetic Objective (AO) for iron is 100 µg/L; above this concentration the water may have a red colour, cause staining of plumbing or fixtures, and may be unpalatable for use (Health Canada, 2024b). Manganese is also commonly present in groundwater found on its own or in water that also has high iron concentration (Health Canada, 2024a). There are two Canadian guidelines for drinking water quality for manganese. The lower Aesthetic Objective (AO) is 20 µg/L, above this concentration the water may have a noticeable colour (e.g. visible black flecks or particulate), unpleasant taste and be less palatable for drinking, and can cause staining of household plumbing fixtures and laundry. A higher Maximum Allowable Concentration (MAC) for manganese of 120 µg/L has also been established; drinking water with manganese above this concentration may be associated with adverse health impacts including effects on neurological development in children. Both manganese and iron concentration can be reduced by water treatment using oxidation, adsorption with specialized granular media, and filtration (Health Canada, 2024b).

8.2.2.1 *Savary Island observations – natural contaminants*

Box plots showing the range in concentration of arsenic, iron and manganese in groundwater samples, by region are shown in Figure 36, and maps showing distribution of iron and manganese are shown in Figure 37. For all regions, the concentration of arsenic was below the MAC, with slightly higher concentrations observed in Area A. The median concentration of iron was below 100 mg/L (AO) and the median concentration of manganese was below 120 µg/L (MAC) and 20 µg/L (AO) in all regions. The exception was for Area D which included a sample from a shallow dug well that is a potential outlier and likely not representative. In Area C, data were available for the period prior to 2000, and for samples collected from 2000-2024; by comparison, the concentrations of iron, manganese and arsenic were lower in the most recent samples, possibly due to changes in sampling or laboratory methods between the two periods.

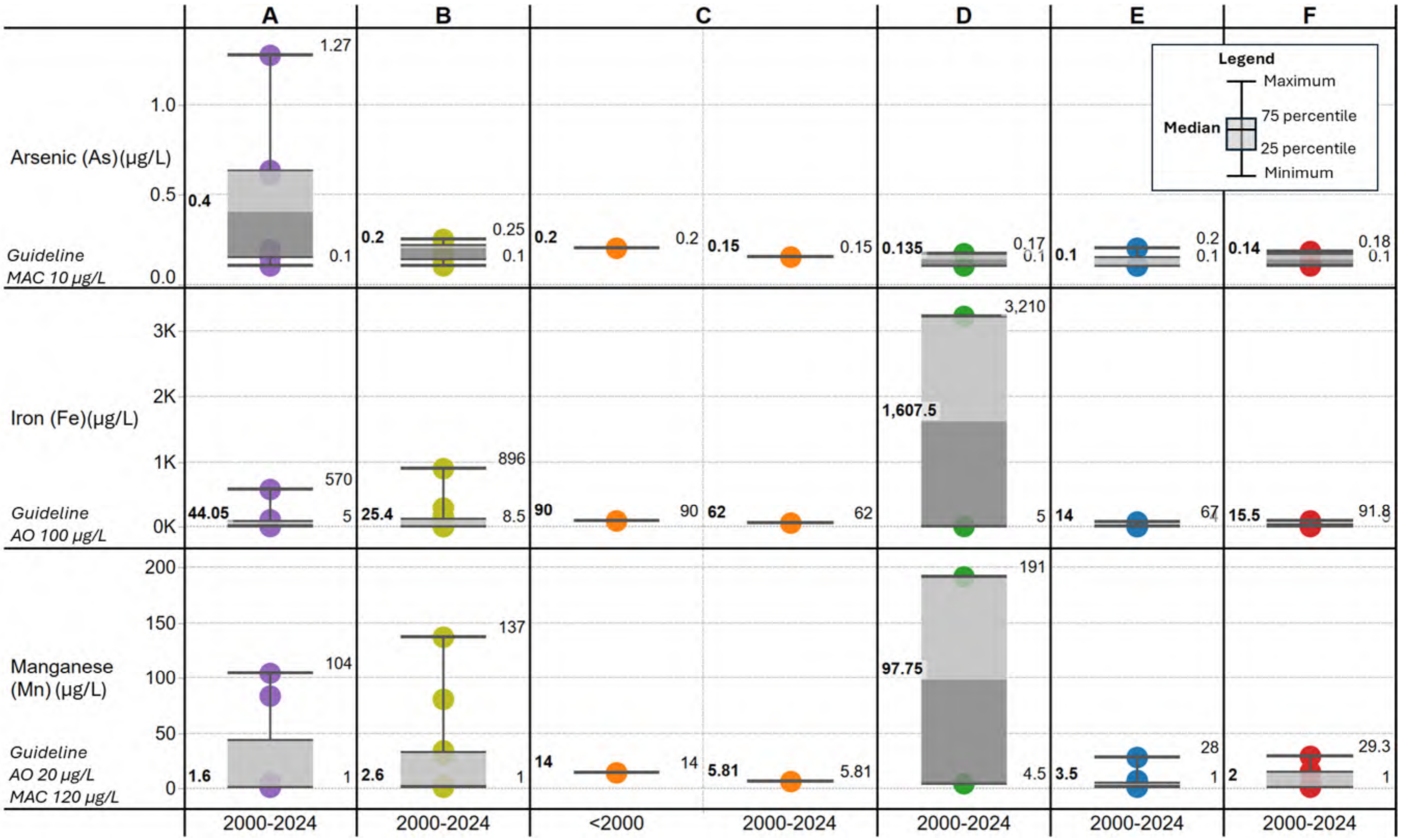


Figure 36. Box plots of arsenic, iron and manganese concentration in Savary Island groundwater samples (MAC=Maximum Acceptable Concentration, AO=Aesthetic Objective).

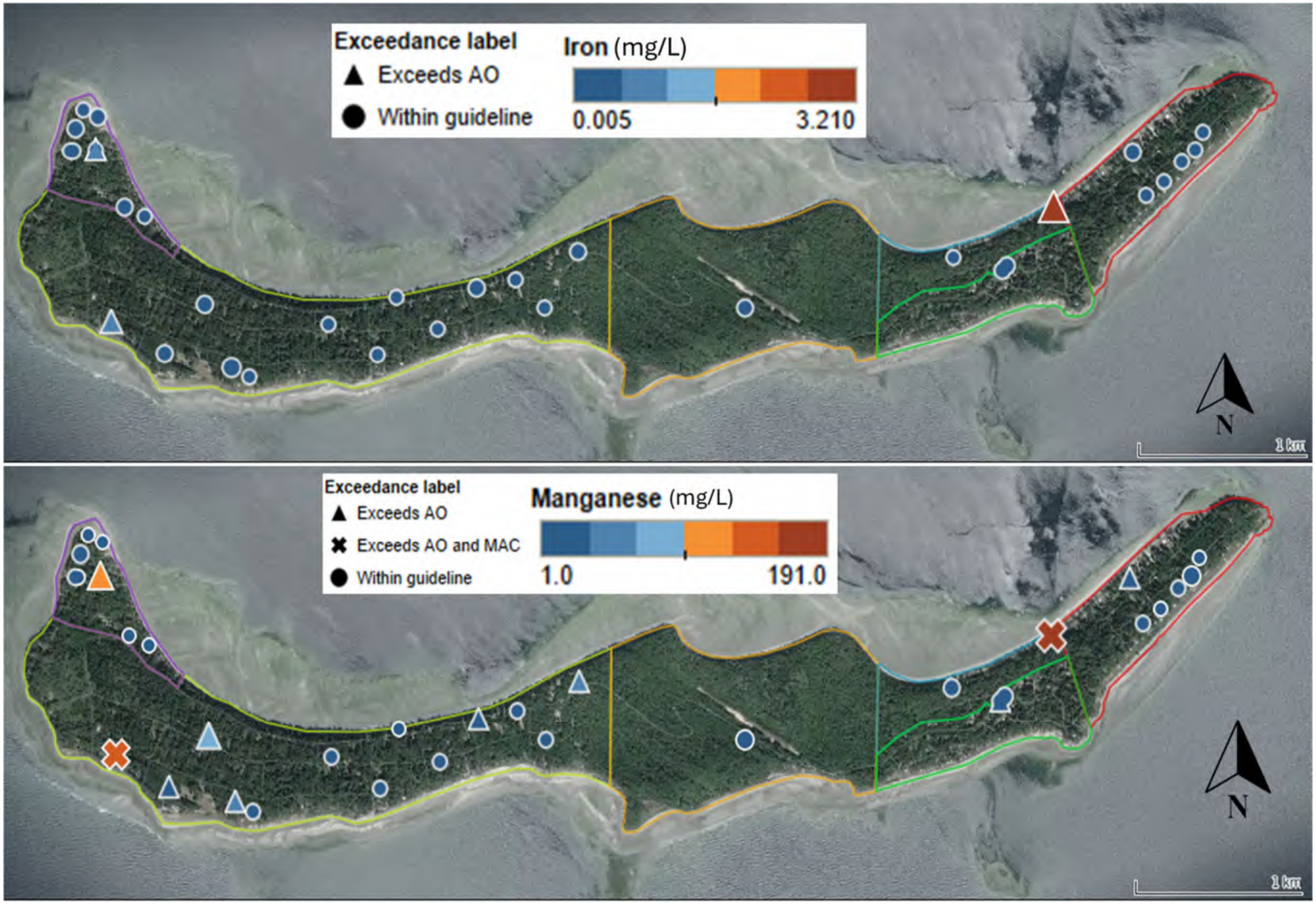


Figure 37. Iron and manganese concentration in Savary Island groundwater samples (maximum reported concentration at each site).

8.2.3 Water quality indicators of aquifer processes and land-use impacts

The concentration and distribution of water quality parameters such as chloride, conductivity, nitrate and sodium can provide information about aquifer processes and land-use impacts.

Chloride (Cl) is a natural element abundant in rocks, soil and natural waters, and most abundant in the world's oceans (Health Canada, 1987). Chloride concentration is generally low in rain, surface water (rivers and lakes), and variable in groundwater depending on the processes occurring in the aquifer. For example, chloride concentration may be higher in water influenced by or mixed with water from marine sources. Other sources of chloride in groundwater include salt application to roadways, leachate from industry, and sewage effluent discharges, such as from septic systems. The drinking water guideline for chloride is an Aesthetic Objective of 250 mg/L. Water above this concentration water has a noticeable salty taste and can corrode water fixtures and distribution pipes (Health Canada, 1987).

Conductivity (EC), also referred to as electrical conductivity or specific electrical conductivity (corrected to a temperature of 25°C) indicates the concentration of elements within a water sample, that lower the resistance of water to transfer of an electrical current (YSI Incorporated, 2009). Conductivity is correlated to the concentration of sodium and chloride and other major ions in the water. The benefit is that EC and total dissolved solids (TDS), which can be calculated from EC, are easily measured in the field to provide a relative indicator of water salinity (US Environmental Protection Agency, 2025).

Sodium (Na) is a component of salt (NaCl) dissolved in water from reactions with sodium containing minerals. It can also be present in water from industrial processes. Although non-toxic, sodium concentration above 200 mg/L can give water an unpleasant taste. Individuals with hypertension are also recommended to avoid ingestion of water with sodium above 20 mg/L (Health Canada, 1992). Sodium can be higher in water treated using a water softener to remove calcium and magnesium (i.e., hardness). In groundwater, sodium concentration can be an indicator of geochemical processes such as cation exchange, or mixing of water from different sources (Allen and Suchy, 2001).

Chloride, total dissolved solids (TDS), and electrical conductivity are indicators of water salinity. Field or laboratory values can be compared to various criteria, shown in Table 16, including the Guidelines for Canadian Drinking Water Quality, and the British Columbia approved water quality guidelines, which depend on the purpose of use, e.g. drinking water, aquatic life, irrigation, or livestock watering. Operational thresholds are also recommended in BC for the prevention of salt water or seawater intrusion in fresh aquifers (Province of BC, 2016).

Nitrate (NO_3) is a water quality parameter that varies in concentration in water impacted by human activities and land use. Nitrate contamination from point and non-point sources is a significant environmental problem impacting both surface and groundwater quality in Canada and worldwide (Rivett et al., 2008; Rudolph et al., 2015). The ambient concentration of nitrate within groundwater in B.C. is typically very low, less than 0.1 mg/L (Wei et al., 2010). Nitrate concentrations greater than 1 mg/L in surface or groundwater are considered indicative of anthropogenic impacts associated with industry, agriculture and urban development (Dubrovsky and et al, 2010). More elevated nitrate concentrations (above 2 mg/L) in groundwater can often be attributed to pollution sources, such as infiltration of surface water or run-off containing residues of chemical fertilizers or animal manure, or from human waste discharges from septic tanks or sewage systems (Health Canada, 2013).

In water, nitrate has no colour, taste, or smell and it can only be measured by a laboratory or chemical test. The drinking water guideline for nitrate in drinking water is a Maximum Acceptable Concentration (MAC) of 10 mg/L (when measured as nitrate-nitrogen) (Health Canada, 2024a). Nitrate is a health concern as it can affect oxygen metabolism in the bloodstream, associated with adverse effects in young children (causing methaemoglobinaemia or “blue baby syndrome”) (Health Canada, 2013). Drinking water with nitrate at concentrations below current drinking water guidelines has also been linked to impacts on normal thyroid function, elevated risk of some cancers (colorectal, ovarian, thyroid, kidney and bladder), and adverse birth outcomes such as low birth rate and preterm birth (Schullehner et al., 2018; Temkin et al., 2019; Ward et al., 2018). Water treatment methods for removal of nitrate include anion exchange, reverse osmosis, biological denitrification, and distillation. However, boiling water can increase nitrate concentration (Health Canada, 2013).

8.2.3.1 *Savary Island observations – Water quality indicators of aquifer processes and land use impacts*

Boxplots illustrating the range and median concentrations of chloride, electrical conductivity (EC), nitrate and sodium in groundwater within groundwater management regions on Savary Island are shown in Figure 38. The data were divided into samples collected before 2000, and samples collected between 2000 and 2024. The spatial distribution of the maximum measured concentrations of chloride and nitrate are shown in Figure 39.

Chloride concentrations are highest in Area F, historically and at present, where the maximum values measured exceed both seawater intrusion operational thresholds and drinking water guidelines. Chloride concentrations are within a similar range in the other management areas, with median concentrations below the threshold of 150 mg/L. Chloride concentrations have not exhibited a significant change over time based on a limited sample set, which included data reported in Tupper (1996). Sodium concentration and electrical conductivity exhibit similar regional distribution compared to chloride. Spatially, numerous wells across the island exceed the chloride concentration of 150 mg/L the operational threshold recommended for prevention of seawater intrusion impacts. Area F exhibits the samples with the several wells exhibiting the highest chloride concentrations on the island, exceeding drinking water aesthetic guidelines.

Nitrate concentration has increase over time in both the range and median values observed regionally. Wells in Areas B, E, and F exhibit higher median nitrate concentrations, while the highest concentrations of nitrate are observed in Area E (data from SSID wells), followed by Area F. All nitrate values are below the drinking water quality guidelines.

Table 16. Guidelines and operational thresholds for salinity indicators Total Dissolved Solids (TDS), Electrical Conductivity (EC) and chloride.

	TDS mg/L	EC µS/cm	Chloride mg/L	Description
Guideline for Drinking Water Quality (Health Canada)	500	ng	250	Aesthetic Objective: Concentration of chloride and Total Dissolved Solids (TDS) which causes a noticeable salty taste to the water. Water with chloride and TDS above these values can also cause corrosion and scaling in pipes, water heaters and household appliances.
Ambient Water Quality Guideline for Irrigation (BC)	ng	ng	100	BC guideline based on potential impacts to more sensitive plant species. Some plant species may be adapted to irrigation with water with higher concentrations of chloride. Irrigating with water containing higher concentrations of dissolved minerals or ions (e.g. sodium, chloride, boron and nitrate) can reduce soil fertility and affect plant health.
Operational Threshold to Prevent Seawater Intrusion	700	1000	150	Thresholds indicate concentrations significantly above the concentration in fresh groundwater sampled in coastal BC (concentration higher than 90th percentile of over 900 samples from aquifers the Vancouver Island and Gulf Islands Region). Because the thresholds are lower than the drinking water guideline, they are precautionary, indicating that well operation (or other factors) may be leading to deterioration of water quality in a well or aquifer, therefore additional actions such as monitoring or changes in practice should be made.

TDS=Total Dissolved Solids EC=Electrical Conductivity or Specific Electrical Conductivity (adjusted to standard temperature) measured in field or lab ng=No guideline References: (Health Canada, 2024a; Klassen et al., 2014; Province of BC, 2024c, 2016).

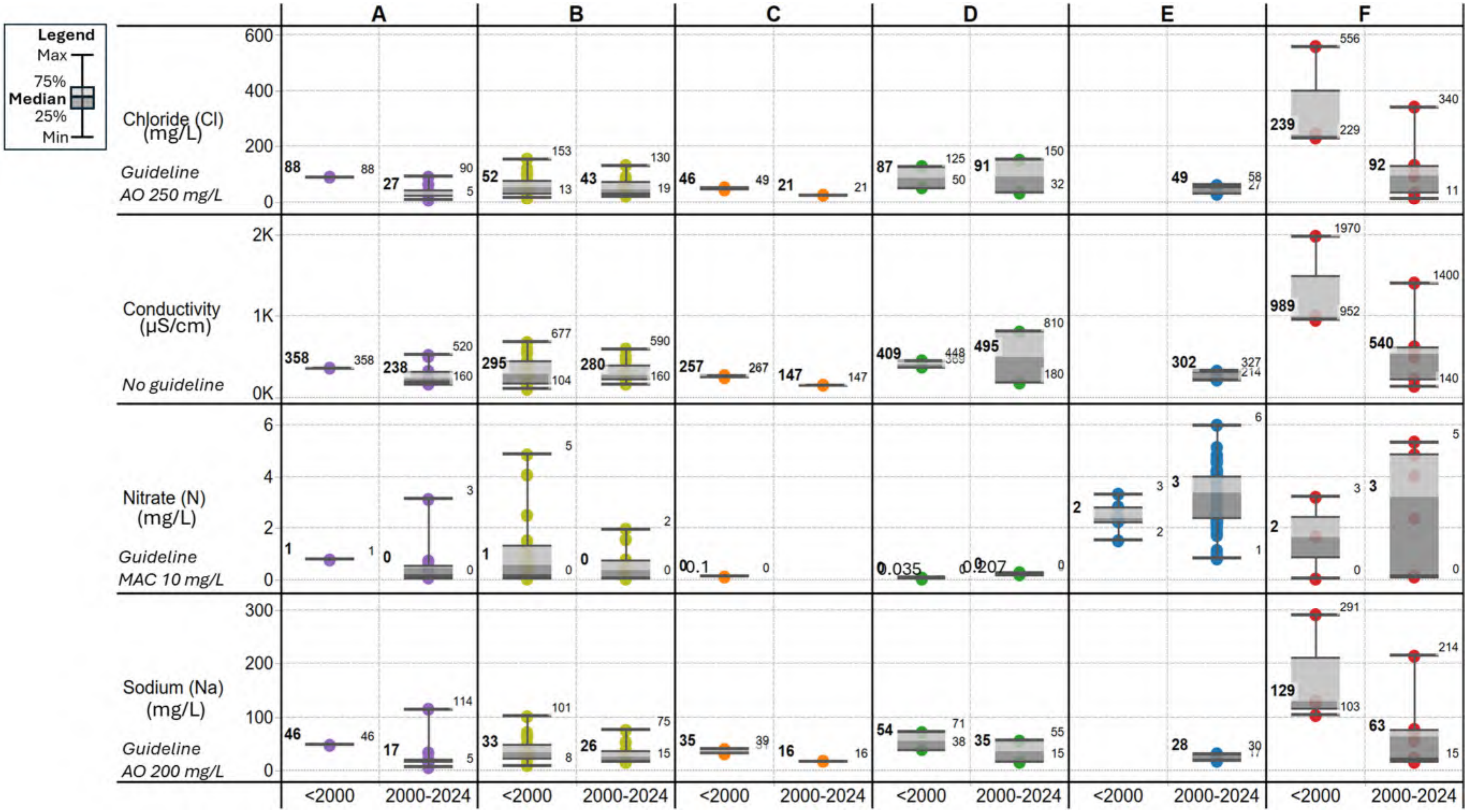


Figure 38. Box plots of chloride, conductivity, nitrate and sodium concentration in Savary Island groundwater samples (MAC=Maximum Acceptable Concentration, AO=Aesthetic Objective).

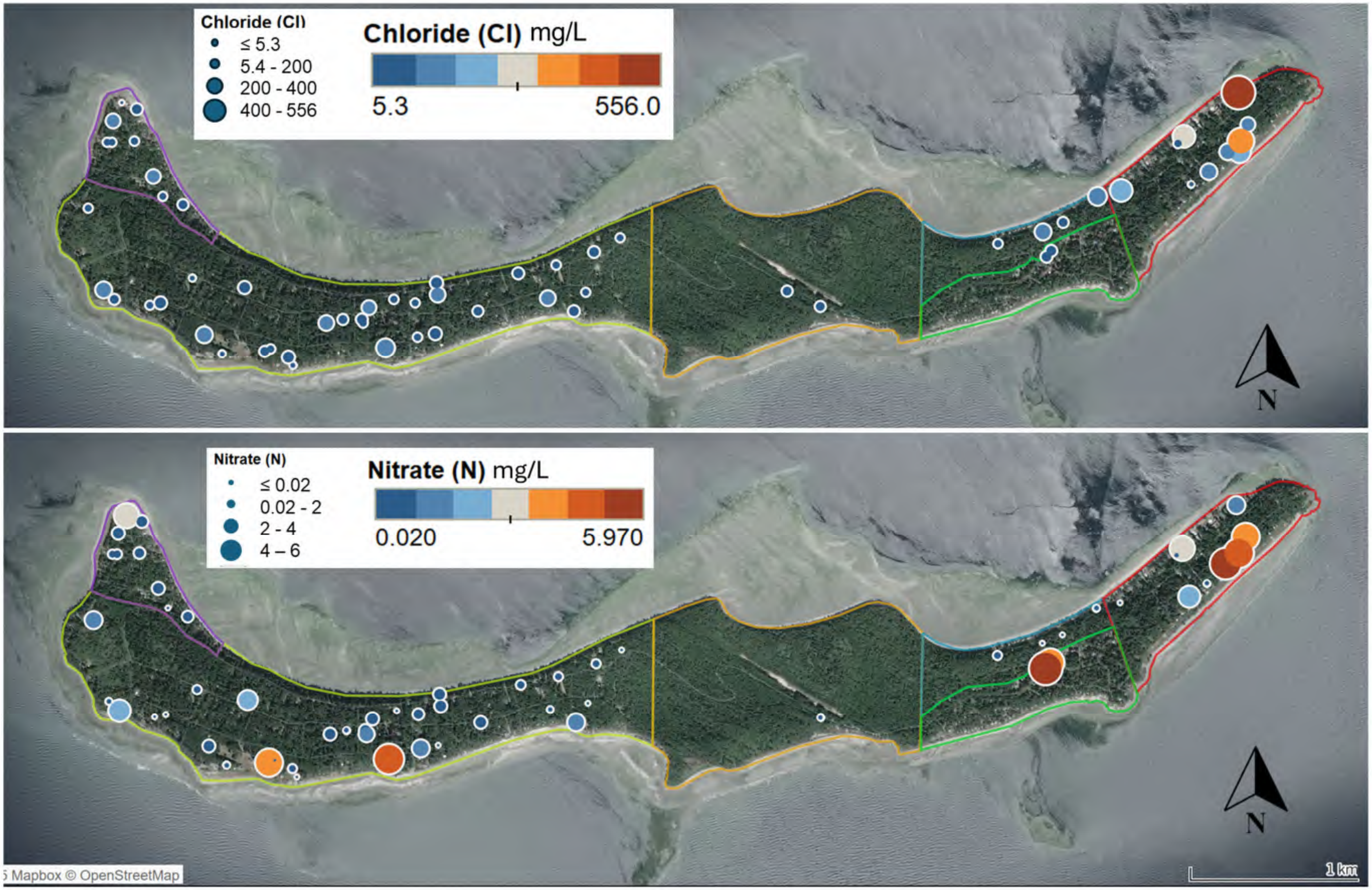


Figure 39. Chloride and nitrate concentration in Savary Island groundwater samples (maximum reported concentration at each site).

Considering change over time, the highest number and most long-term samples available are from Savary Shores Improvement District (SSID) Well 1 and Well 2, while data from multiple sample events are also available for provincial observation wells, OW511 and WTN 107896 (OW500). The concentrations of chloride and nitrate over time in groundwater sampled from these wells are shown in Figure 40.

In SSID Well 1, the concentration of nitrate in samples has increased over time from around 2 mg/L in 1989 up to a maximum of nearly 6 mg/L in 2018. In recent years nitrate has stabilized in samples from SSID Well 1, with concentrations in the range of 4 mg/L. SSID Well 2 was constructed later and began operation in 2012. Since that time, the concentration of nitrate in samples from SSID Well 2 has increased from 0.8 mg/L up to 4 mg/L in recent years. Nitrate is higher in samples collected in winter compared to summer. Figure 40 also shows an increasing trend in chloride concentration in samples from Well 2, while the chloride concentration is in the freshwater range (from 30 to 60 mg/L) in both SSID Well 1 and Well 2, with some seasonal variability.

Previous studies have indicated that the source of nitrates in groundwater from the production wells is septic discharge within the wellfield capture zone (Enterprise Geoscience Services Ltd., 2017). The increasing trend in chloride in Well 2 also appears consistent with septic origin. The SSID sample results exhibit higher nitrate concentrations than measured elsewhere on the island. Yet the subdivision density in Area E, within the zone of pumping influence or capture zone for the SSID well field, is comparable to some other densely developed areas (e.g. Area B) and nitrate loading to the aquifer is likely to be similar. The difference may be that the production wells pump at higher rates, and year-round, and therefore draw from a larger aquifer capture zone. Well pumping can create vertical drawdown in the aquifer drawing nitrate and chloride downward from shallower, soil and saturated zones. Domestic wells pump at lower rates, have a smaller capture zone, and a greater proportion of these wells are inactive in the winter. Well or aquifer vulnerability could be a further factor, e.g., short-circuiting of infiltration along a more rapid, preferential pathway.

In Figure 39, the concentration of nitrate and chloride in groundwater samples was compared to spatial variables including distance of the sample location from the shoreline and the number of inhabited lots within 60 m. Developed (non-vacant) lots were identified based on the land use analysis discussed in section 5.4. Savary Island is understood as being one of the most densely developed, small islands in the south coast region (Tupper, 1996). As an example, by this analysis one well in Area A (Thah teq) had 17 inhabited lots within 60 m, reflecting a significant density of wells and septic systems within the potential capture zone for the well. Although there is a large variability in the water quality between sites, the general trends (dotted black lines) indicate higher nitrate and chloride concentrations in the samples from wells with a greater number of adjacent inhabited lots. While setbacks and septic field density are associated with differences in water quality between sites, factors related to construction also influence a well's vulnerability to contaminants or pathogens. The distance of a well from the shoreline did not appear to be correlated to water quality, except in Area F which reflects higher hazard of seawater intrusion in this area.

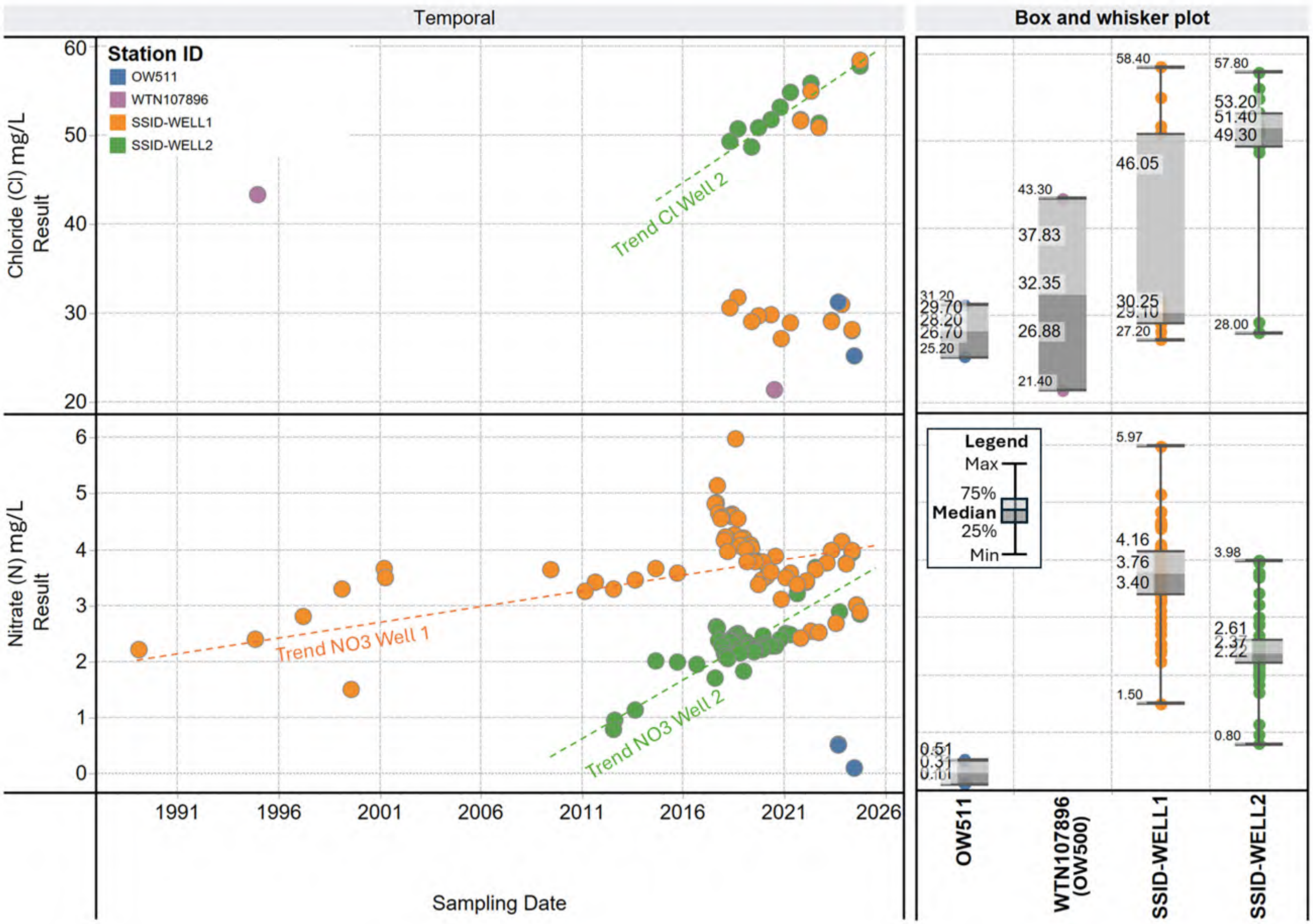


Figure 40. Concentration of chloride and nitrate over time SSID Well 1 and Well 2, OW511 and OW500.

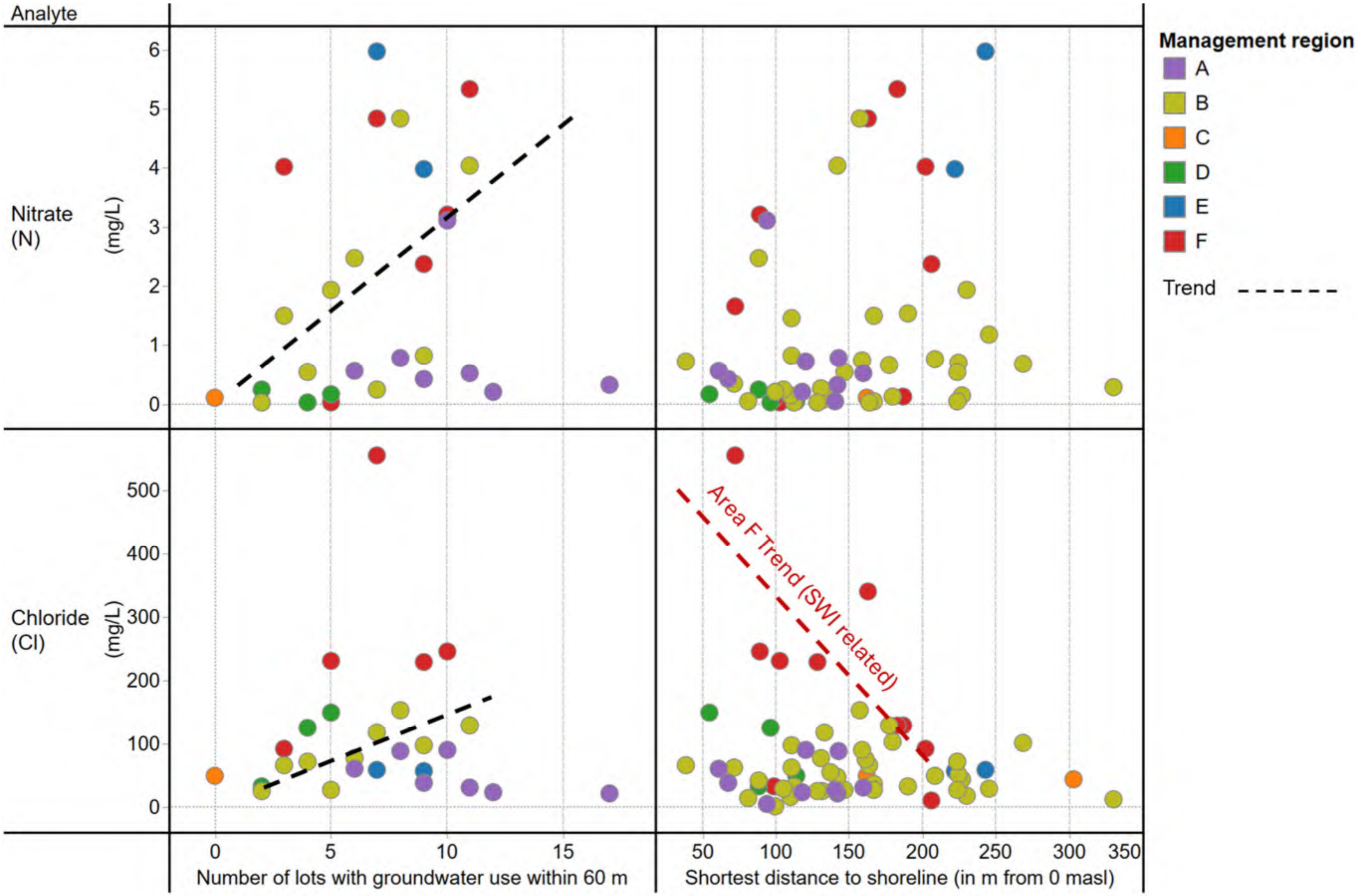


Figure 41. Nitrate and chloride concentrations in groundwater samples by region compared to proximity to inhabited lots and seashore.

8.2.4 Bacteriological quality

Eight samples were collected from domestic wells and Qaye qwun Spring for analysis of bacteriological quality, including total coliforms and *Escherichia coli* (*E. coli*). Bacteria samples are time-sensitive and must be transported off-island and delivered to the laboratory within 24 hours of collection, therefore it was not logistically possible to collect bacteriological samples from all sites during a time-limited field program. The results of bacteriological sampling are presented in Table 17.

Total coliform bacteria occur in surface water, shallow soil and organic material, therefore if present in samples from a well, they can indicate the influence of shallow recharge or surface water (Health Canada, 2020). For two of the three sites, it is believed that total coliforms were present due to the sampling configuration (inability to remove or bypass the ceramic filter receptacle). At the third site, the presence of total coliforms was potentially linked to land disturbance around the well head. *E. coli* was not detected in any of the bacteria samples. Neither total coliform nor *E.coli* were detected in the sample from Qaye qwun Spring.

Table 17. Bacteriological sample results.

Area	Source type	Bacteria sample	Total coliforms	E. coli	Note
A	Sand point	Y	L1	L1	
A	Drilled well	Y	L1	L1	
B	Drilled well	Y	L1	L1	
B	Drilled well	Y	16.4 MPN	L1	(1)
B	Drilled well	Y	2 MPN	L1	(2)
B	Drilled well	Y	290 CFU/100 mL	L1	(3)
F	Drilled well	Y	L1	L1	
B	Spring (Qaye qwun Spring)	Y	L1	L1	

Notes:
MPN=Most Probable Number CFU=Colony Forming Units L1=Not detected
(1) Low quantity of total coliforms detected. Land disturbance including excavation was observed near well head possibly allowing shallow recharge to enter the subsurface or anulus.
(2) Low quantity of total coliforms detected. Possibly introduced from sample location, or filter cartridge receptacle (filter was removed prior to sampling but receptacle could not be bypassed).
(3) High total coliform but no E.coli detected. Possible contamination from bacteria growth in ceramic water filter (filter could not be removed prior to sample point).

8.2.5 Background concentrations

A background concentration is defined as the concentration of a parameter or substance naturally present in an environment which has had minimal alteration from human sources or activities. The occurrence of a substance above the background concentration can provide information on processes or contamination sources that are influencing changes in the environment (Panno et al., 2006).

To estimate the background concentration of chloride and nitrate in Savary Island groundwater, a probabilistic approach was used based on methods adapted from mineral exploration and applied to drinking water studies (Panno et al., 2006; Kelly and Panno, 2008). Measured environmental variables such as concentrations of a water quality parameter often have a log-normal distribution, i.e. there are a larger number of values centred around the lower end of the measurement scale. When concentrations of a parameter are plotted on a cumulative frequency (probability curve), datasets with log-normal distribution will plot as a straight line. If there are multiple straight segments, variations in the slope of the line highlight thresholds that define the boundaries between different populations or groups within the data set.

Aquifers receive recharge that originated first as rain or snowmelt. This water infiltrates into the subsurface undergoing various physical and chemical processes, such as dissolving natural minerals or mixing with water or elements from contamination sources. Rainfall in the south coast of BC is characterized by low concentrations of major ions such as chloride, sodium and nitrate. For example, long-term monitoring of rain chemistry at the Saturna Island station operated by the Canadian Air and Precipitation Monitoring Network are shown in Figure 42. A seasonal effect is observed in the rain chemistry, in which concentrations of chloride and sodium are higher in precipitation during the winter, when sea spray particulates are entrained in rainfall during winter storms. Conversely, the median concentration of nitrate in rain is low (median 0.2 mg/L) but higher in the spring and summer compared to winter, due to the presence of dust and soil particles containing nitrate from decomposed organic materials and agricultural fertilizers applied to fields and wind-borne during this time of year.

In comparison, the concentration of chloride and nitrate can vary in groundwater depending on factors such the time of travel, how long the water has been stored in the aquifer or impacts from land use and sources of contamination. Sources of elevated chloride in groundwater include dissolution of minerals or mixing with connate groundwater originating from a marine setting, septic field leakage, effluent from wastewater treatment plants agricultural runoff, wastewater from industries, and road salting (Health Canada, 1987). Nitrate concentration in groundwater is generally low, but can be elevated if introduced from agricultural runoff, leachate from sewage discharges (septic systems, sewage treatment plants) (Health Canada, 2013).

Chloride (Cl): Figure 43 shows a cumulative frequency plot of chloride concentrations in 86 groundwater samples from Savary Island (1994 to 2024). Labels indicate the inflection points in the curve that define different categories or sample groups containing chloride concentration within in a similar range. From this diagram we observe:

- There are two inflection points in the curve, one at 19 mg/L and a second at 65 mg/L.
- The first inflection point suggests that the background concentration of chloride in groundwater on Savary Island 19 gm/L or less.
- Groundwater samples with chloride above 19 mg/L may be mixed with a source that is higher in chloride, such as septic discharges.
- Groundwater with chloride concentrations above 65 mg/L may be impacted by additional chloride sources or processes, such as mixing with deeper, more mature groundwater, or seawater intrusion.

Nitrate (NO3): Figure 44 shows a cumulative frequency plot of nitrate concentrations in 181 groundwater samples from Savary Island (1989 to 2024). The labels indicate concentrations that demark different categories or groups of samples with groundwater quality in a similar range. From this diagram we observe:

- There are two three inflection points in the curve, one at 0.5 mg/L, one at 2.1 mg/L, and one at 4.2 mg/L.
- The first inflection point suggests that the background concentration of nitrate in groundwater on Savary Island is at or below 0.5 mg/L.
- Groundwater samples with nitrate concentration between 2 and 4 mg/L are likely impacted by nitrate sources such as septic effluent.
- Considering the aquifer setting, samples with concentration above 4 mg/L are likely impacted by nitrate sources, such as septic discharges, but may also be influenced by other factors.

8.2.6 Water quality conclusions

Based on the geochemistry review and point in time (2024) water quality assessment, groundwater on Savary Island is mainly fresh with good quality that meets the guidelines for drinking water quality. A small number of samples exceeded drinking water guidelines for manganese or iron, which is common for aquifers in this region. Nitrate concentrations are similarly below drinking water guidelines, however, concentrations above background in some areas confirm that the aquifer and wells are vulnerable to land use impacts. A further examination of vulnerability, potential hazards and recommendations for aquifer protection are discussed in the next sections.

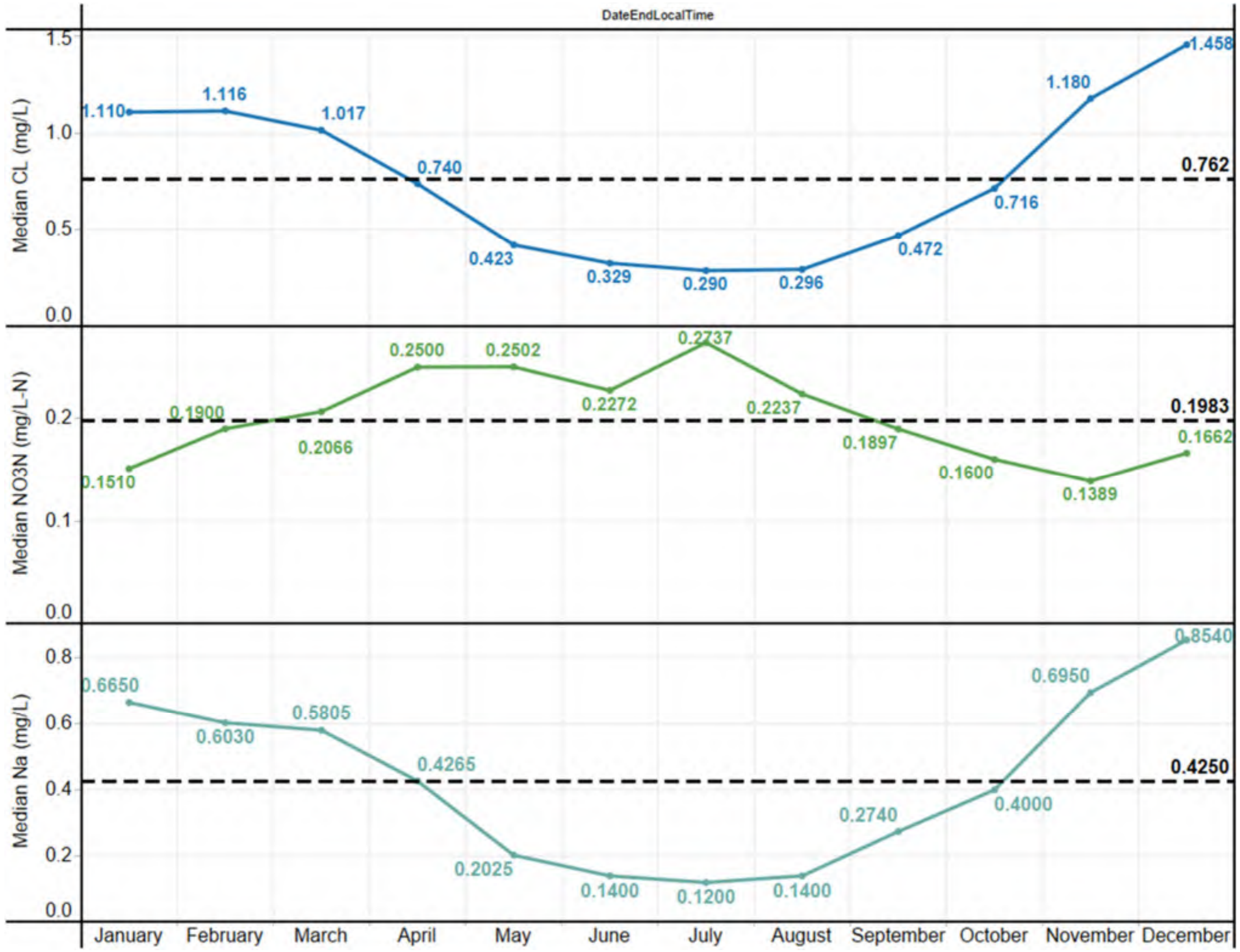


Figure 42. Long-term seasonal rainfall composition Saturna Island. Data source: (Canadian Air and Precipitation Monitoring Network, 2024).

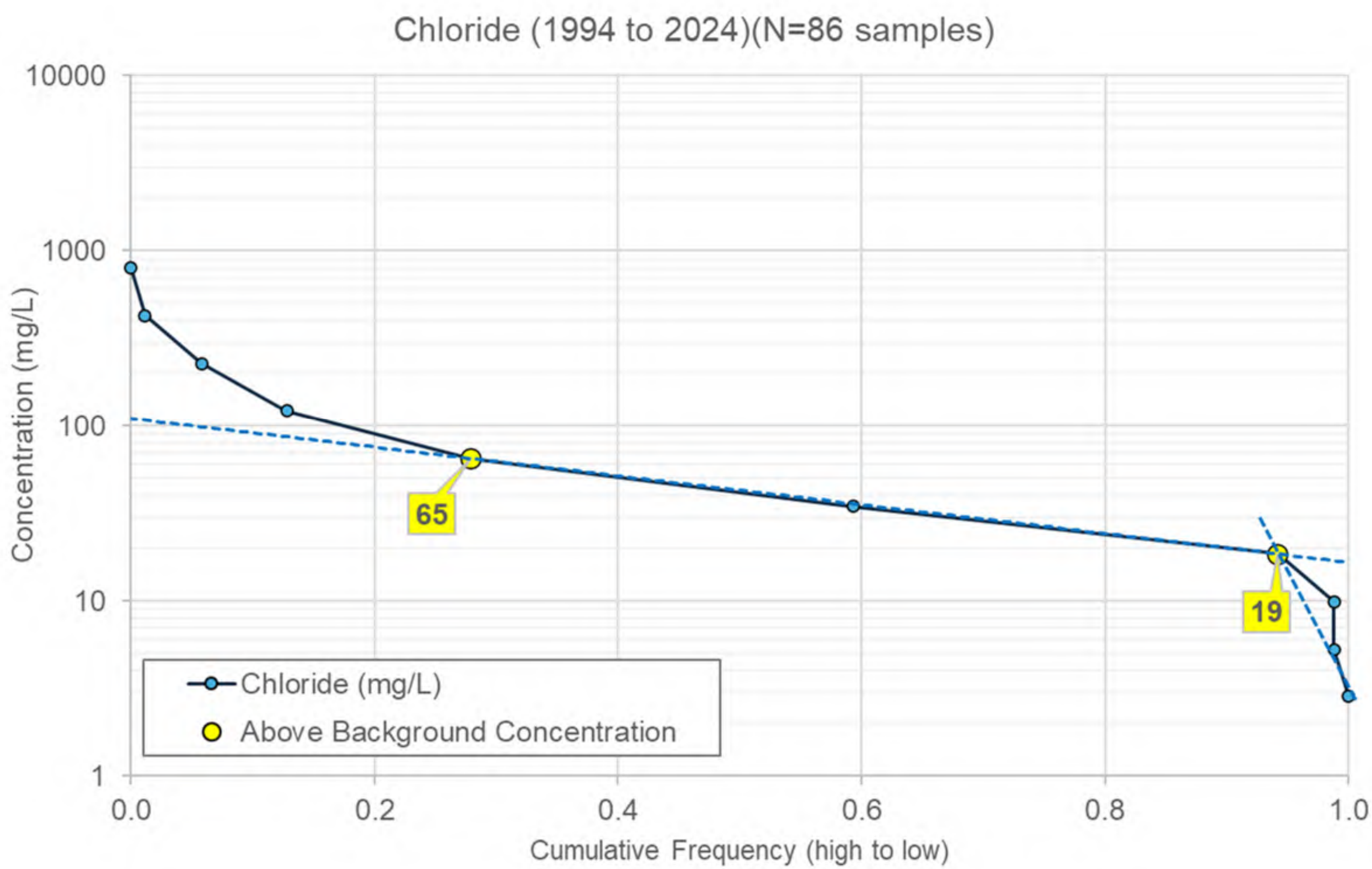


Figure 43. Cumulative frequency plot of chloride concentrations in Savary Island groundwater samples. Labels indicate inflection points in the probability curve that divide the water quality results into groups representing background concentrations or values above background.

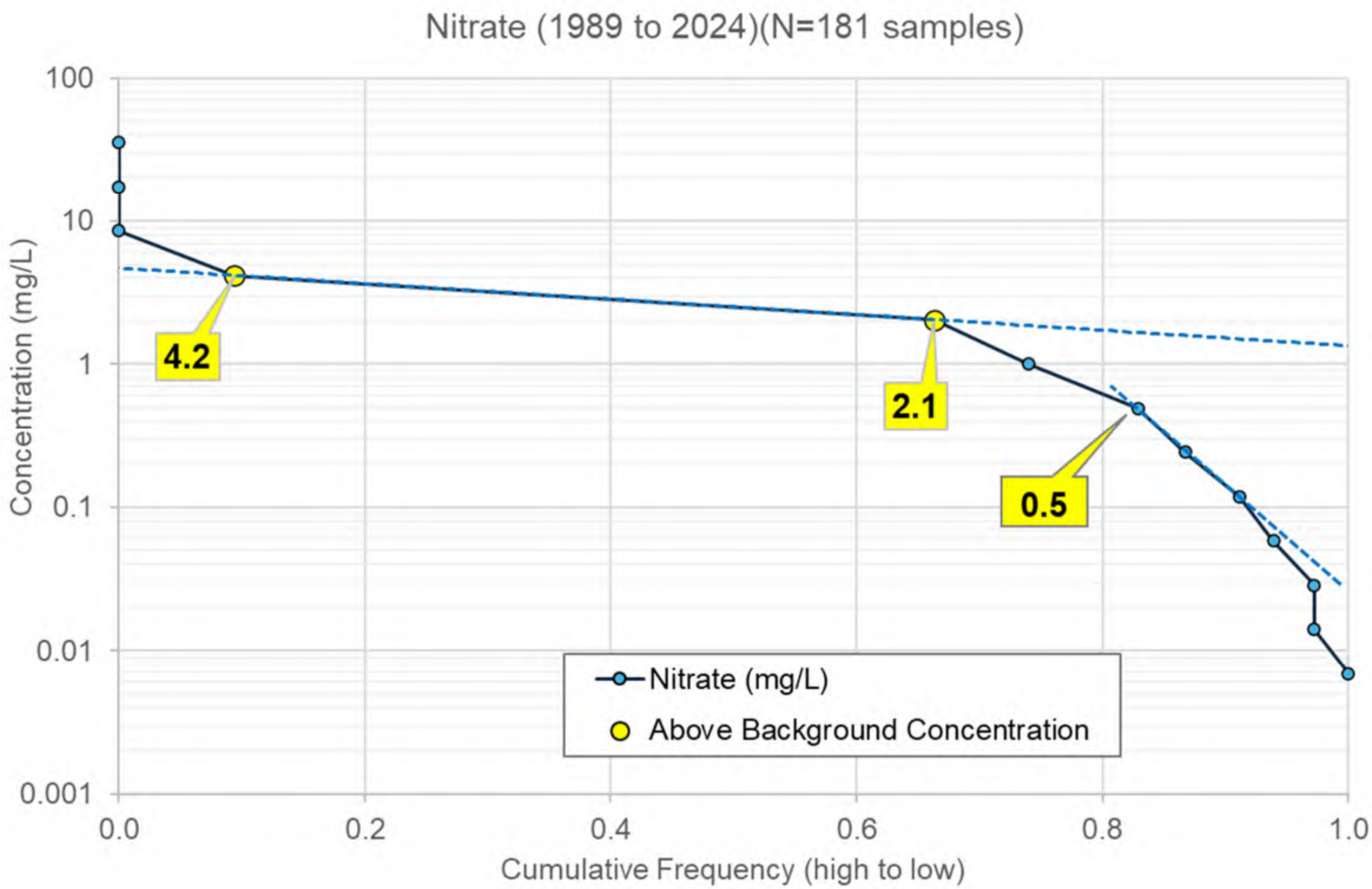


Figure 44. Cumulative frequency plot of nitrate concentrations in Savary Island groundwater samples. Labels indicate inflection points in the probability curve that divide the water quality values into groups representing background concentrations or values above background.

9 AQUIFER HAZARD ASSESSMENT

9.1 Aquifer vulnerability

The intrinsic vulnerability of an aquifer to contamination depends on factors such as the groundwater depth and the hydraulic properties of the materials that overlie and comprise the aquifer itself. Low permeability sediments such as clay, silt and glacial till (a general term often used to describe a densely compacted mix of clay, silt and coarser sediments) are referred to as confining materials, because, if present, they protect the underlaying aquifer from contaminants that may be introduced at the land surface.

The relative vulnerability of the Savary Island aquifer to contamination was mapped using an approach adapted from (Van Stempvoort et al., 1993; Van Stempvoort and Ewert, 1992). Using the aquifer vulnerability method, the hydraulic resistance of materials in the unsaturated zone above the aquifer was estimated based on the thickness, and relative permeability of the different sedimentary layers. Using GIS, a network of points was generated across the footprint of the island at which the depth between the land surface elevation and interpolated groundwater table was determined. These sample points were then imported into the hydrostratigraphic model, and the relative thickness and type of the sediment layers at each sample point was then calculated.

The hydraulic resistance to vertical flow, c, was calculated according to the formula:

$$C = \sum \frac{d_i}{K_i}$$

where, K=hydraulic conductivity (m/d) and d=the depth of each layer from 1 to i.

The hydraulic conductivity of each material type was determined based on published values (Freeze and Cherry, 1979), and historical Savary Island studies (Livingston, 1970). The estimated hydraulic conductivity of the different mapped materials and the calculated average hydraulic resistance for each groundwater management region are summarized in Table 18. The resulting map showing relative aquifer vulnerability is shown in Figure 45. The aquifer vulnerability is considered high according to the hydraulic resistance categories proposed by Van Stempvoort (1993; 1992). For the local study area, a sub-classification from high (hydraulic resistance of 1 year to greater than 10 years, to extremely high (hydraulic resistance of one month or less) was applied. The map provides a relative indication of areas that are more or less vulnerable based on the spatial distribution and thickness of lower permeability sediments (confining layers) but should not be used to infer site specific conditions or provide a literal interpretation of the vertical time of travel. In general, the areas of extremely high vulnerability include Area A (Thah tec) where the groundwater is very shallow within sandy sediments, and in the east island at Mace Point, where bedrock is exposed at the land surface or overlain by a thin veneer of sediments. Area B has very high vulnerability, while Areas C to E have high vulnerability where the groundwater table is deeper and deposits of till, silt and clay are mapped.

Table 18. Hydraulic conductivity values for sedimentary materials.

Material	K (m/day)
clay	0.0001
clay/sand	0.09
clay/silt	0.03
sand	80
silt	7
till	0.4

Average hydraulic resistance in Savary Island groundwater management regions		
Area	average c (days)	average c (years)
A	4	0.01
B	3,777	10.35
C	4,407	12.07
D	4,250	11.64
E	1,510	4.14
F	1,064	2.91

Figure 45. Savary Island aquifer vulnerability.

9.2 Groundwater contamination hazards

9.2.1 Septic systems and sewage discharges

There are no community or municipal sewerage systems on Savary Island, therefore all property owners are required to install and manage their own onsite wastewater treatment. As reported in the 2024 community survey, most developed lots use a septic system. However, some residents reported using a composting toilet, or pit toilet (outhouse). Nearly a quarter of those surveyed indicated that they have never maintained their septic system.

Sanitary wastewater contains a variety of substances including nitrogen from feces and urine, household chemicals (e.g. cleaning products, solvents, pesticides/herbicides), pathogens such as viruses, bacteria and protozoa, pharmaceuticals excreted in bodily waste and others. Although septic systems are a widely used method of sewage treatment, they can cause groundwater contamination and spread waterborne illnesses and diseases (Robertson, 2021).

Household septic systems usually consist of a septic tank, distribution box, and drain field (Robertson, 2021). The tank is made of plastic, fiberglass or concrete, and is designed to capture solids, and to hold the wastewater for a period of time to allow bacterial processes to start to decompose the waste. The solids are held in the tank, while the partially processed wastewater flows from the tank, through the distribution box to the drain field, a series of pipes with holes buried in trenches below the ground. Water drains out from the drainpipes, and percolates into the soil and underlying sediments.

Factors influencing groundwater vulnerability to contamination from septic systems (Figure 46) include:

Siting and setback distances: Septic systems should be set back a minimum of 30 m from wells and water sources, including streams.

Although a setback distance of 30 m from contaminant sources will provide some protection, a well's vulnerability to contamination depends on its construction characteristics, the gradient and direction of groundwater flow and location of the well relative to the contaminant sources, and on the properties of the aquifer (e.g. depth to groundwater, presence and thickness of confining, low permeability sediments, that can slow contaminant infiltration). Pathogens such as bacteria and viruses can remain viable and travel large (e.g. hundreds of meters) distances in an aquifer (Pang et al., 2021).

The early subdivision of much of Savary Island into very small lots (median parcel size 1279 m^2 or 0.3 acres) with limited to no shared services likely did not consider the potential water supply and public health implications. Current subdivision bylaws and policies in BC typically require a minimum lot size of 1 to 2 hectares (2.5 to 5 acres) when reliant on both an onsite well and septic system (Ministry of Municipal Affairs and Housing, 2017; Province of BC, 2022; Ministry of Transportation and Infrastructure, 2023). Bremer and Harter (2012) found that a lot sizes less than 8 ha (20 acres) significantly increase the risk of a well pumping septic leachate.

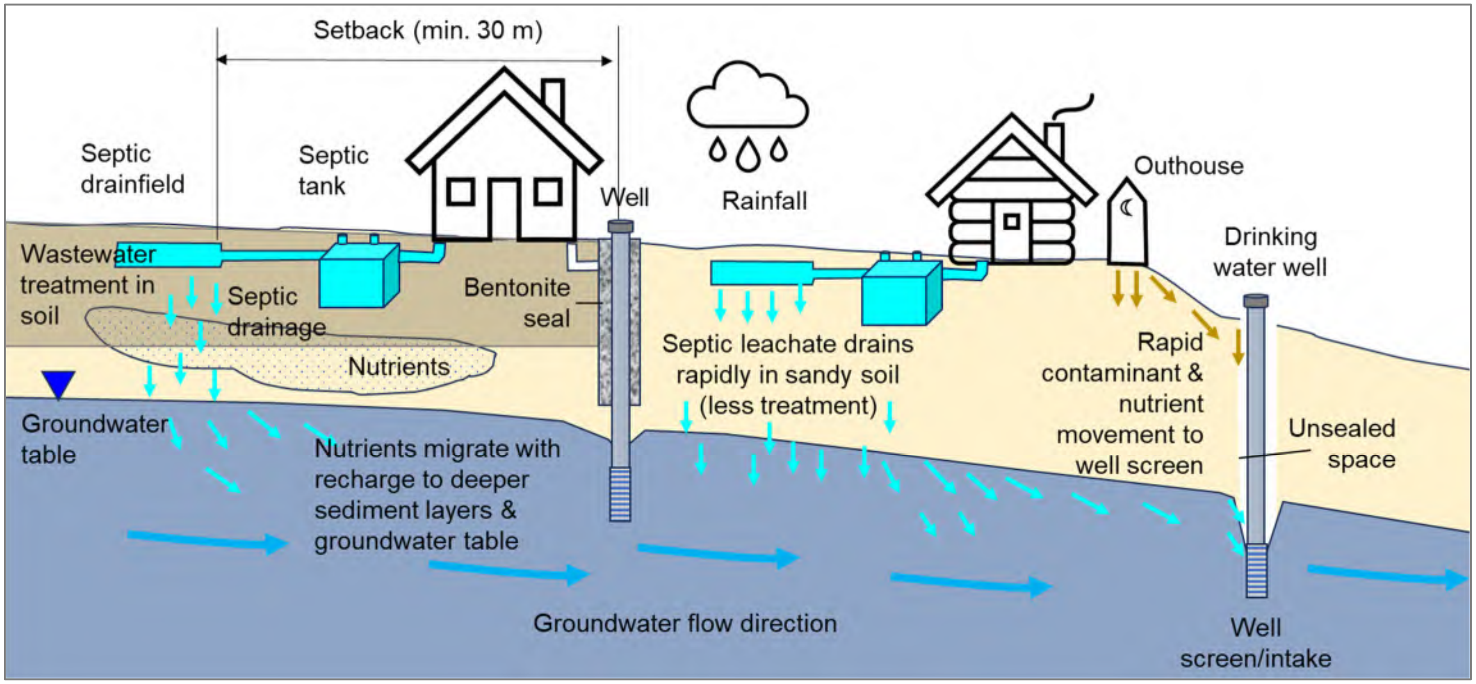


Figure 46. Septic systems and groundwater contamination pathways.

Soil conditions: Shallow soils and sandy materials such as observed on Savary Island allow more rapid drainage of wastewater from the septic field, and vertical infiltration to aquifer and water table. This limits the time for processes such as denitrification to occur to reduce nitrate concentrations. Viruses and bacteria can be trapped by the negative charge on the surface of clay and silt particles or travel rapidly with minimal attenuation through coarser materials such as sand and gravel.

Aquifer properties: Unconfined, shallow and sandy (highly permeable) aquifers, fractured rock and karst (limestone) aquifers are more vulnerable to contamination, compared to deeper aquifers that are confined by lower permeability sediments.

Well construction and maintenance: Wells that are improperly constructed or maintained are more vulnerable. An unfilled annular space (between the drilled borehole and the well casing), failing surface seal or loose gravel pack around the screen and casing can provide a pathway for rapid movement of contamination into the water source (Bremer and Harter, 2012).

Outhouses or pit toilets provide little to no reduction of nutrients or pathogens putting water supplies at increased risk; these should be replaced with a more effective form of waste collection and treatment and older/unused sewage waste pits should be deconstructed and infilled.

Septic system maintenance including completing an annual inspection and pumping of solids every 3 to 5 years will help ensure that the systems are functioning properly and not contributing to groundwater contamination (USEPA, 2001).

9.2.2 Other land use impacts

Land clearing and forest loss can impact both the quantity and quality of water. The type of impact depends on weather, soil type, slope, topography, plant species and their stage of development. When forest cover is removed, excess water (not used by the trees anymore) can generate increased surface runoff (depending on slope, soil type, surface disturbance and rainfall intensity), or alternatively can lead to increased infiltration into the subsurface, increasing pore water pressure and raising groundwater levels. Forest regrowth can affect the long-term water balance depending on the evapotranspiration requirements of vegetation in different stages of growth i.e., young vs older trees (Lachassagne, 2016). Forest loss can also affect water quality, increasing turbidity in surface runoff, and increasing nutrient (nitrate, phosphorus) concentrations in streams and groundwater recharge (Smerdon et al., 2009).

Impervious surfaces such as paved roads and driveways reduce the available area for water infiltration and groundwater recharge. The roads on Savary Island are not asphalted, and pervious roadside shoulders and swales currently promote water infiltration.

Solid waste and garbage can be a source of contaminants affecting groundwater quality. There are no solid waste handling or collection facilities on Savary Island, and residents and visitors are required to remove their waste. Locations where garbage or hazardous materials are accumulated can become point sources for aquifer contamination.

9.3 Seawater intrusion hazard

In coastal aquifers, such as on Savary Island, fresh groundwater which has a lower density than seawater, forms a lens that floats above the denser seawater around it (Bear et al., 1999). Beneath the Island, saline water circulates and extends inland from the coast forming a saline zone or wedge. Where the groundwater and ocean water come into contact is referred to as the freshwater-saltwater interface. A transition zone above this interface can contain a brackish mix of water from the two sources. The equilibrium been freshwater and seawater is maintained by groundwater that is recharged in higher elevation areas and discharges in lower elevation areas along the coast. A conceptual diagram is shown in Figure 47.

Seawater intrusion (SWI) refers to the change in groundwater quality that occurs from the mixing and movement of seawater into a freshwater aquifer. Sea water has roughly 35,000 mg/L total dissolved solids, including 19,000 mg/L chloride (US Geological Survey, 2000). Therefore, mixing in a very small quantity of sea water can significantly alter water quality in a freshwater aquifer. Mixing with 2% seawater can cause freshwater to taste noticeably salty (chloride 250 mg/L), while freshwater mixed with 4% seawater is unusable for many purposes (Klassen et al., 2014).

Aquifer vulnerability to SWI depends on multiple factors including topography, climate and hydrologic conditions and human activities (Werner et al., 2013). Many of the well or aquifer characteristics that increase seawater intrusion risk are observed on Savary Island, including:

- Aquifers located in low-lying areas close to the coast, on narrow islands or peninsulas with a limited up-gradient recharge area.
- Aquifers with groundwater level close to sea level.
- Coastal areas with a high density of wells or high rates of groundwater pumping.
- Wells where the static or pumping water level is close to or below sea level.
- Coastal areas where wells are drilled deeper toward the freshwater saltwater interface, promoting circulation and movement of water between saline and freshwater zones.

Climate change is expected to exacerbate existing sea water intrusion risk in this region (Klassen and Allen, 2016). For example, some areas will be inundated by rising sea levels. While storm surges are likely to overtop and flood lower elevation coastal zones. Changes in precipitation, higher temperatures, higher rates of evapotranspiration, and reduced groundwater recharge will limit the groundwater flux to discharge areas along the coast, enabling sea water to encroach further inland (Chesnaux et al., 2021). Increased water demand and increased rates groundwater pumping will add further stress aquifers and therefore water demand is a critical area of focus to manage and protect coastal aquifers (Ferguson and Gleeson, 2012).

Figure 47 illustrates the characteristics and properties of island aquifers and seawater hazards.

The concentration of chloride, electrical conductivity and total dissolved solids (TDS) in a water sample can be used identify groundwater that is affected seawater intrusion (Klassen et al., 2014). Groundwater from islands in BC's south coast is generally fresh. In the southern Gulf Islands, from a dataset of over 900 groundwater samples, over 90% had chloride (Cl) concentration below 150 mg/L, electrical conductivity (EC) below 1000 µS/cm and TDS below 700 mg/L (Klassen et al., 2014). These values have been recommended as SWI operational thresholds, meaning the well should not be operated or the cause should be further assessed if the concentrations of chloride, TDS and EC are above this level. In the San Juan Islands, wells with chloride concentration over 100 mg/L were considered impacted by SWI (US Geological Survey, 2000).

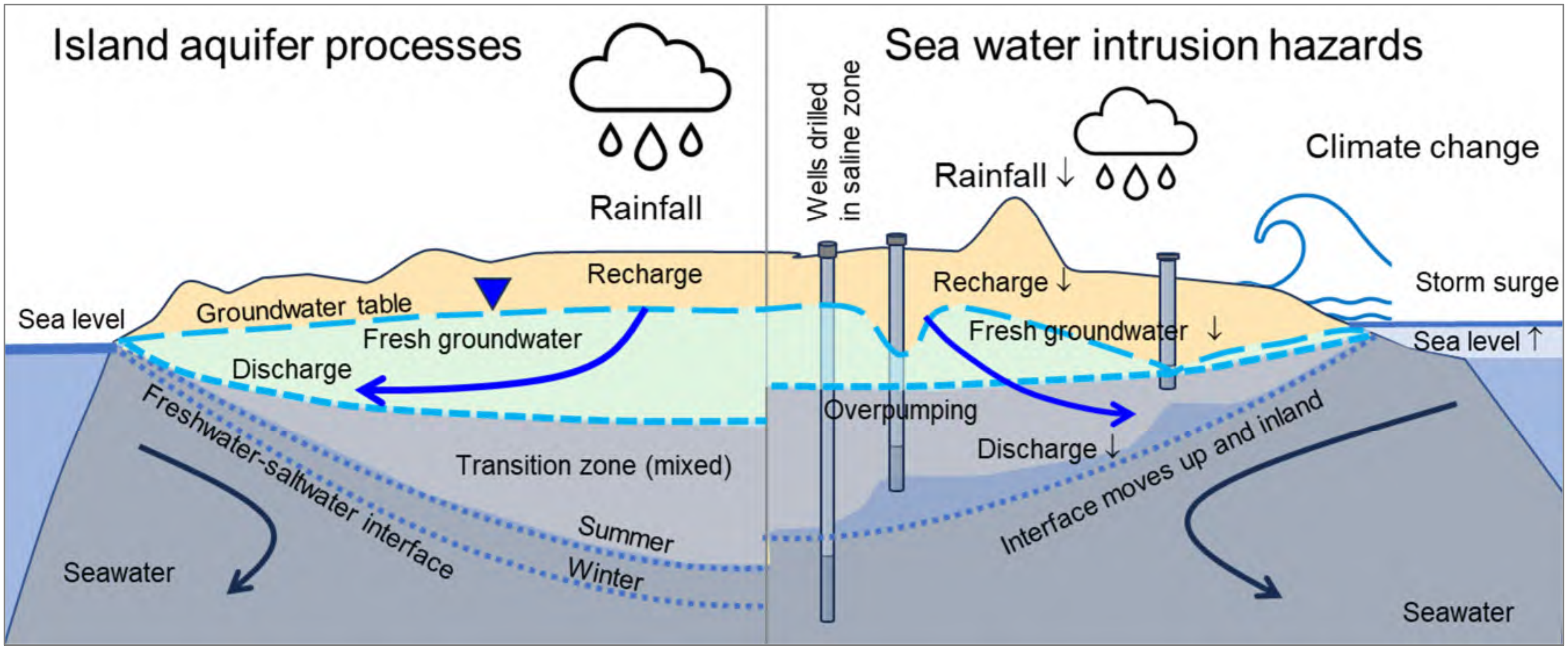


Figure 47. Seawater intrusion processes and hazards. After (Bear et al., 1999; Klassen and Allen, 2016; US Geological Survey, 2000).

Chloride concentration and EC in Savary Island groundwater samples from September 2024 are plotted in Figure 48. Most sites plot in the lower range of chloride and EC, which is considered to represent groundwater quality on the island that has not been influenced by SWI. A second group of samples plot above background concentrations likely represent groundwater that has been mixed with a source of water that is higher in chloride. Groundwater sampled from two sites had chloride concentration greater than 150 mg/L and EC 1000 µS/cm. Site observations provided further evidence of SWI as the likely cause.

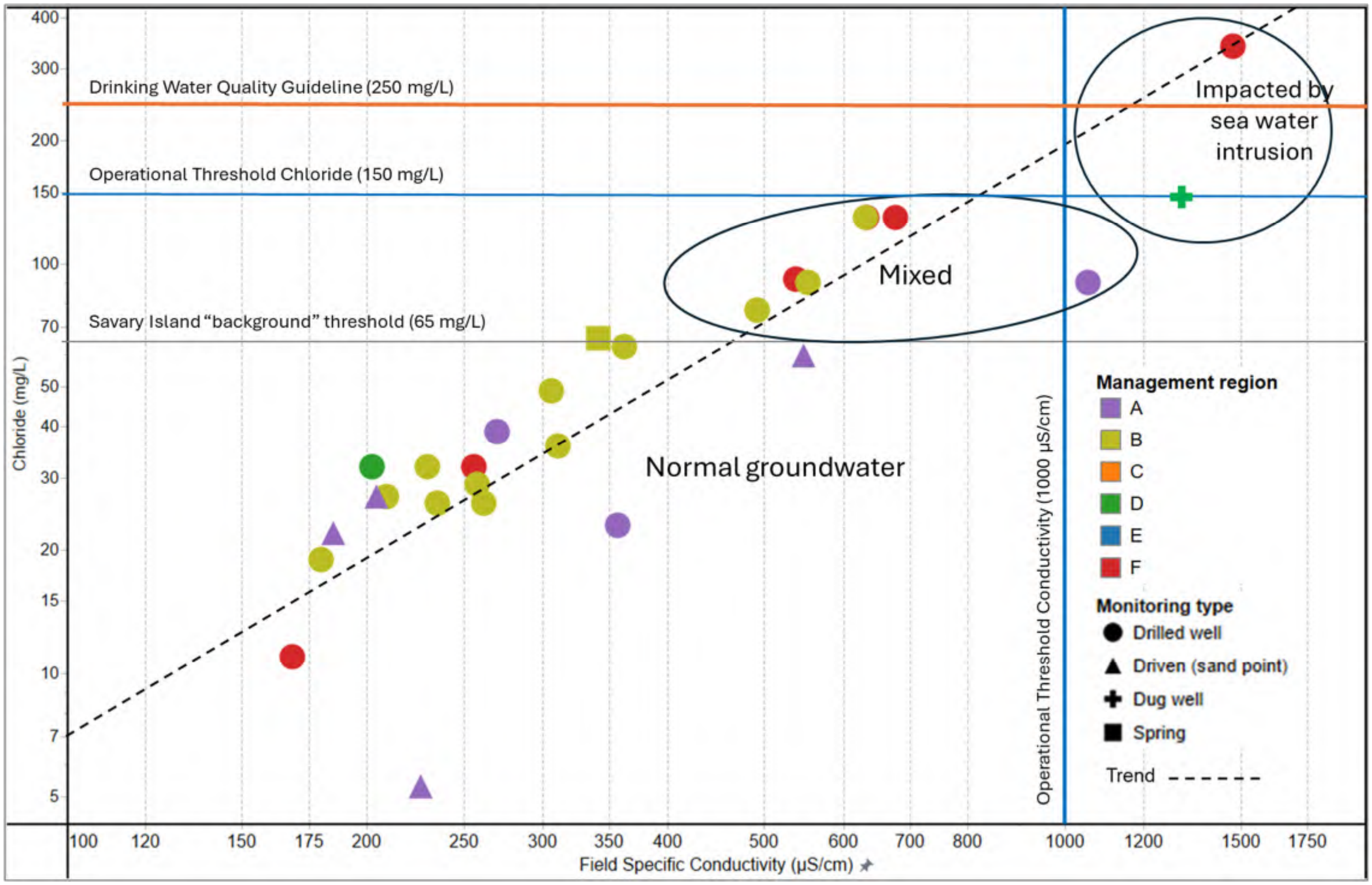


Figure 48. Savary Island groundwater quality and SWI indicators.

9.3.1 Depth of transition zone and saline interface

The thickness of the freshwater lens in the Savary Island aquifer, and depth of the transition zone between fresh and saline water below the Island, was estimated using a solution that considers the interaction of fluids with different density (Verruijt, 1980). A network of sampling points (75 m spacing) was created in the 3D model. The thickness (d_i) of each lithological layer at the sample point on the grid was calculated. The hydraulic conductivity was then estimated for each geologic layer, based on the values from literature and historic reports for the study area (Freeze and Cherry, 1979; Livingston, 1970). The equivalent hydraulic conductivity (K) was calculated at each point according to the equation:

$$K = \frac{\sum k_i \times d_i}{\sum d_i}$$

A grid layer was developed for the Island interpolating the K values from the sample points to represent horizontal hydraulic conductivity. Similar grid layers were developed for groundwater elevation (H_f) and distance from the coastline (x). Groundwater flow (qi) and the elevation of the sea water interface (Hs) were calculated using the raster calculator tool in QGIS, using the formulas from Verruijt (1980):

$$q = \frac{{H_f}^2 K(1+\beta)}{2\beta x}$$

$$H_s = -\sqrt{\frac{q^2}{\beta^2 K^2} \times \frac{1-\beta}{1+\beta} + \frac{2qx\beta K}{\beta K(1+\beta)}}$$

The density of freshwater samples was calculated using the AqQA program (RockWare) based on the 2024 groundwater sample results. Density of sea water in the Georgia Strait was obtained from Ocean Networks Canada (Ocean Networks Canada, 2024). The density ratio, β is approximately 0.02, calculated based on the density difference between fresh (ρ_f) and saline water (ρ_s):

$$\beta = \frac{\rho_s - \rho_f}{\rho_f} \approx 0.02$$

To calibrate the model, the generated grid layer for the elevation of the saline-fresh water interface was compared to measured field water quality data (electrical conductivity). In situ conductivity measurements and/or downhole conductivity profiles were completed in September 2024 in 12 wells and provided information on the depth of transition between fresh and mixed or brackish water. QGIS was then used to interpolated contours of saline interface depth from the raster layer.

A map showing the approximate depth of the seawater interface below Savary Island is shown in Figure 49. The depth is reported in meters above sea level, with a negative value indicating it is below sea level. The depth of the transition zone near the coastal margins is relatively shallow, in the range of 5 m below sea level. In comparison, where the island is wider at the centre and below higher elevation areas the transition zone is up to 35 meters or deeper below sea level. The depth of the interface will move in response to tidal fluctuations, seasonal variations in groundwater discharge, and mixing within the transition zone containing a mix of freshwater and seawater above the interface (Bear et al., 1999).

Understanding and managing the hazard of seawater intrusion is crucial to sustainability of freshwater resources on Savary Island. Table 19 provides a summary of best practices to manage and prevent seawater intrusion.

Table 19. Best practices for prevention of seawater intrusion.

Well drillers	• Research local conditions and plan when drilling in areas at risk of seawater intrusion • Site wells a minimum of 30 m from seashore • Test for salinity indicators during drilling (electrical conductivity (EC) or total dissolved solids (TDS)) • If saline groundwater is encountered stop drilling and test the water quality • Backfill and seal off saline zones • Educate well owners regarding the hazards and prevention of SWI
Well pump installers	• Install well pump at shallower depth and include automated shutoffs to limit groundwater level drawdown below sea level • Set pump to operate for timed shorter cycles at a low pumping rate to refill water storage ("well sipping") • Install meters and alarms to identify and quickly fix uncontrolled leaks • A datalogger can be installed that monitors groundwater level, temperature and EC, to develop an understanding of changes in water quality during pumping • Install monitoring equipment to measure EC or TDS while pumping, and to shut off pumping if water quality exceeds an identified limit (e.g. operational threshold or drinking water guideline) (Note: Cost for this type of monitoring would be relatively high and only recommended for a water supply systems or higher capacity production wells in which SWI impacts are being managed)
Well owners	• Record observations that could indicate changes in water quality over time (salty taste, observed corrosion or discolouration of pipes and fixtures) • Purchase a low-cost water quality monitor (e.g. pen style conductivity or TDS meter) and record periodic measurements of groundwater quality, making note of trends, seasonal differences, or changes during periods of higher water use • Collect samples for lab analysis of geochemical water quality annually or semi-annually, and include analysis of salinity indicators (chloride, EC, TDS) • Install low water use fixtures (low flush or suction toilets, low flow shower heads and faucets) • Practice water conservation, limit non-essential water use including limiting outdoor irrigation in areas at highest risk of intrusion • Consider options for water re-use in the home or outdoors • Check for and fix uncontrolled leaks, hoses left open, etc. which could draw down water levels in the well

	• Educate residents and guests regarding low water use practices • Use water cisterns to store water from the well or other backup supplies (e.g., rainwater collection). Observing tank storage and drawdown is also an easy way to measure and manage water demand. • If well produces salty water seasonally or periodically, use an alternate supply, investigate the cause and seek advice from a driller, pump installer or other qualified person • Properly decommission (backfill) unused wells that could provide a pathway for circulation and movement of saline water from deeper to shallower aquifer zones • In multi-well systems, alternate the pumping of each well to allow water levels to recover

References:(Province of BC, 2016; US Geological Survey, 2000; Werner et al., 2013).

Well drillers on Savary Island have adapted well installation practices to combat the rusting of steel casing caused by saline groundwater. Electrochemical reactions between metals and salts can accelerate rust. In some new wells it was reported that the steel external casing is being installed to a shallower depth, above the water table. The stainless-steel screen is then installed with an internal casing or PVC liner. This practice may help increase the lifespan of a well and prevent deterioration of the casing. Sand point screens also rust and deteriorate over time and may need to be replaced or repaired approximately every 15 years.

Desalination, a technology used in areas of severely limited freshwater availability, is not an optimal solution for drinking water and household use. The treatment process is costly, utilizes a significant amount of energy and the concentrated saline brine that is created can cause environmental harm if not disposed of safely (Orfi et al., 2025). Careful management and conservation of limited freshwater supplies is a more cost effective and long-term solution for small island communities such as Savary Island.

Figure 49. Savary Island depth of saline-freshwater interface.

10 REGIONAL SUMMARY OF AQUIFER CHARACTERISTICS AND HAZARDS

The groundwater assessment has highlighted Island-wide characteristics as well as regional differences that could be considered when developing a long-term aquifer protection strategy.

Area A Thah teq (Indian Point): Area A on the western end of Savary Island has mainly small lots, situated on a low elevation coastal plain. The groundwater table here is very shallow (less than 2 m below ground) and the aquifer has both an extremely high vulnerability to contamination from the high density of septic systems and extremely high vulnerability to seawater intrusion. Unique to this region is the widespread use of driven sand point wells. And both the mode of sand point construction and the natural limits that the well design places on water exploitation are likely beneficial. When constructing a sand point, an initial hole is opened using a post hole digger, but the sand point itself is driven or pounded into the water-bearing zone, reducing disturbance of materials surrounding the screen. This likely helps prevent short-circuiting of shallow drainage (i.e., septic effluent) through the annular space surrounding the exterior casing. Area A is a discharge zone with an upgradient area that is more lightly developed by Island standards, which may be beneficial in reducing inputs and improved dilution and dispersion of septic nutrients. Improving the sand point installations by retrofitting or installing surface seals is likely to provide further protection. Because sand points are shallow (typically <20 m deep), and narrower diameter (3 to 5 cm), they also limit how much water can be pumped, coincidentally limiting drawdown of groundwater levels, which is beneficial for reducing the sea water intrusion hazard. Some property owners are transitioning from sand point to drilled wells to provide a more reliable, plumbed supply to their residences. Application of best practices to prevent saltwater intrusion is critical. For example, caution must be employed by drillers to avoid drilling into the brackish transition zone between fresh and saline water. While operation of drilled wells must be carefully managed so they are not over pumped, drawing saline water upward and inward from the coast and adversely affecting the aquifer water quality and other users in the area. Due to the low topography, this area is also at high risk of coastal flooding and wave overtopping during storm events, and inundation due to sea level rise (Tetra Tech, 2022). An interpreted cross-section of area A is included in Figure 50.

Area B West Island and Meadowlands: As the largest groundwater management area on Savary Island, Area B has the highest number of developed lots providing their own water supply, and the largest annual water use. Vulnerability of the aquifer to contamination is very high. Groundwater levels are moderately to very deep below ground, and some of the deepest wells on the island are below the upland (higher elevation) of this area. The low lower permeability confining sediments such as till, silt and clay are present within the central and eastern sections. Nitrate concentrations are spatially variable, with samples from several wells having concentrations above background indicating the impact of septic system discharges. The high number and density of wells, the disturbance of permeable sediments around the well column during drilling, the lack of surface seals in historical wells or compromised surface seals in new wells, and the land disturbance around the wellheads may be promoting the formation of preferential pathways for more rapid infiltration of shallow drainage. This increases the concentration of nitrate and chloride and increases the risk of pathogens entering the water supply. Well upgrades and surface seal retrofits could be completed to try to reduce these impacts. Unused and abandoned wells, including shallow dug wells historically reported in this area, must also be properly decommissioned to eliminate these potential conduits for shallow water to contaminate groundwater. Water supply options such as neighbourhood or multi-parcel shared water systems, including wells located on undeveloped “water lots” with an increased setback from contaminant sources should be considered. An interpreted cross-section of Area B is included in Figure 51.

Area C Central Island: This unsubdivided conservation area separates the western and eastern sections of the island, provides wildlife habitat and shared recreational green space that benefits the community. Continued monitoring of groundwater levels in this area will provide information on ambient conditions in the aquifer, including the effects of long-term climatic changes.

Area D Savary Lane: Management Area D consists of one of the earliest subdivided neighbourhoods of mainly larger (4000 to 8000 m^2, 1 to 2 acre) parcels, north of the SSID water service area, and situated along the Malaspina Promenade frontage west of the main dock. The aquifer in Area D has a greater protection from contamination due to the lower well density and larger lot size. Most of the resident’s water supply wells are in the largely undeveloped upland area of each linear parcel, at further distance from the seashore, while the housing and associated septic systems are downslope near the shoreline. Although the freshwater lens is thicker near the centre of this part of the island, deeper wells in Area D could still intersect the transition zone between fresh and saline water. Improved well inventory and measurement of water levels in a larger number of locations would benefit from an understanding of groundwater conditions here. Some homes are in this area are quite large, and may be associated with higher water use, therefore water conservation is a priority.

Area E Savary Shores: This area is defined by the service area for the Savary Shores Improvement District (SSID). Most developed parcels in this area receive water supply from the SSID. The aquifer has a high to extremely high vulnerability to contamination, depending on the spatially variable presence of silt and clay layers overlying the aquifer. The well field capture zone has a high density of septic systems, which has led to increasing concentrations of nitrate in groundwater. Groundwater pumping is likely drawing nitrate-rich waters within septic system discharge plumes towards the production wells. The SSID wells are located near the centre of the Island where the thickness of the freshwater lens is deeper, providing an increased setback from the seashore and reducing the seawater intrusion hazard. However, there is a very limited height of water above sea level and thus continued water conservation and monitoring of SWI indicator parameters (EC, chloride and TDS) and evaluation of trends over time is recommended. Adverse impacts due to interference from other wells operating within management area are not anticipated based on the current usage, but unlicensed non-domestic groundwater use on unserviced lots is noted. An interpreted cross-section of the island in Areas D and E is included in Figure 52.

Area F East Island: This management area encompasses the eastern section of the island, including the fractured bedrock outcrops at Mace Point. Steeper topography in this area, and the presence of confining layers of till and silt, limit the amount of recharge that is received. Wells on the south bluff have a very limited upgradient recharge zone from which to capture groundwater. The water table is deep, while the freshwater lens is relatively thin increasing the risk of seawater intrusion in this area. Higher than background nitrate concentrations observed in groundwater may be due to well construction issues (i.e., impaired or absent surface seals creating preferential flow pathways that allow the infiltration of septic effluent to the shallow groundwater), combined with reduced dilution of the groundwater due to the limited aquifer recharge in this area. Higher electrical conductivity and elevated concentrations of chloride were measured in deeper wells with screens that intersect the brackish transition zone between freshwater and sea water. Limited information is available regarding groundwater conditions in the fractured bedrock at Mace Point. However, anecdotally, few successful wells have been constructed here and it is not anticipated to be a good water supply due to blocky fractures that are likely to intersect with saline zones. The development of alternate water supplies such as rainwater collection is recommended for new development in Area F. Application of best practices including regular testing of SWI indicator parameters (electrical conductivity and chloride) by well owners is also advised to observe changes over time and mitigate SWI hazards. An interpreted cross-section of Area F is included in Figure 53.

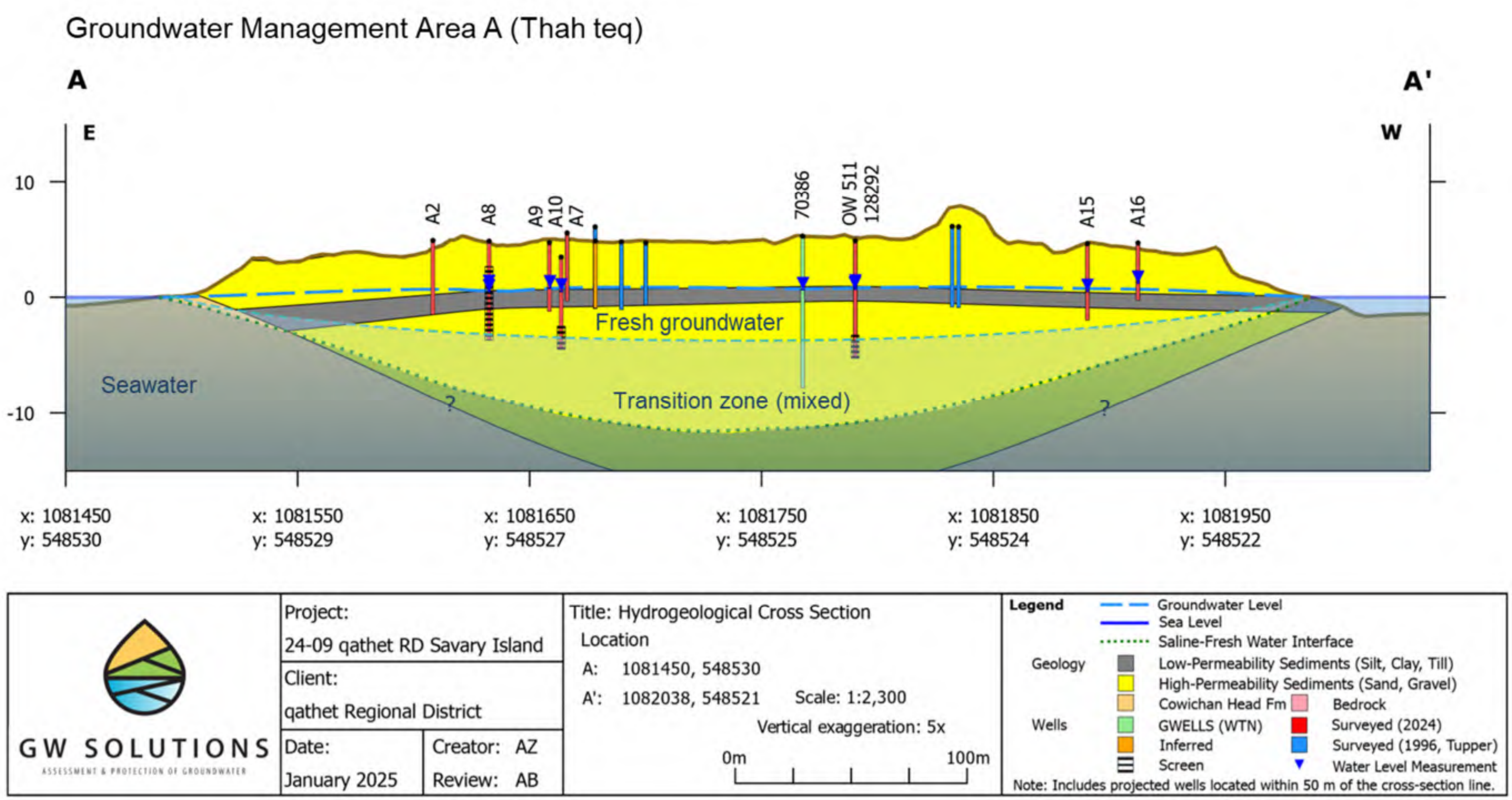


Figure 50. Savary Island interpreted cross-section A-A' Management Area A, Thah teq (Indian Point). The depth of the mixed transition zone was based on field electrical conductivity measured in downhole conductivity profiles completed in Sept 2024.

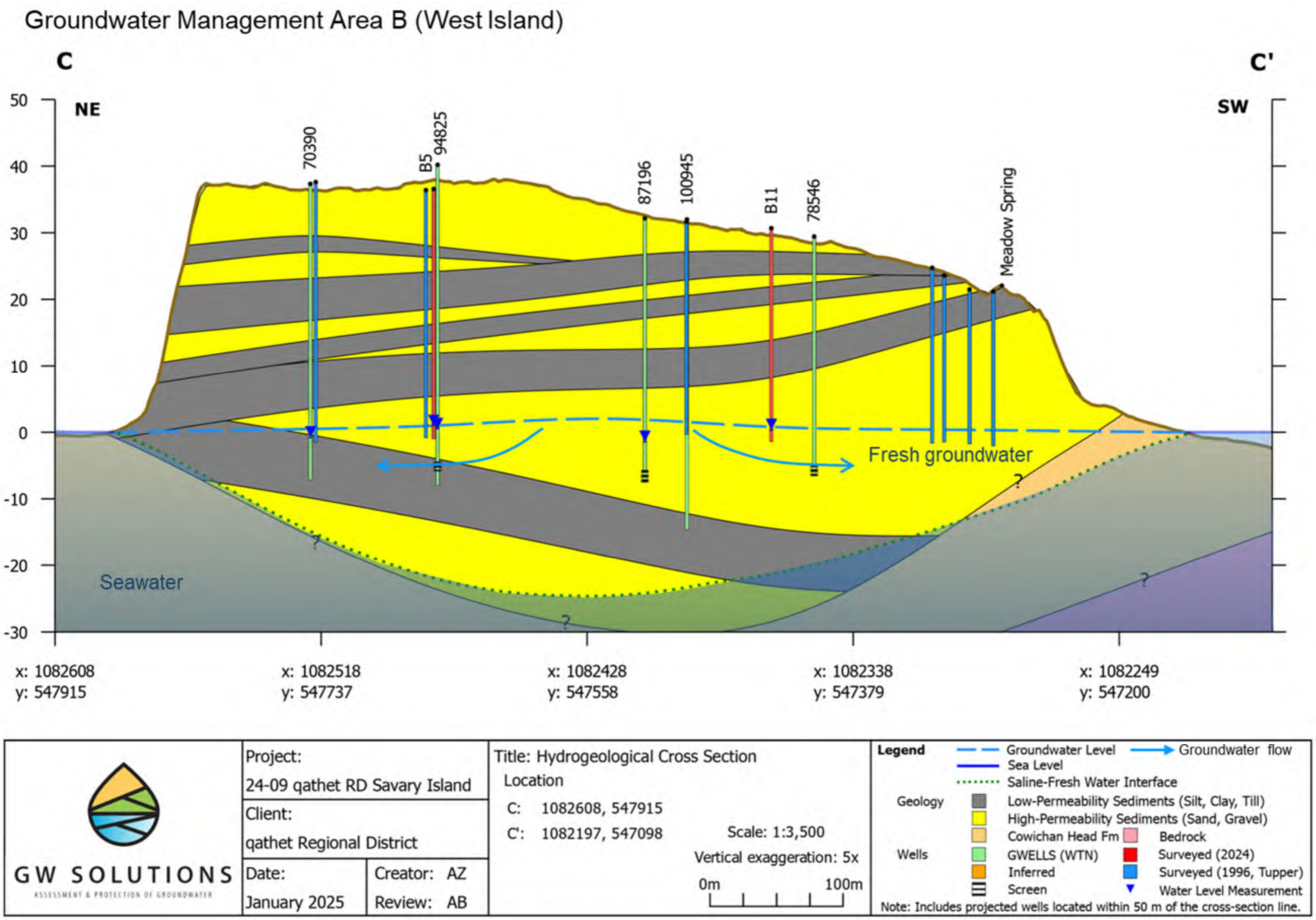


Figure 51. Savary Island interpreted cross-section C-C' Management Area B, West Island.

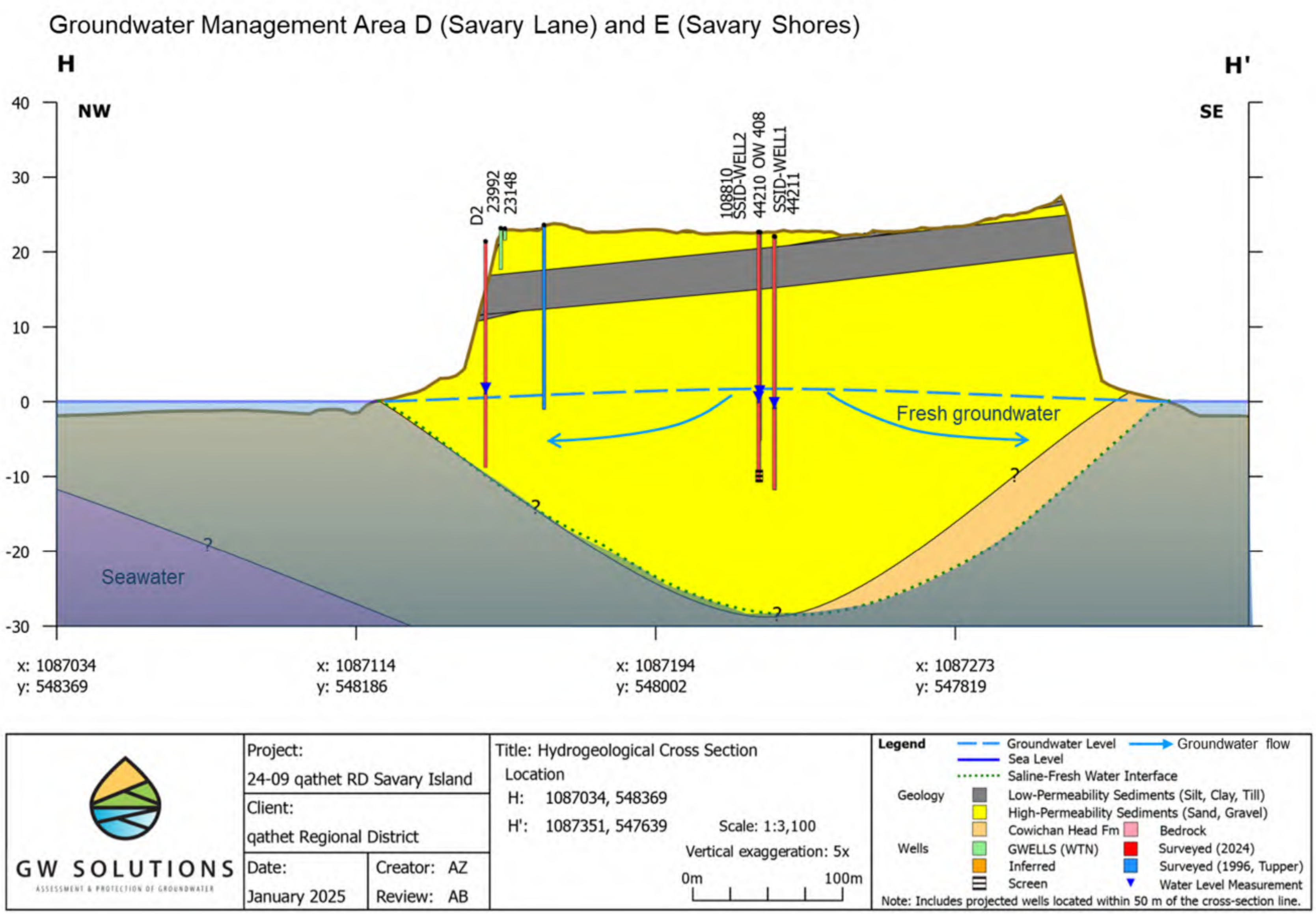


Figure 52. Savary Island interpreted cross-section H-H' Management Area D, Savary Lane, and Area E, Savary Shores.

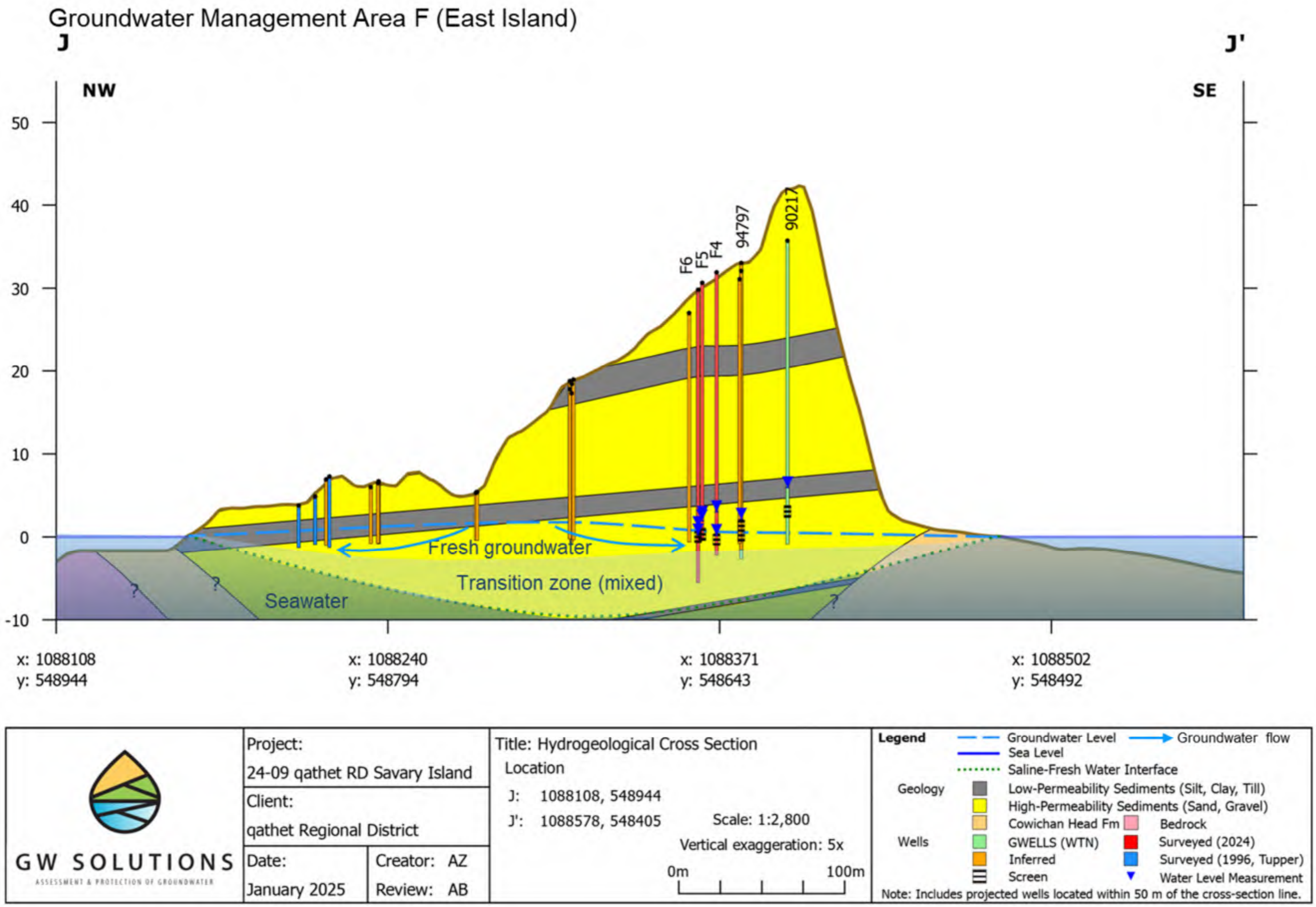


Figure 53. Savary Island interpreted cross-section J-J' Management Area F, East Island. The depth of the mixed transition zone was based on field electrical conductivity measured in downhole conductivity profiles completed in Sept 2024.

11 GROUNDWATER PROTECTION AND MANAGEMENT PLAN

The sustainability and protection of groundwater supplies on Savary Island depends on the shared actions of community members, local government, tradespeople, and visitors to the island. A groundwater protection and monitoring plan should include actions within the following areas.

Private Well Protection and Operation

Providing opportunities for well owner education would be beneficial to increase awareness of groundwater protection concerns. Improved wellhead protection and completion of upgrades has potential benefits not only to individual well owners but also for the aquifer and adjacent groundwater users. Currently only a small proportion of well owners regularly test the quality of their water source, and few employ any form of disinfection or treatment, putting water users at risk of water-borne illness from pathogens. Increased testing and awareness overall, and disinfecting groundwater from the most vulnerable wells should be promoted. New development and operation of wells in the areas at highest risk of seawater intrusion (e.g. Areas A and F) can have serious impacts on existing water users. Understanding and applying best practices to prevent seawater intrusion in all areas is critical to preserve the freshwater resources on the island over the long term.

Rural Water Supply and Servicing Options

Residents and property owners on Savary Island are largely left to their own devices when it comes to designing and investing in water supply and sewerage options. What and when to invest in different water options for a property is determined based on financial considerations, and personal priorities or plans, such as desire to live on the island for more or less of the year, or to develop a home-based business such as a vacation rental. At the neighbourhood level, development is similarly piecemeal, with some individuals investing in larger homes and infrastructure, and others residing in more simple or temporary dwellings with limited amenities. The appropriate water source for a property is likely to vary depending on the location on the island, resources available, siting setbacks and other considerations, but each water source has inherent benefits or drawbacks. Options to consider for independent water supply include rainwater harvesting, sand point wells, and drilled wells. Inclusion of water storage is also an asset. Dug wells are not recommended as a water source due to their very high risk of contamination and likelihood of drying up seasonally. If one considers the expense of investing in a private well and water system, it may be more cost effective for neighbours to collaborate and develop a small-scale shared system e.g. that could serve multiple families or parcels. Undeveloped “water lots” with communal wells could be purchased and established further away from contaminant sources, to serve a neighbourhood or group of homes. Shared systems currently exist on the island but operate largely under the radar. Rather than discouraging this practice, provincial guidelines and policies could be developed to assist property owners to identify the best water options for their property, and to legally establish and effectively manage a small shared system if this is identified as the best option.

Community Water Supplies

The Savary Shores Improvement District (SSID) is a valued and carefully managed water service on the Island, that measures water use, promotes water conservation, regularly tests the water quality, and completes needed capital improvements funded by user fees. Unfortunately, based on current provincial policies, improvement districts are largely ineligible for grants and funds available to regional and municipal water providers and utilities. The qRD and SSID could further explore ways to work together to prioritize and fund needed upgrades. An excellent example is the proposed addition of solar power to operate SSID pumps and distribution systems, which could add redundancy and reduce reliance on diesel generators. The SSID also provides a model for other potential community water supplies or utilities that could be considered and developed by the qRD in priority areas on the Island. If this option is considered, new water system wells must be carefully planned, sited and managed to avoid anthropogenic contamination or overexploitation that could exacerbate seawater intrusion risk.

Water Conservation Planning and Education

Freshwater resources on Savary Island are limited and must be carefully conserved. Fresh groundwater in the Island's aquifer occupies a thin lens overlying a brackish mix of fresh and saline water, which transitions to seawater at depth. While the island receives abundant rainfall and groundwater recharge during the wet season, peak demand occurs during the dry season when there is little to no rainfall and aquifer recharge. Climate change is increasing water used by plants and evaporated from the soil and lengthening the period during which no rainfall occurs. Water conservation has long been a community ethic on the island, however, especially with newer residents and visitors, the importance of water conservation in protecting precious water must continue to be emphasized. By the same token, larger, urban style water-intensive buildings, and "green lawns" are less compatible with water sustainability on the Island, especially in the most densely develop areas.

Groundwater Level Monitoring

There are currently three observation wells on the Island in which groundwater level and temperature are monitored: OW408 in the SSID well field (Area E), OW511 in Area A on the western tip of the island, and OW500 (WTN 107896) which monitors ambient conditions in Area C but is not an official location in the provincial network. Monitoring in the SSID well field benefits the understanding of aquifer conditions for the water system, therefore, further collaboration between SSID and the ENV/WLRS to download and maintain this station would be beneficial. It is recommended that OW500 be incorporated as a permanent monitoring site. Volunteer monitoring by private well owners in other areas (e.g. Area B and Area F) would provide additional information on aquifer conditions.

Groundwater Quality Monitoring

Apart from the SSID which conducts regular water testing, the understanding of groundwater quality on Savary Island is limited. The keen interest in the community to participate in the current study shows that well owners would like more information on the quality of groundwater. However, logistical aspects (how to sample, store, transport) and high cost are perceived as a barrier. Well owners, particularly those who's primary or full-time residence is on the Island, should be supported and encouraged to conduct regular (bi-annual, wet and dry season) testing for bacteriological quality and semi-annual (dry season) testing of geochemical quality, including parameters for the assessment of seawater intrusion hazard (electrical conductivity, chloride and total dissolved solids). The Health Authority or qRD could establish an on-Island location to provide sample bottles and provide further outreach and education regarding well testing. Neighbourhood surveys of field water quality could be repeated in future to evaluate changes in concentration of salinity indicators (e.g. electrical conductivity).

For the provincial observation wells (OW408, OW500, and OW511 and), it is recommended to continue monitoring water quality (potability lab testing) at least twice a year (winter and summer) to assess the temporal change and evolution of groundwater.

Well Drillers and Pump Installer Education and Compliance

Well drillers and pump installers play a crucial role enabling property owners to develop and access water supplies on the Island. Proper well installation that meets the requirements of the Groundwater Protection Regulation and other rules is critical, including ensuring adequate setbacks from contaminant sources, installing surface seals of adequate depth and thickness, and registering wells in the GWELLS database. Pump installers must ensure that surface seals are restored if damaged during installation (i.e. if material around the well is removed to install a pitless adapter). Understanding and applying best practices to prevent seawater intrusion is also essential, including understanding the hazards in different areas, measuring and testing water quality during drilling, abandoning dry holes, and sealing off saline zones if encountered. The provincial government (Ministry of Water, Land and Resource Stewardship) should develop a seawater intrusion advisory for Savary Island and increase efforts to inspect and enforce compliance with the regulations.

Sewerage and Septic System Installation and Maintenance

The management and treatment of sewerage waste, including proper design and installation of sewerage systems is essential to protect drinking water supplies on the Island. Many areas of Savary have limited soil depth, which influences the effectiveness of pollution attenuation. Only a small proportion of property owners reported completing regular inspection and maintenance of their septic systems (such as pumping out of solids). Most sewerage systems are also only operated seasonally. While this has the benefit of reducing nutrient loading to the aquifer (i.e. less waste is being discharged on an annual basis), conversely it may inhibit the development of the bacteria essential to the proper functioning of the system. Older installations such as outhouses can increase contamination hazard and should be decommissioned and replaced with a more effective mode of sewage management. Increased education and awareness of rural sewage treatment options for residents, and increased oversight of septic installers is likely to benefit groundwater protection. Residents should consider alternative techniques for treating human waste that do not contaminate water such as composting toilets and urine-diverting systems.

Water Management and Licensing

The *Water Sustainability Act* requires a water license for non-domestic groundwater use, such as for hotels, industrial, government or commercial operations. Although this category likely applies to a limited number of parcels or land uses on the Island, further communication, education and compliance with licensing requirements would help prevent over-exploitation of groundwater from unauthorized water diversion.

Land Use Planning

Within the current land use planning process, the qRD are working with the community to envision the desired future of Savary Island. As a part of this process, the facilitators could lead a planning session focussed specifically on water issues, which could include the participation of groundwater professionals. Resources and strategies that increase awareness and encourage best practices related to water could be further developed, while looking to models from other communities that have developed similar plans e.g. Islands Trust, Regional District of Nanaimo, and Cowichan Valley Regional District.

12 CONCLUSIONS

This study summarized current understanding of hydrologic conditions and groundwater quality on Savary Island, a small, sandy strip island west of Lund, BC in the qathet Regional District.

The key conclusions are as follows:

1. **Hydrogeology:** Groundwater supplies on Savary Island are obtained from a highly permeable sand aquifer. The aquifer is vulnerable to contamination and seawater intrusion due to its geological structure and the high density of wells.

2. **Water Quality:** Generally, groundwater quality meets drinking water standards, with some natural contaminants like iron and manganese exceeding aesthetic guidelines. Nitrate levels indicate vulnerability to land use impacts, particularly from septic systems.

3. **Water Demand and Balance:** Current water use is sustainable under present occupancy patterns but could face stress with increased full-time residency. Although the region receives abundant rainfall, seasonal water demand occurs during a period of seasonal deficit. Water conservation and efficient resource management are critical to maintaining aquifer health.

4. **Environmental Challenges:** Climate change poses significant risks, including altered precipitation patterns, increased evaporation, and increased seawater intrusion hazard, necessitating adaptive management strategies.

5. **Community Involvement:** Collaboration with local stakeholders, education on best practices for water use and well management, and regulatory compliance are essential for protecting groundwater resources.

Overall, proactive measures in water conservation, monitoring, and infrastructure planning are needed to ensure the long-term sustainability of Savary Island's limited freshwater resources.

13 RECOMMENDATIONS

We make the following recommendations:

- **Enhance Well Protection and Maintenance:** Educate well owners on proper maintenance practices, focusing on sealing and protecting wells to prevent contamination and seawater intrusion.
- **Promote Water Conservation:** Implement community-wide campaigns to reduce water use, especially during peak demand periods, and encourage the adoption of water-saving technologies.
- **Continue Monitoring and Data Collection:** Continue current monitoring in provincial Observation Wells. Seek opportunities to expand groundwater data collection through volunteer well networks, to better assess aquifer conditions and changes over time within each groundwater management area.
- **Support Community Collaboration:** Encourage local partnerships, including potential shared water systems, to optimize resource use and reduce individual costs while maintaining sustainable practices.
- **Adapt to Climate Challenges:** Develop strategies to address the impacts of climate change to ensure the resilience of water resources.
- **Foster Regulatory Compliance:** Work with regional and provincial authorities to ensure adherence to water protection and water authorization regulations and promote responsible water management practices.

- **Explore Alternative Water Sources and Wastewater Options:** Consider the development of rainwater harvesting systems and other non-traditional water sources to augment groundwater supplies, such as in areas of higher seawater intrusion hazard. Consider wastewater options that do not impact water resources (e.g. composting toilets, urine diversion).

- **Collaboration and Community Engagement:** Foster partnerships between local governments, communities, and organizations to manage and protect groundwater resources collectively.

Best Practices for Groundwater and Domestic Septic Systems:

- **Well Location and Construction:** Ensure wells are located at least 30 meters from potential contamination sources like septic systems. Use proper construction techniques, including the installation of secure well caps and surface seals to prevent contamination.

- **Regular Testing and Maintenance:** Test groundwater quality regularly for contaminants such as bacteria, nitrates, and other potential pollutants. Maintain wells by repairing surface seals, and ensuring foreign matter, including vehicle parking and contaminants are kept away from the well.

- **Septic System Design:** Install septic systems with adequate drainage fields that are appropriately sized based on local soils and the number of household occupants. Complete regular septic system maintenance including pumping out of solids.

- **Sewage Management:** Avoid disposing harsh chemicals, fats, or non-biodegradable items in the septic system. Periodically pump out the septic tank to prevent overflow and system failure.

- **Public Education:** Educate homeowners and developers about groundwater protection and the importance of regular maintenance of wells and septic systems.

- **Water Conservation:** Adopt water-saving appliances and practices to reduce the stress on groundwater resources and the septic system.

- **Monitoring and Regulation:** Ensure compliance provincial regulations concerning water quality and waste disposal, including the registration and proper decommissioning of wells.

Best Practices to Prevent and Mitigate Seawater Intrusion:

- **Well Drillers:**

    1. Research local conditions and plan when drilling in areas at risk of seawater intrusion.
    2. Site wells a minimum of 30 m from the seashore.
    3. Test for salinity indicators during drilling (electrical conductivity or total dissolved solids). If saline groundwater is encountered, stop drilling and test the water quality.
    4. Backfill and seal off saline zones.
    5. Educate well owners regarding the hazards and prevention of seawater intrusion.

- **Well Pump Installers:**

    1. Install well pumps at shallower depths and include automated shutoffs to limit groundwater level drawdown below sea level.
    2. Set pumps to operate for timed shorter cycles at a low pumping rate to refill water storage ("well sipping").
    3. Install meters and alarms to identify and quickly fix uncontrolled leaks.
    4. Consider installing dataloggers to monitor groundwater level, temperature, and EC, to understand changes in water quality during pumping.
    5. Install monitoring equipment to measure EC or TDS while pumping, and shut off pumping if water quality exceeds an identified limit (e.g., operational threshold or drinking water guideline).

- **Well Owners:**

    1. Record observations that could indicate changes in water quality over time (salty taste, observed corrosion, or discoloration of pipes and fixtures).

2. Purchase a low-cost water quality monitor (e.g., pen-style conductivity or TDS meter) and record periodic measurements of groundwater quality, noting trends, seasonal differences, or changes during periods of higher water use.

3. Collect samples for lab analysis of geochemical water quality annually or semi-annually, including analysis of salinity indicators (chloride, EC, TDS).

4. Install low water use fixtures (low flush or suction toilets, low flow shower heads, and faucets).

5. Practice water conservation, limit non-essential water use, including limiting outdoor irrigation in areas at highest risk of intrusion.

6. Check for and fix uncontrolled leaks, hoses left open, etc., which could draw down water levels in the well.

7. Educate residents and guests regarding low water use practices.

8. Use water cisterns to store water from the well or other backup supplies (e.g., rainwater collection). Observing tank storage and drawdown is also an easy way to measure and manage water demand.

9. If the well produces salty water seasonally or periodically, use an alternate supply, investigate the cause, and seek advice from a driller, pump installer, or other qualified person.

10. Properly decommission (backfill) unused wells that could provide a pathway for circulation and movement of saline water from deeper to shallower aquifer zones.

11. In multi-well systems, alternate the pumping of each well to allow water levels to recover.

Study Limitations

This document was prepared for the exclusive use of the qathet Regional District (qRd). The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others and are based solely on the condition of the site at the time of the site studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques and other factors.

In evaluating the subject study area and water quality data, GW Solutions has relied in good faith on information provided. The factual data, interpretations and recommendations pertain to a specific project as described in this document, based on the information obtained during the assessment by GW Solutions on the dates cited in the document, and are not applicable to any other project or site location. GW Solutions accepts no responsibility for any deficiency or inaccuracy contained in this document as a result of reliance on the aforementioned information.

The findings and conclusions documented in this document have been prepared for the specific application to this project and have been developed in a manner consistent with that level of care normally exercised by hydrogeologists currently practicing under similar conditions in the jurisdiction.

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If new information is discovered during future work, including excavations, sampling, soil boring, predictive geochemistry or other investigations, GW Solutions should be requested to re-evaluate the conclusions of this document and to provide amendments, as required, prior to any reliance upon the information presented herein. The validity of this document is in initiating or completing the project. The graphs, images, and maps have been generated to visualize results and assist in presenting information in a spatial and temporal context. The conclusions and recommendations presented in this document are based on the review of information available at the time the work was completed, and within the time and budget limitations of the scope of work.

The qRD may rely on the information contained in this memorandum subject to the above limitations.

14 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This letter report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix I.

GW Solutions was pleased to produce this document. If you have any questions, please contact the authors.

GW Solutions Inc. (Engineers and Geoscientists BC Permit to Practice Number 1002916)

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APPENDIX A

RESULTS OF ONLINE RESIDENT SURVEY

Savary Island Groundwater Assessment

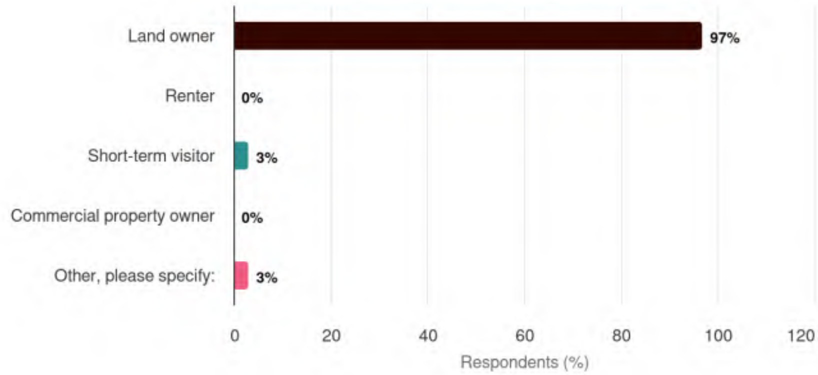
2024-10-16 10:00

Latest response: 2024-10-15 04:07

Filter: Submitted

1) Which of the following best describes your connection to Savary Island?

59 respondents



	%	Frequency	
Land owner	96.61%	57	
Renter	0.00%	0	
Short-term visitor	3.39%	2	
Commercial property owner	0.00%	0	
Other, please specify:	3.39%	2	
Total		59	

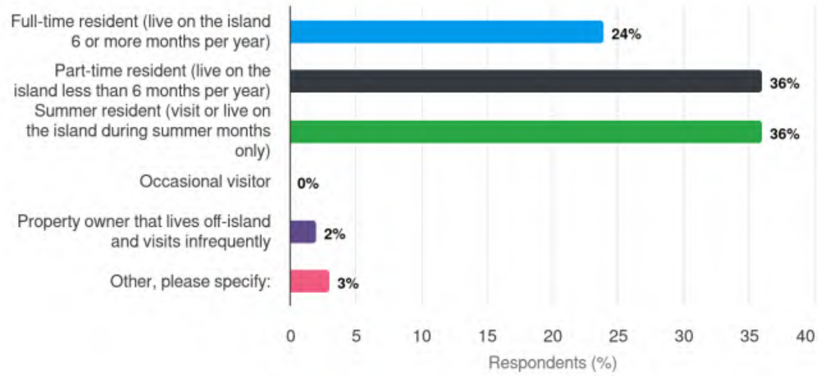
Other, please specify:

2 respondents

1 Summer cabin owner	10/5/2024 4:22:00 AM
2 Child of land owner	10/5/2024 2:24:00 AM

2) Indicate your residential status on Savary Island

59 respondents



	%	Frequency	
Full-time resident (live on the island 6 or more months per year)	23.73%	14	
Part-time resident (live on the island less than 6 months per year)	35.59%	21	
Summer resident (visit or live on the island during summer months only)	35.59%	21	
Occasional visitor	0.00%	0	
Property owner that lives off-island and visits infrequently	1.69%	1	
Other, please specify:	3.39%	2	
Total		59	

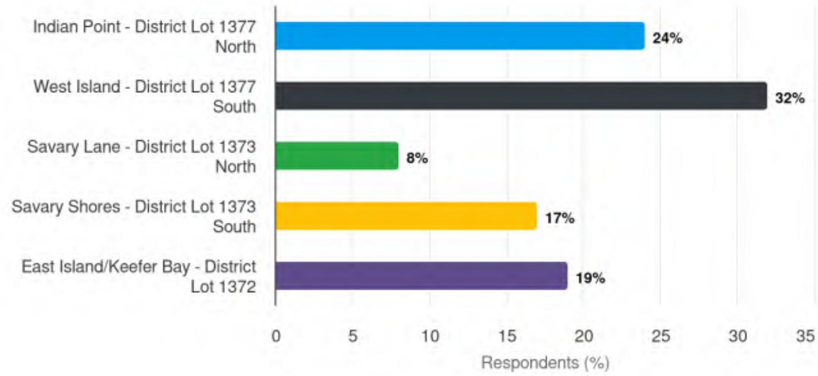
Other, please specify:

2 respondents

1 Property/cottage owner , visit as often as I can in spring, summer and fall	9/23/2024 3:23:00 PM
2 We visit for 1-3 weeks at a time, not only in summer	9/16/2024 12:18:00 AM

3) Based on the map of water management areas on Savary Island, in which general area is your property located?

59 respondents



	%	Frequency	
Indian Point - District Lot 1377 North	23.73%	14	
West Island - District Lot 1377 South	32.20%	19	
Savary Lane - District Lot 1373 North	8.47%	5	
Savary Shores - District Lot 1373 South	16.95%	10	
East Island/Keefer Bay - District Lot 1372	18.64%	11	
Total		59	

4) How many people reside on the property?

59 respondents

59 respondents

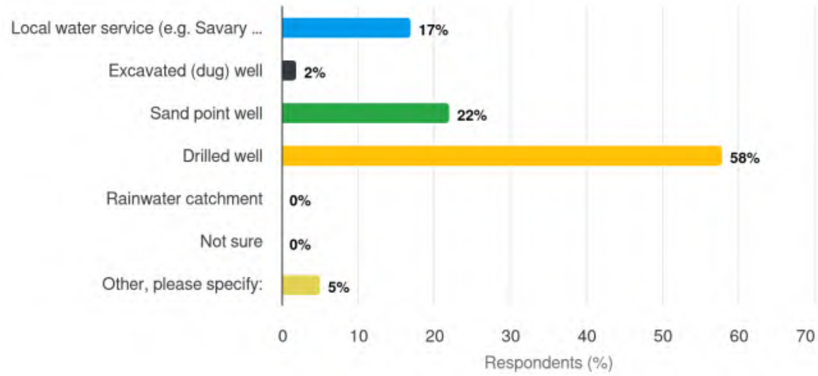
Score	Responses	Min.	Mean	Median	Max.	Std. dev.	Variance
182.00	59	0.00	3.08	2.00	15.00	2.26	5.11

5) Please indicate the location of your property (optional):

Answers removed for privacy protection.

6) What is the source of water supply for the property?*

59 respondents



	%	Frequency	
Local water service (e.g. Savary Shores Improvement District)	16.95%	10	
Excavated (dug) well	1.69%	1	
Sand point well	22.03%	13	
Drilled well	57.63%	34	
Rainwater catchment	0.00%	0	
Not sure	0.00%	0	
Other, please specify:	5.08%	3	
Total		59	

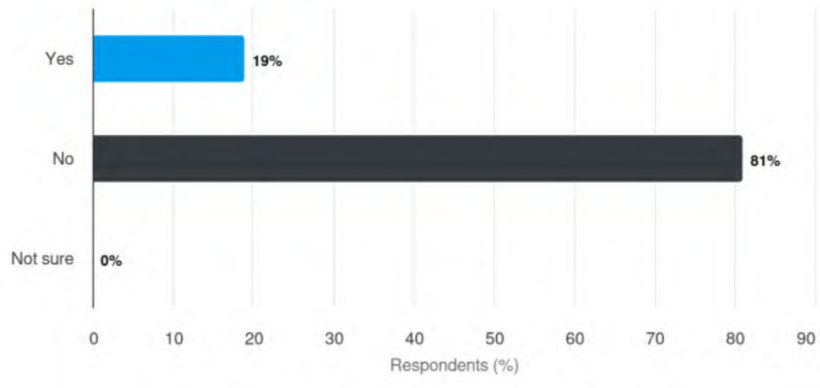
Other, please specify:

3 respondents

1 Well does not have water	9/20/2024 7:07:00 PM
2 bring bottled water for drinking	9/18/2024 9:01:00 PM
3 we bring our water over in jugs	9/17/2024 5:17:00 PM

7) Do you use a shared well or water source (e.g. a water supply that is shared between multiple households or parcels)?

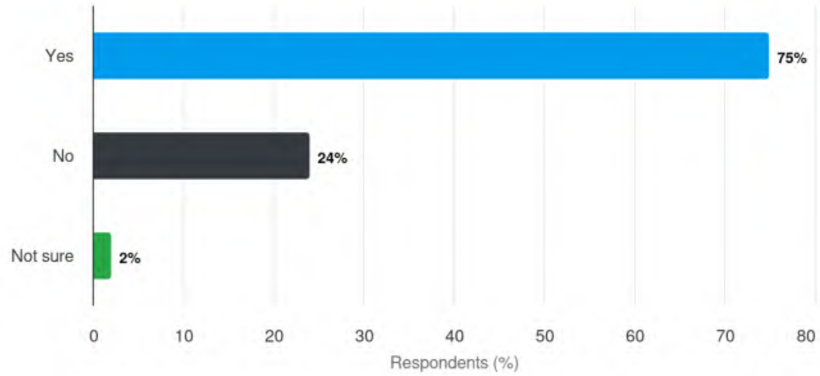
59 respondents



	%	Frequency	
Yes	18.64%	11	
No	81.36%	48	
Not sure	0.00%	0	
Total		59	

8) Does your property have a well?

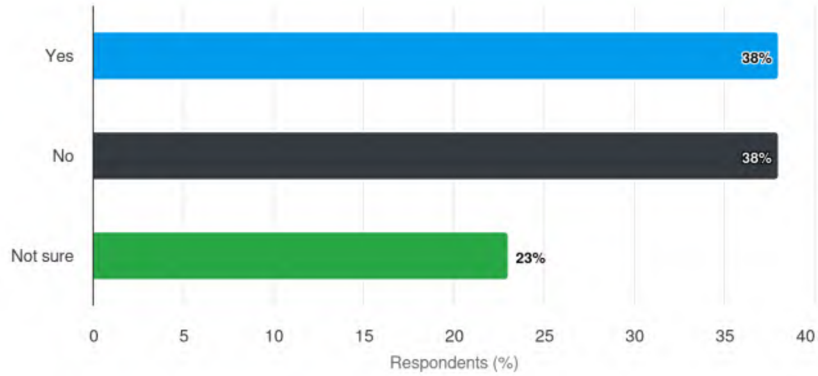
59 respondents



	%	Frequency	
Yes	74.58%	44	
No	23.73%	14	
Not sure	1.69%	1	
Total		59	

9) If there is a well on your property, do you have a well construction record for the well?

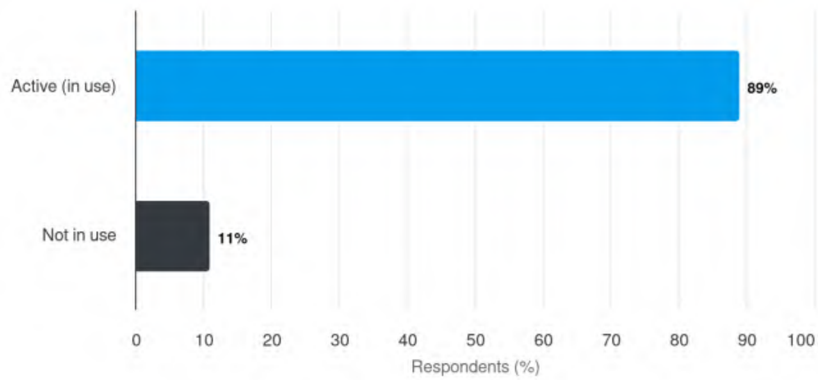
47 respondents



	%	Frequency	
Yes	38.30%	18	
No	38.30%	18	
Not sure	23.40%	11	
Total		47	

10) If there is a well on your property, what is the status of use of the well?

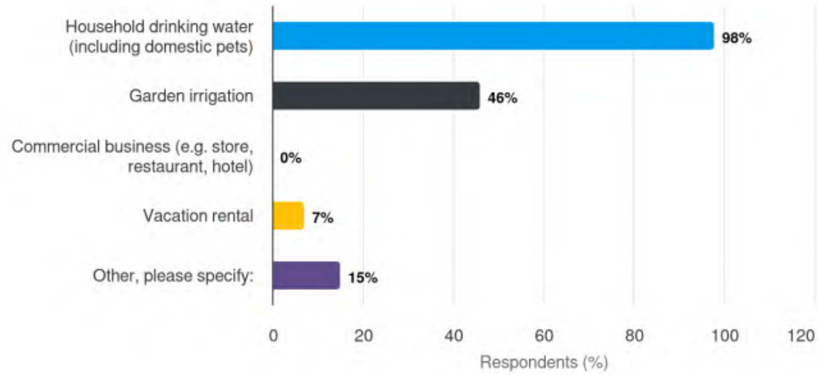
45 respondents



	%	Frequency	
Active (in use)	88.89%	40	
Not in use	11.11%	5	
Total		45	

11) What is the purpose of water use on the property?

59 respondents



	%	Frequency	
Household drinking water (including domestic pets)	98.31%	58	
Garden irrigation	45.76%	27	
Commercial business (e.g. store, restaurant, hotel)	0.00%	0	
Vacation rental	6.78%	4	
Other, please specify:	15.25%	9	
Total		59	

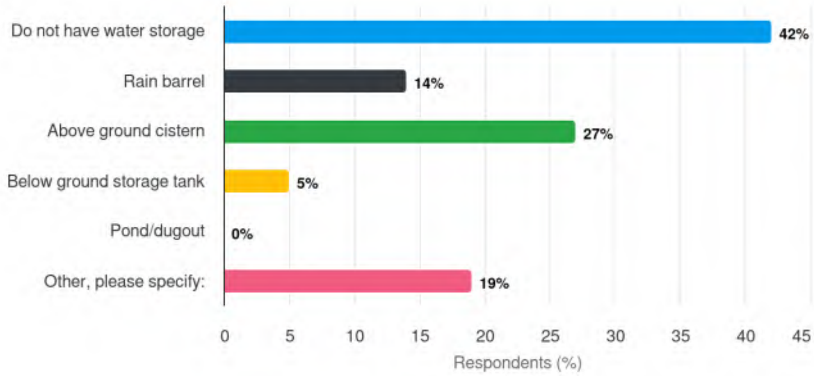
Other, please specify:

9 respondents

1 Showers and toilets	10/5/2024 2:27:00 AM
2 cooking/cleaning	9/26/2024 6:25:00 PM
3 Cleaning	9/23/2024 2:57:00 PM
4 Wash, showers	9/20/2024 7:53:00 PM
5 would be drinking and showers	9/20/2024 7:07:00 PM
6 Washer; Showers; Cooking	9/19/2024 7:09:00 AM
7 general household use, eg. washing dishes, floors, showers	9/18/2024 9:01:00 PM
8 Laundry	9/17/2024 10:24:00 PM
9 Personal hygiene	9/16/2024 12:25:00 AM

12) What types of water storage do you have on the property

59 respondents



	%	Frequency	
Do not have water storage	42.37%	25	
Rain barrel	13.56%	8	
Above ground cistern	27.12%	16	
Below ground storage tank	5.08%	3	
Pond/dugout	0.00%	0	
Other, please specify:	18.64%	11	
Total		59	

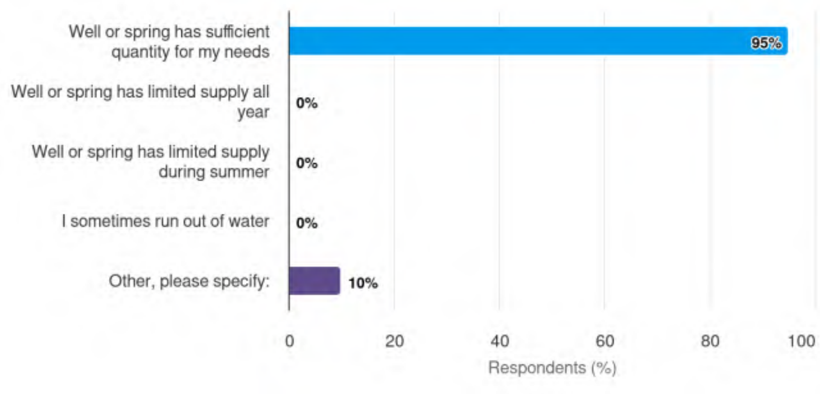
Other, please specify:

11 respondents

1 Pressure tank	10/5/2024 4:25:00 AM
2 Pressure tanks	9/24/2024 1:14:00 AM
3 Cistern on tower	9/23/2024 3:25:00 PM
4 pressure tank	9/22/2024 2:04:00 PM
5 Above ground tank	9/20/2024 7:37:00 PM
6 250 gallon above ground tank , gravity fed to the house for running water	9/18/2024 9:01:00 PM
7 Bladders	9/18/2024 3:13:00 AM
8 250 gal tank on 35' tower	9/17/2024 12:49:00 AM
9 pressure tank	9/16/2024 6:05:00 PM
10 pressure tank in house	9/14/2024 6:46:00 PM
11 Pressure Tank	9/13/2024 5:28:00 PM

13) Does your water source have any problems related to water QUANTITY?

59 respondents



	%	Frequency
Well or spring has sufficient quantity for my needs	94.92%	56
Well or spring has limited supply all year	0.00%	0
Well or spring has limited supply during summer	0.00%	0
I sometimes run out of water	0.00%	0
Other, please specify:	10.17%	6
Total		59

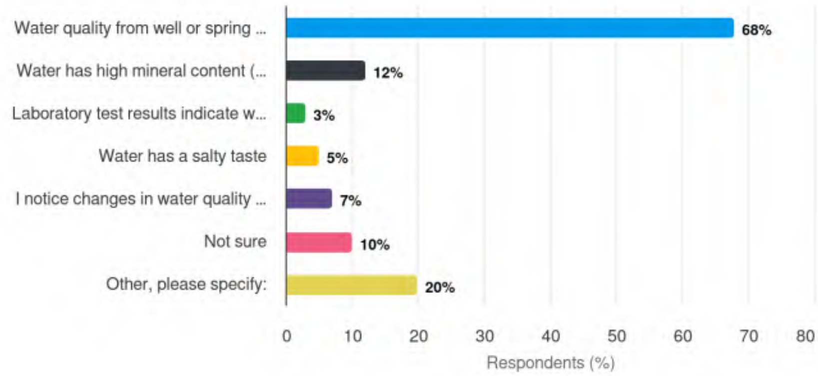
Other, please specify:

6 respondents

1 We are very careful with use	9/23/2024 3:25:00 PM
2 Water pumping re amount and time to fill Depends on the year, other usage in our area and drought or heavier rainfall in year	9/21/2024 2:53:00 AM
3 non productive from date of install	9/20/2024 7:07:00 PM
4 we dont use our well yet	9/17/2024 5:17:00 PM
5 Been good for 31 years	9/17/2024 12:49:00 AM
6 We use community water source and do not run out of water	9/12/2024 6:10:00 PM

14) Does your water source have any problems related to water QUALITY?

59 respondents



	%	Frequency	
Water quality from well or spring is fresh and meets Drinking Water Guidelines	67.80%	40	
Water has high mineral content (e.g. rusty or dark colour, sulphur odour, etc.)	11.86%	7	
Laboratory test results indicate water quality concern e.g. bacteria or water quality parameters with concentrations above Drinking Water Guidelines	3.39%	2	
Water has a salty taste	5.08%	3	
I notice changes in water quality during different times of year	6.78%	4	
Not sure	10.17%	6	
Other, please specify:	20.34%	12	
Total		59	

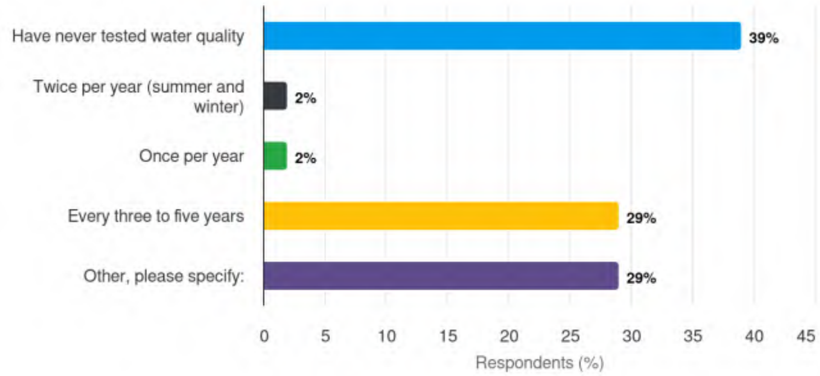
Other, please specify:

12 respondents

1 High sodium content	10/4/2024 11:20:00 PM
2 Boil before drinking, looks & tastes fine	9/23/2024 3:25:00 PM
3 This year the water seemedwarmer in temperature with more rust like sediment, it used to be cold, mineral tasting this year was warmer and more rust like sediment	9/21/2024 2:53:00 AM
4 Our drilled well is new	9/20/2024 8:53:00 PM
5 Has not been tested for many years	9/18/2024 9:01:00 PM
6 Fresh. DWG?	9/18/2024 4:36:00 PM
7 We boil water for drinking	9/18/2024 12:56:00 AM
8 we don't use our well yet	9/17/2024 5:17:00 PM
9 Not tested in 15 years	9/17/2024 12:49:00 AM
10 background coliform detected years ago. We filter drinking/cooking water water	9/16/2024 11:13:00 PM
11 never tested, seems like good quality water, in previous draught periods we have noticed a change in smell and taste.	9/16/2024 4:11:00 PM
12 Community water is excellent	9/12/2024 6:10:00 PM

15) How often do you test the quality of your water source (i.e. collect a sample for laboratory analysis)?

59 respondents



	%	Frequency	
Have never tested water quality	38.98%	23	
Twice per year (summer and winter)	1.69%	1	
Once per year	1.69%	1	
Every three to five years	28.81%	17	
Other, please specify:	28.81%	17	
Total		59	

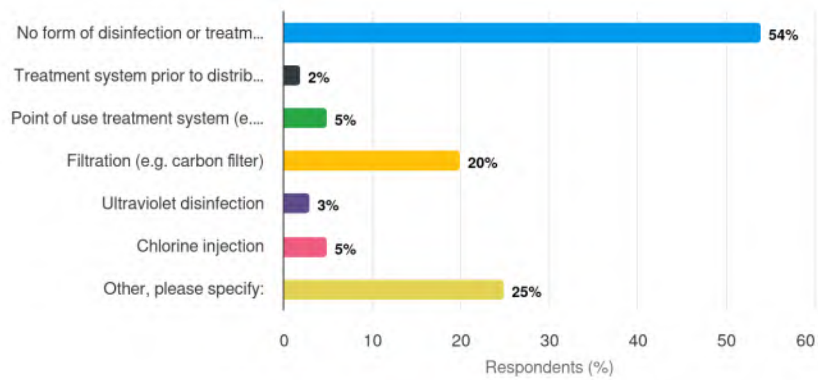
Other, please specify:

16 respondents

1 Once a month	10/5/2024 4:51:00 AM
2 Every 10 years	10/4/2024 11:20:00 PM
3 SSID tests the water periodically	9/21/2024 2:59:00 PM
4 The well is 1 year old	9/20/2024 8:53:00 PM
5 bring own water to Savary	9/20/2024 7:07:00 PM
6 Per SSID Guidelines	9/19/2024 6:12:00 PM
7 Has not been tested for several years	9/18/2024 9:01:00 PM
8 done by ssid	9/18/2024 5:18:00 PM
9 Once	9/18/2024 4:36:00 PM
10 SSID does testing	9/17/2024 10:24:00 PM
11 3 times in 30 years	9/17/2024 12:49:00 AM
12 Savary Shores	9/16/2024 11:48:00 PM
13 once many years ago	9/16/2024 11:13:00 PM
14 Not enough	9/16/2024 11:06:00 PM
15 N/a	9/16/2024 12:25:00 AM
16 Monthly Testing by SSID	9/12/2024 11:58:00 PM

16) What form of water treatment do you use for your water supply?

59 respondents



	%	Frequency	
No form of disinfection or treatment is used	54.24%	32	
Treatment system prior to distribution system (e.g. in pumphouse)	1.69%	1	
Point of use treatment system (e.g. at kitchen tap)	5.08%	3	
Filtration (e.g. carbon filter)	20.34%	12	
Ultraviolet disinfection	3.39%	2	
Chlorine injection	5.08%	3	
Other, please specify:	25.42%	15	
Total		59	

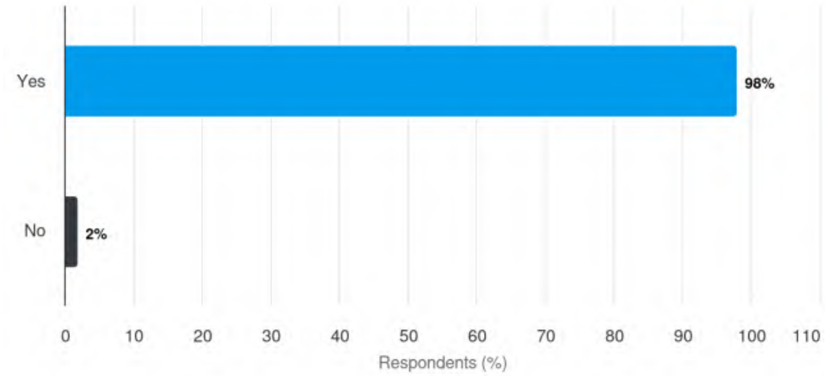
Other, please specify:

15 respondents

#	Response	Date
1	Dalton filter for drinking water only	10/4/2024 11:20:00 PM
2	Water softner	9/24/2024 10:40:00 PM
3	SSID is responsible	9/21/2024 2:59:00 PM
4	Rain filter when working and a brita	9/21/2024 2:53:00 AM
5	I don't know	9/20/2024 8:53:00 PM
6	no water to treat	9/20/2024 7:07:00 PM
7	String filter	9/18/2024 9:01:00 PM
8	Boiled for drinking	9/18/2024 12:56:00 AM
9	SSID guidelines	9/17/2024 10:24:00 PM
10	na	9/17/2024 5:17:00 PM
11	Dalton ceramic Water Filter for Drinking water	9/17/2024 12:49:00 AM
12	Savary Shores	9/16/2024 11:48:00 PM
13	N/a	9/16/2024 12:25:00 AM
14	spindown and 5 micron filter	9/15/2024 12:32:00 AM
15	BritaTM filter for drinking	9/14/2024 6:46:00 PM

17) Does the property have a residence or building?

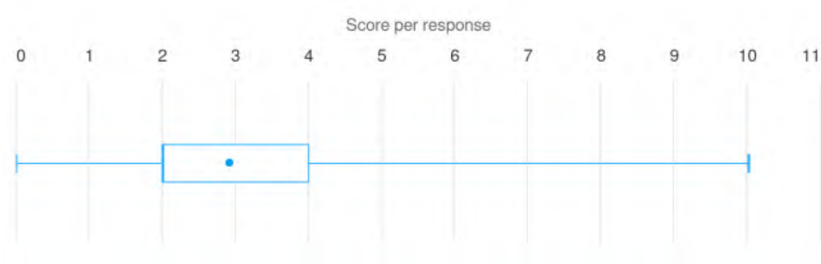
59 respondents



	%	Frequency
Yes	98.31%	58
No	1.69%	1
Total		59

18) On average, how many people reside in the residence or building?

58 respondents

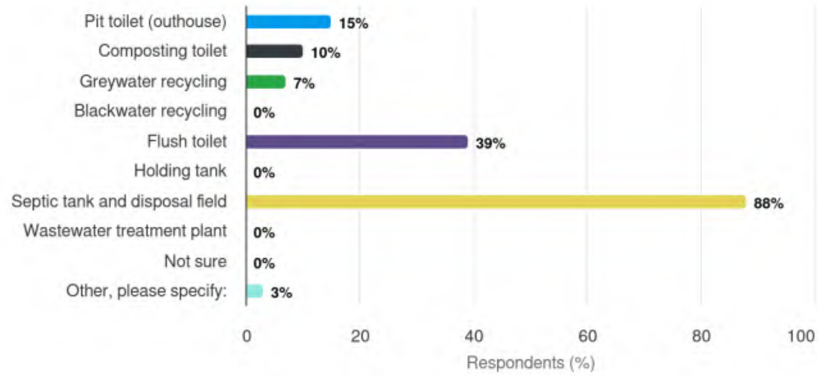


58 respondents

Score	Responses	Min.	Mean	Median	Max.	Std. dev.	Variance
170.00	58	0.00	2.93	2.00	10.00	1.60	2.56

19) How is the wastewater and sewage treated and disposed of on the property?

59 respondents



	%	Frequency
Pit toilet (outhouse)	15.25%	9
Composting toilet	10.17%	6
Greywater recycling	6.78%	4
Blackwater recycling	0.00%	0
Flush toilet	38.98%	23
Holding tank	0.00%	0
Septic tank and disposal field	88.14%	52
Wastewater treatment plant	0.00%	0
Not sure	0.00%	0
Other, please specify:	3.39%	2
Total		59

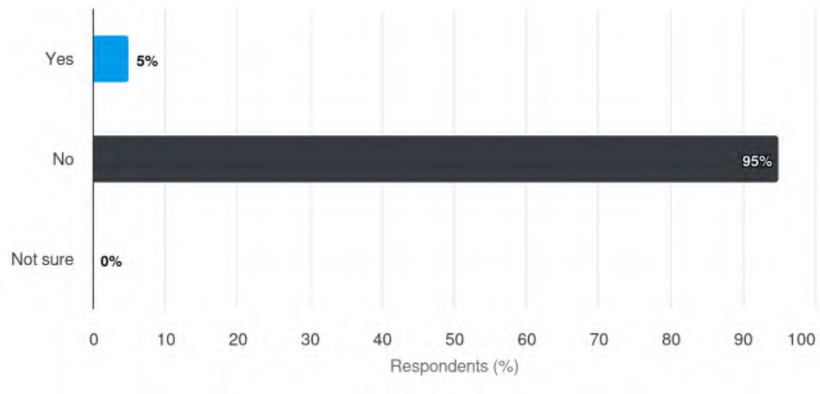
Other, please specify:

2 respondents

1 We believe disposable field	9/23/2024 3:27:00 PM
2 Septic tank for toilet. Greywater goes into ground	9/18/2024 12:58:00 AM

20) Do you use a shared wastewater treatment system (e.g. wastewater disposal system shared between multiple land parcels or households)?

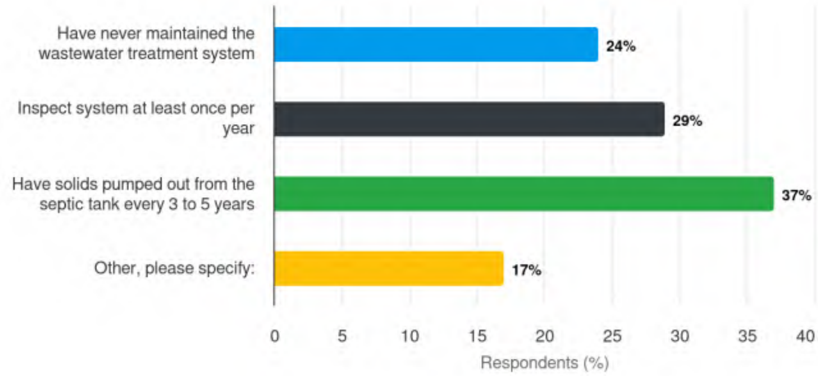
59 respondents



	%	Frequency	
Yes	5.08%	3	
No	94.92%	56	
Not sure	0.00%	0	
Total		59	

21) How frequently do you check and perform maintenance on your wastewater treatment system?

59 respondents



	%	Frequency	
Have never maintained the wastewater treatment system	23.73%	14	
Inspect system at least once per year	28.81%	17	
Have solids pumped out from the septic tank every 3 to 5 years	37.29%	22	
Other, please specify:	16.95%	10	
Total		59	

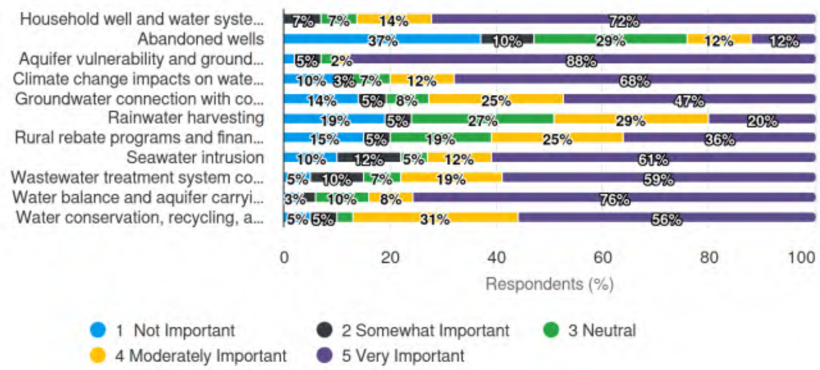
Other, please specify:

10 respondents

1 Pump every 10 years	10/4/2024 11:21:00 PM
2 When needed	9/23/2024 2:58:00 PM
3 I have an outhouse	9/20/2024 8:55:00 PM
4 pumped 8-10 years	9/20/2024 8:35:00 PM
5 Have septic checked every 2 to 3 years and pumped if necessary	9/19/2024 8:38:00 PM
6 septic is fairly new, so no need for maintenance at this time	9/18/2024 5:22:00 PM
7 Solids pumped out of septic tank as needed (once only in 40 years)	9/18/2024 12:58:00 AM
8 na	9/17/2024 5:18:00 PM
9 Pump out septic every 8-10 years	9/17/2024 12:51:00 AM
10 pumped when necessary	9/14/2024 6:48:00 PM

22) For the water topics listed below, please rank each based on the level of importance to you, where 1=Not Important and 5=Very Important

59 respondents



	1 Not Important	2 Somewhat Important	3 Neutral	4 Moderately Important	5 Very Important	Total
Household well and water system construction, operation, and maintenance	0% 0	6.78% 4	6.78% 4	13.56% 8	72.88% 43	59
Abandoned wells	37.29% 22	10.17% 6	28.81% 17	11.86% 7	11.86% 7	59
Aquifer vulnerability and groundwater contamination	1.69% 1	5.08% 3	3.39% 2	1.69% 1	88.14% 52	59
Climate change impacts on water resources	10.17% 6	3.39% 2	6.78% 4	11.86% 7	67.80% 40	59
Groundwater connection with coastal ecosystems	13.56% 8	5.08% 3	8.47% 5	25.42% 15	47.46% 28	59
Rainwater harvesting	18.64% 11	5.08% 3	27.12% 16	28.81% 17	20.34% 12	59
Rural rebate programs and financial supports (e.g. for well repairs, quality testing, water storage, or low water use fixtures)	15.25% 9	5.08% 3	18.64% 11	25.42% 15	35.59% 21	59
Seawater intrusion	10.17% 6	11.86% 7	5.08% 3	11.86% 7	61.02% 36	59
Wastewater treatment system construction, operation, and maintenance	5.08% 3	10.17% 6	6.78% 4	18.64% 11	59.32% 35	59
Water balance and aquifer carrying capacity	3.39% 2	3.39% 2	10.17% 6	8.47% 5	74.58% 44	59
Water conservation, recycling, and reuse	5.08% 3	5.08% 3	3.39% 2	30.51% 18	55.93% 33	59

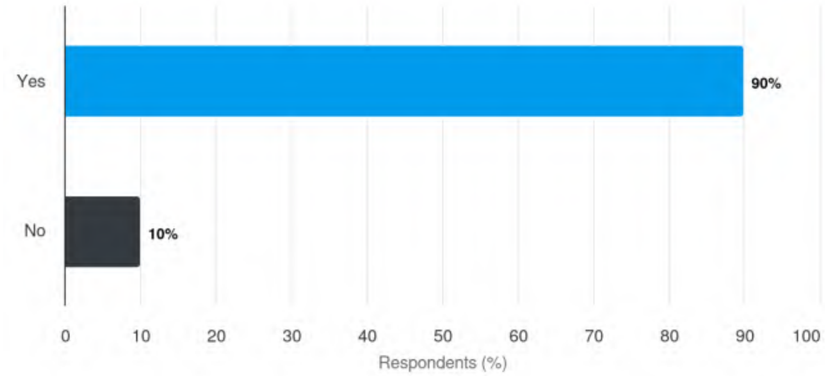
23) Do you have additional thoughts or comments on Savary Island water issues?

Specific responses removed for privacy reasons, general themes:

Theme (# of respondents)
Water conservation education, awareness and guidelines needed (10)
New developments, land clearing, density, size of new dwellings being built and possible impacts on water quality/quantity (10)
Interest in project (6)
Aquifer and island carrying capacity (4)
Savary Island has good groundwater resources (3)
Potential contaminants from septic systems (4)
Well drilling practices and regulation (3)
Water use for vacation rentals (2)
Suggestions to improve survey (2)
Local water supplier does a good job of financing and managing the community water system (2)
Land conservation needed for water protection (2)
Changes in water quality and quantity observed (1)
Water security, quantity & quality (1)
Water needed for community services like fire protection (1)
Residents and land owners need to be better informed about the planning process and groundwater study (improve communication) (1)
Property has problems with water supply (1)
More shared water sources should be established (1)

24) Do you want to sign up to receive project updates?

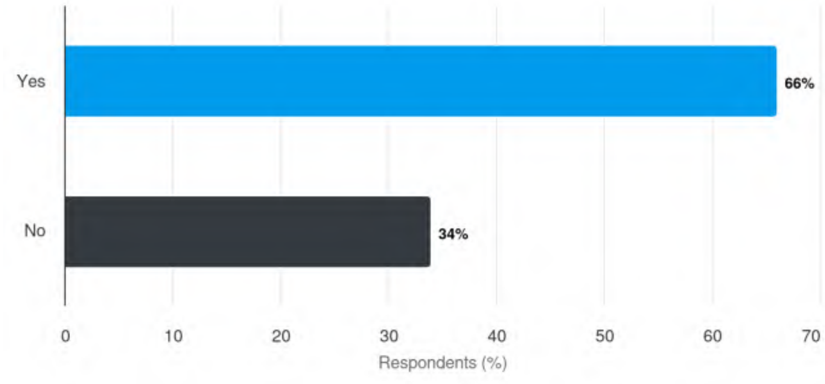
59 respondents



	%	Frequency
Yes	89.83%	53
No	10.17%	6
Total		59

30) Do you want to be entered into the prize draw to win one of two rain barrels?

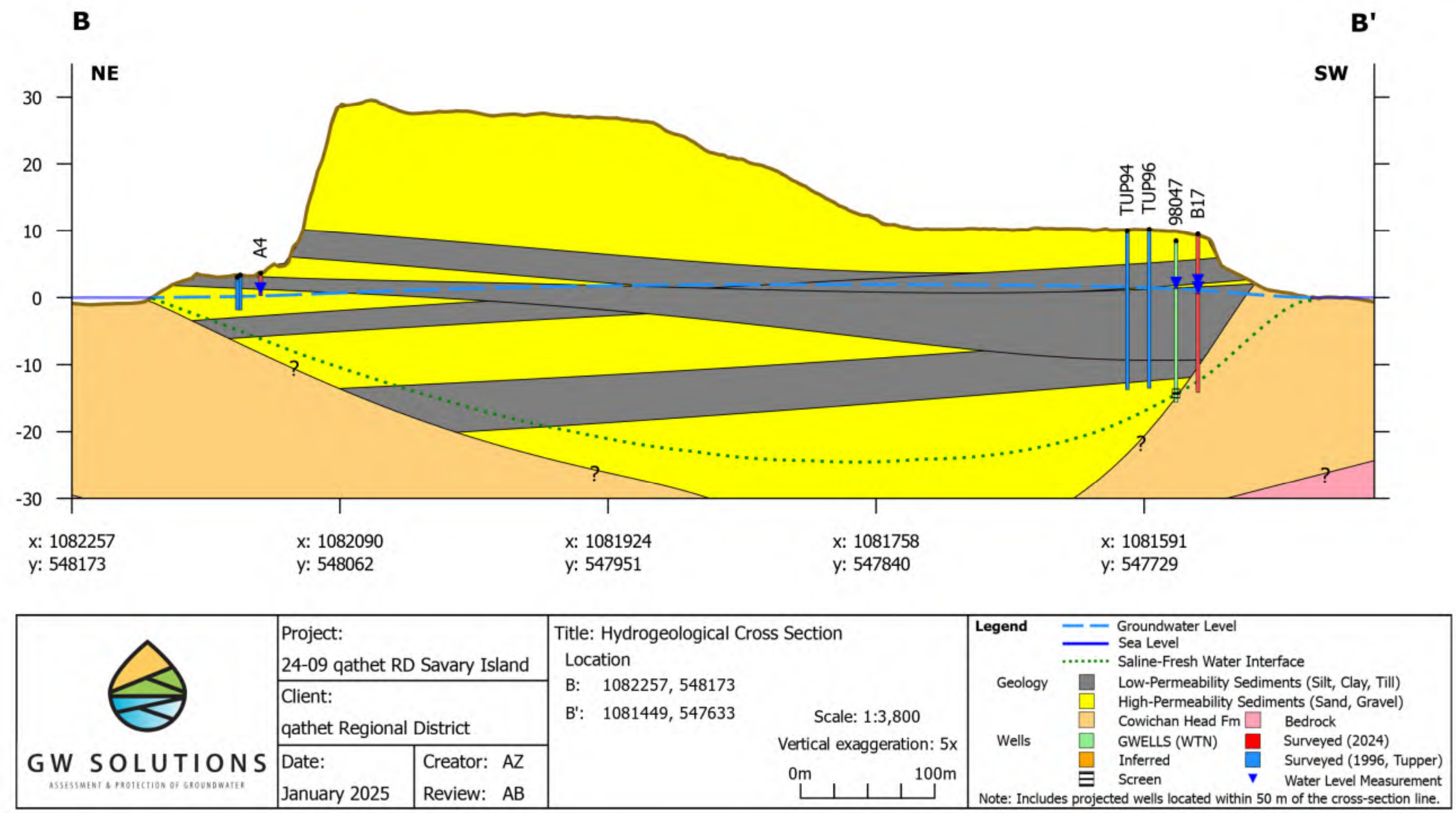
59 respondents

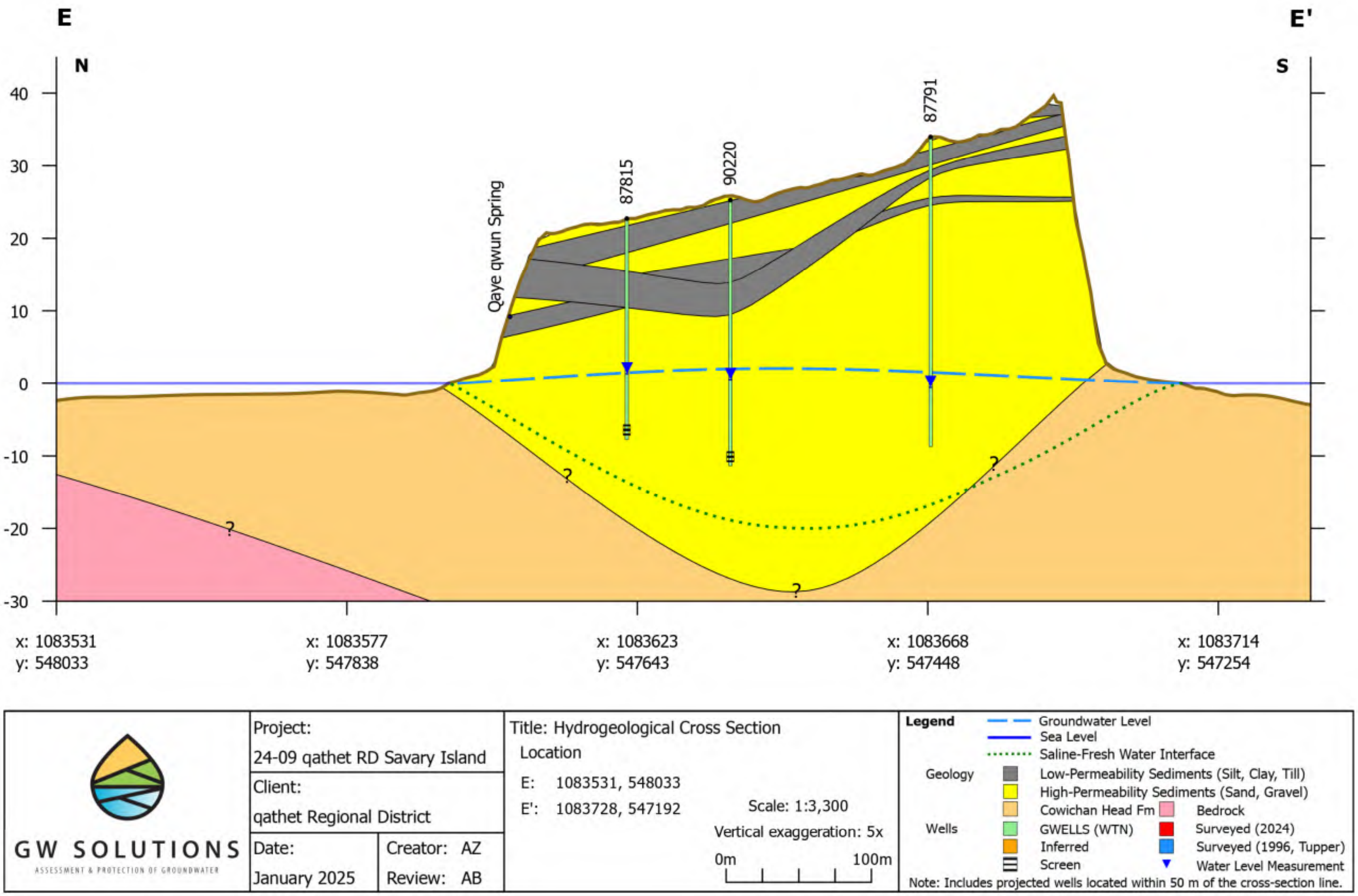


	%	Frequency
Yes	66.10%	39
No	33.90%	20
Total		59

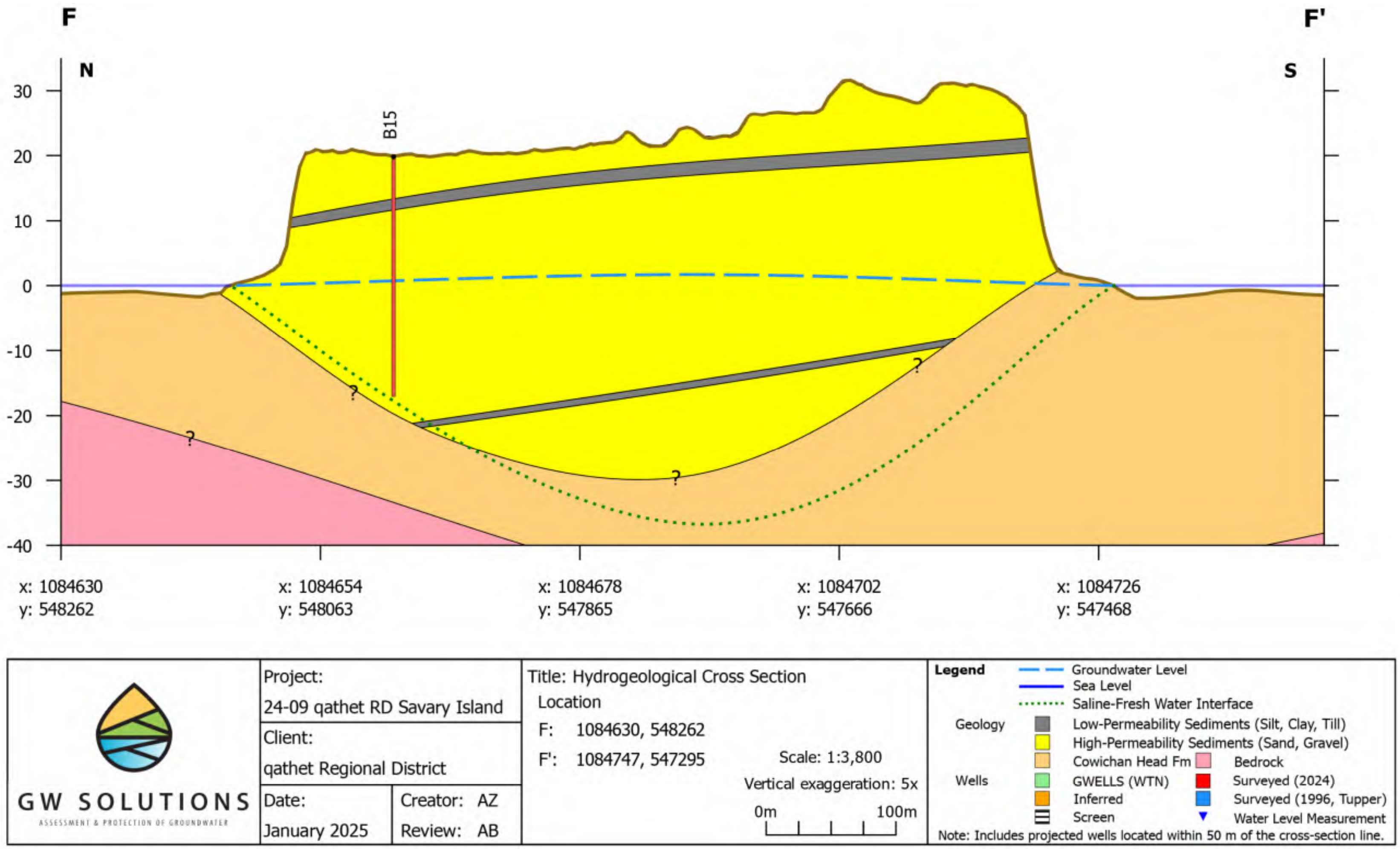
APPENDIX B

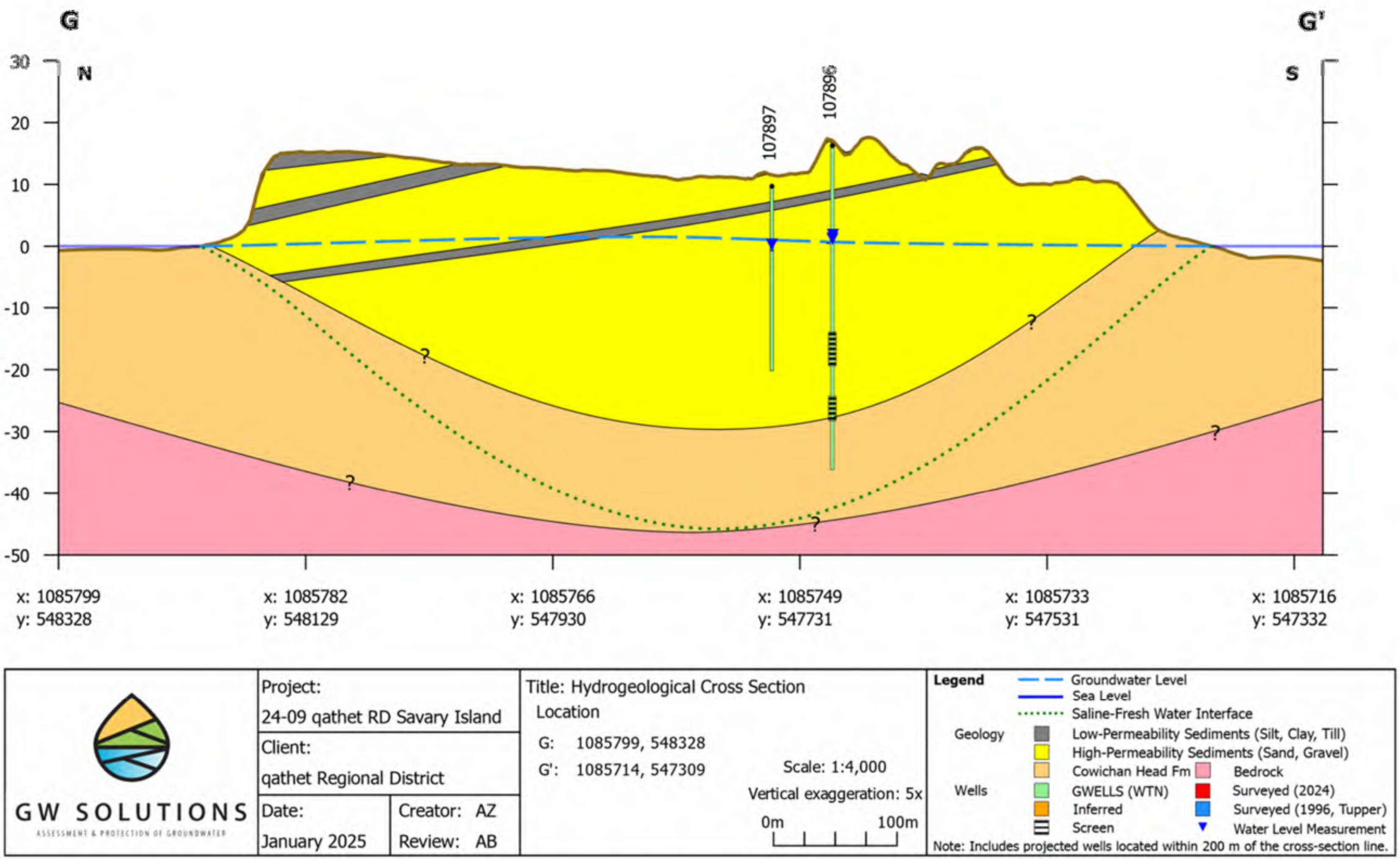
SAVARY ISLAND HYDROGEOLOGIC MODEL – ADDITIONAL CROSS-SECTIONS

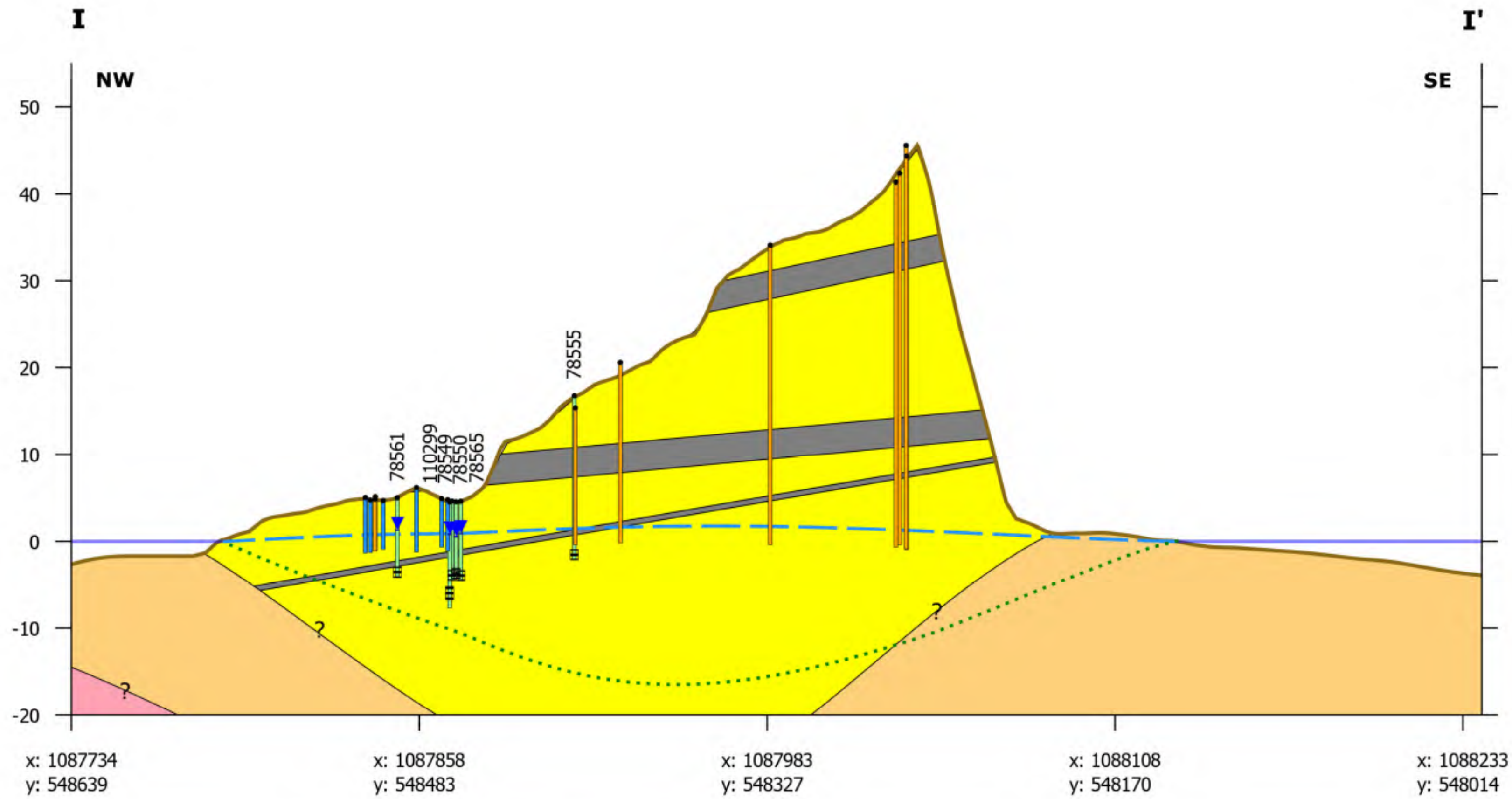

B
B'
NE
SW
30
20
10
0
-10
-20
-30
A4
TUP94
TUP96
98047
B17
?
x: 1082257
y: 548173
x: 1082090
y: 548062
x: 1081924
y: 547951
x: 1081758
y: 547840
x: 1081591
y: 547729
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER
Project:
24-09 qathet RD Savary Island
Client:
qathet Regional District
Date:
January 2025
Creator: AZ
Review: AB
Title: Hydrogeological Cross Section
Location
B: 1082257, 548173
B': 1081449, 547633
Scale: 1:3,800
Vertical exaggeration: 5x
0m
100m
Legend
Groundwater Level
Sea Level
Saline-Fresh Water Interface
Geology
Low-Permeability Sediments (Silt, Clay, Till)
High-Permeability Sediments (Sand, Gravel)
Cowichan Head Fm
Bedrock
Wells
GWELLS (WTN)
Surveyed (2024)
Inferred
Surveyed (1996, Tupper)
Screen
Water Level Measurement
Note: Includes projected wells located within 50 m of the cross-section line.



GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER


F
F'
N
S
B15
30
20
10
0
-10
-20
-30
-40
?
x: 1084630
y: 548262
x: 1084654
y: 548063
x: 1084678
y: 547865
x: 1084702
y: 547666
x: 1084726
y: 547468
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER
Project:
24-09 qathet RD Savary Island
Client:
qathet Regional District
Date:
January 2025
Creator: AZ
Review: AB
Title: Hydrogeological Cross Section
Location
F: 1084630, 548262
F': 1084747, 547295
Scale: 1:3,800
Vertical exaggeration: 5x
0m
100m
Legend
Groundwater Level
Sea Level
Saline-Fresh Water Interface
Geology
Low-Permeability Sediments (Silt, Clay, Till)
High-Permeability Sediments (Sand, Gravel)
Cowichan Head Fm
Bedrock
Wells
GWELLS (WTN)
Surveyed (2024)
Inferred
Surveyed (1996, Tupper)
Screen
Water Level Measurement
Note: Includes projected wells located within 50 m of the cross-section line.


G
G'
N
S
107897
107896
30
20
10
0
-10
-20
-30
-40
-50
?
x: 1085799
y: 548328
x: 1085782
y: 548129
x: 1085766
y: 547930
x: 1085749
y: 547731
x: 1085733
y: 547531
x: 1085716
y: 547332
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER
Project:
24-09 qathet RD Savary Island
Client:
qathet Regional District
Date:
January 2025
Creator: AZ
Review: AB
Title: Hydrogeological Cross Section
Location
G: 1085799, 548328
G': 1085714, 547309
Scale: 1:4,000
Vertical exaggeration: 5x
0m
100m
Legend
Groundwater Level
Sea Level
Saline-Fresh Water Interface
Geology
Low-Permeability Sediments (Silt, Clay, Till)
High-Permeability Sediments (Sand, Gravel)
Cowichan Head Fm
Bedrock
Wells
GWELLS (WTN)
Surveyed (2024)
Inferred
Surveyed (1996, Tupper)
Screen
Water Level Measurement
Note: Includes projected wells located within 200 m of the cross-section line.



GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

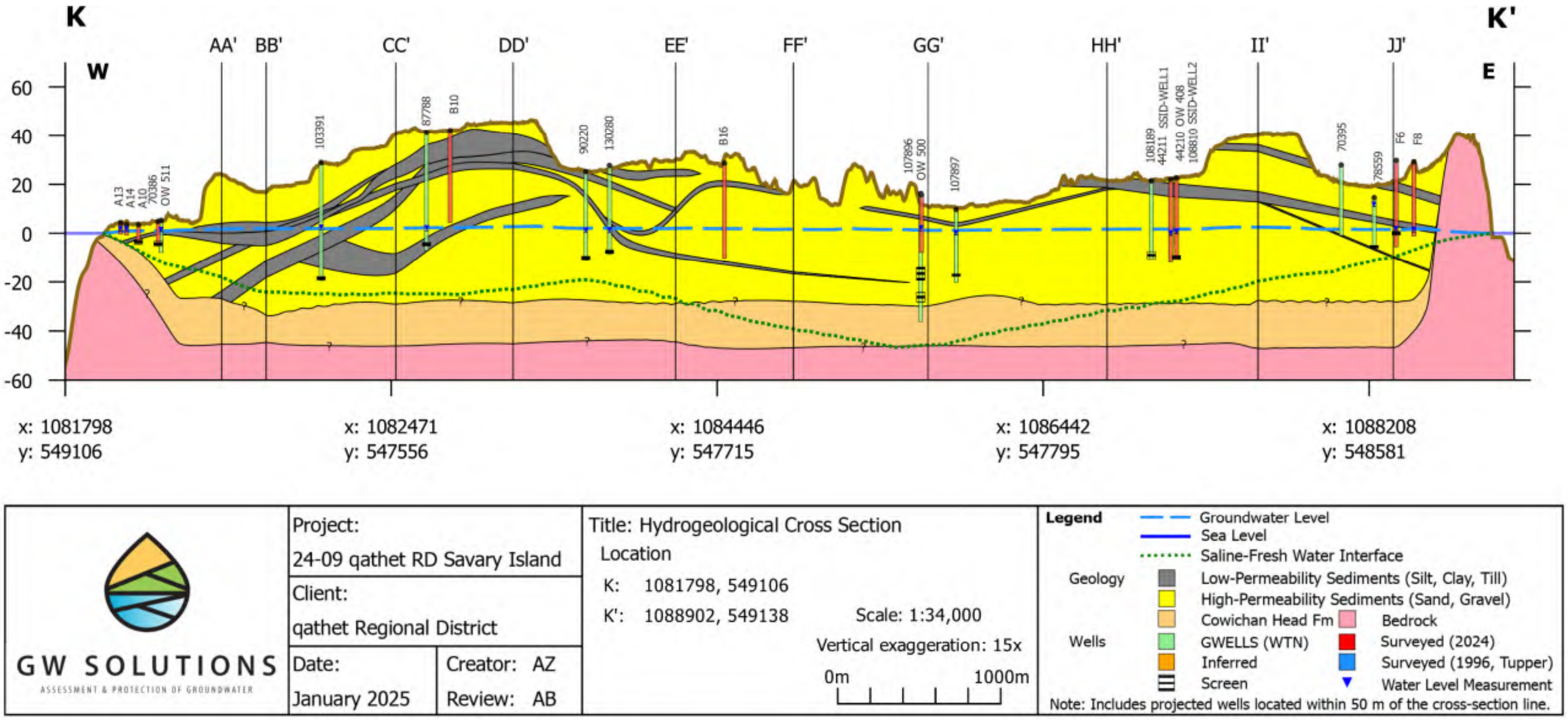
Project:
24-09 qathet RD Savary Island

Client:
qathet Regional District

Date: January 2025
Creator: AZ
Review: AB

Title: Hydrogeological Cross Section
Location
I: 1087734, 548639
I': 1088239, 548006
Scale: 1:3,100
Vertical exaggeration: 5x
0m 100m

Legend
Groundwater Level
Sea Level
Saline-Fresh Water Interface
Geology
Low-Permeability Sediments (Silt, Clay, Till)
High-Permeability Sediments (Sand, Gravel)
Cowichan Head Fm
Bedrock
Wells
GWELLS (WTN)
Surveyed (2024)
Inferred
Surveyed (1996, Tupper)
Screen
Water Level Measurement
Note: Includes projected wells located within 50 m of the cross-section line.


K
K'
W
E
AA'
BB'
CC'
DD'
EE'
FF'
GG'
HH'
II'
JJ'
60
40
20
0
-20
-40
-60
A13
A14
A10
70386
OW 511
103391
87788
B10
90220
130280
B16
107896
OW 500
107897
108189
44211
SSID-WELL1
44210
OW 408
108810
SSID-WELL2
70395
78559
F6
F8
x: 1081798
y: 549106
x: 1082471
y: 547556
x: 1084446
y: 547715
x: 1086442
y: 547795
x: 1088208
y: 548581
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER
Project:
24-09 qathet RD Savary Island
Client:
qathet Regional District
Date:
January 2025
Creator: AZ
Review: AB
Title: Hydrogeological Cross Section
Location
K: 1081798, 549106
K': 1088902, 549138
Scale: 1:34,000
Vertical exaggeration: 15x
0m
1000m
Legend
Groundwater Level
Sea Level
Saline-Fresh Water Interface
Geology
Low-Permeability Sediments (Silt, Clay, Till)
High-Permeability Sediments (Sand, Gravel)
Cowichan Head Fm
Bedrock
Wells
GWELLS (WTN)
Surveyed (2024)
Inferred
Surveyed (1996, Tupper)
Screen
Water Level Measurement
Note: Includes projected wells located within 50 m of the cross-section line.

APPENDIX C

SAVARY SHORES IMPROVEMENT DISTRICT WATER USE ANALYSIS

SSID Monthly consumption data 1998 - 2023 (Imperial Gallons)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (reported value)	Annual (re-calculated, sum monthly)
2023	22,022	26,292	36,542	103,761	175,250	215,970	396,180	303,556	110,880	55,308	23,210	25,256	1,490,443	1,494,227
2022	34,027	28,864	45,379	60,810	129,043	145,415	361,720	372,398	167,156	96,756	24,816	128,128	1,590,818	1,594,512
2021	30,448	54,758	73,744	96,272	164,956	215,556	521,393	356,312	134,970	62,511	35,900	61,600	1,808,420	1,808,420
2020	13,332	16,874	-	88,572	116,618	153,182	414,647	390,958	161,480	71,896	50,842	28,776	1,507,176	1,507,177
2019	14,366	11,462	49,808	29,546	128,216	201,344	305,492	326,216	154,110	38,720	11,968	18,876	1,290,124	1,290,124
2018	10,516	14,608	51,040	32,384	160,072	117,854	306,724	384,978	109,230	31,372	18,370	18,062	1,236,840	1,255,210
2017	17,072	16,830	24,926	46,376	164,912	173,382	330,704	340,934	95,810	38,588	13,222	11,506	1,274,262	1,274,262
2016	10,978	54,164	27,434	385,968	80,806	88,264	258,038	355,278	91,674	32,450	17,160	20,262	1,400,476	1,422,476
2015	13,508	10,736	24,728	40,986	83,094	139,656	260,414	310,486	85,470	57,992	61,644	11,308	1,100,022	1,100,022
2014	9,790	16,896	57,684	46,222	60,038	152,482	260,370	296,472	107,030	57,838	27,588	20,834	1,113,244	1,113,244
2013	9,108	11,198	22,198	32,406	68,838	82,874	243,870	261,030	76,516	43,912	12,408	17,930	882,288	882,288
2012	14,894	11,902	24,288	35,508	50,688	65,912	230,582	288,134	77,242	34,496	18,150	10,186	861,982	861,982
2011	11,990	9,262	21,296	38,258	49,632	109,890	231,726	319,396	82,434	58,322	24,640	18,436	975,282	975,282
2010	23,936	26,532	134,728	76,560	110,022	90,794	281,314	274,736	66,374	31,328	25,960	12,210	1,154,494	1,154,494
2009	7,392	-	38,962	46,178	66,132	126,302	265,540	286,264	81,510	49,082	38,632	38,698	1,044,692	1,044,692
2008	104,324	28,028	28,072	26,950	81,422	124,850	335,192	182,270	73,436	30,822	18,106	17,666	1,051,138	1,051,138
2007	25,300	16,588	31,944	50,380	62,260	82,940	245,982	280,610	60,698	26,928	14,256	12,716	910,602	910,602
2006	18,128	14,212	28,578	39,776	50,204	77,154	238,766	285,868	70,620	36,388	18,590	14,212	892,496	892,496
2005	12,496	22,750	51,148	35,290	57,968	75,548	238,040	245,696	58,564	28,248	30,712	47,234	903,694	903,694
2004	18,524	16,192	36,036	54,516	81,950	95,150	238,858	231,832	57,310	30,360	28,050	23,980	912,758	912,758
2003	34,716	29,854	47,300	76,296	64,900	101,288	281,974	274,705	66,867	45,914	35,860	27,808	1,087,482	1,087,482
2002	133,254	34,166	49,060	40,062	65,604	104,876	233,198	271,900	70,354	67,980	33,660	36,586	1,140,700	1,140,700
2001	23,056	17,248	35,904	42,416	58,674	78,034	201,498	220,066	66,198	36,938	26,444	28,292	834,768	834,768
2000	27,148	27,852	26,532	47,586	41,382	77,458	213,910	229,658	73,656	41,822	21,824	22,242	851,070	851,070
1999	26,239	30,954	57,726	81,668	52,703	80,065	212,285	264,376	35,262	42,280	44,658	26,882	955,097	955,098
1998	22,150	18,781	37,096	57,451	69,566	111,472	212,837	249,242	84,843	47,291	25,274	26,754	962,757	962,757

Monthly Consumption Statistics 1998-2023 (Imperial Gallons)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (reported value)	Annual (re-calculated, sum monthly)
25th Percentile	12,705	14,608	27,434	38,638	59,015	82,891	234,409	261,867	67,739	32,962	18,205	17,732	911,141	911,141
Average	26,489	22,680	42,486	65,854	88,267	118,758	281,587	292,437	89,219	45,982	26,998	27,940	1,124,351	1,126,191
Median	18,326	17,248	36,542	46,299	69,202	107,383	259,204	286,066	79,376	42,051	25,045	21,538	1,069,310	1,069,310
75th Percentile	26,004	28,028	49,808	72,425	114,969	143,975	306,416	324,511	104,225	57,206	32,923	28,171	1,264,907	1,269,499

SSID Monthly consumption data 1998 - 2023 (Litres)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (reported)	Annual (re-calculated, sum monthly)
2023	100,114	119,526	166,123	471,707	796,703	981,819	1,801,071	1,379,994	504,071	251,435	105,515	114,816	6,775,691	6,792,893
2022	154,690	131,218	206,297	276,448	586,641	661,070	1,644,412	1,692,956	759,907	439,862	112,816	582,482	7,232,005	7,248,798
2021	138,419	248,935	335,247	437,661	749,905	979,937	2,370,301	1,619,827	613,586	284,181	163,205	280,039	8,221,244	8,221,244
2020	60,608	76,711	-	402,656	530,156	696,379	1,885,023	1,777,331	734,103	326,846	231,132	130,818	6,851,761	6,851,765
2019	65,309	52,107	226,432	134,319	582,882	915,328	1,388,795	1,483,008	700,598	176,025	54,408	85,812	5,865,022	5,865,022
2018	47,807	66,409	232,033	147,221	727,702	535,775	1,394,396	1,750,145	496,570	142,620	83,512	82,112	5,622,788	5,706,300
2017	77,611	76,511	113,316	210,830	749,705	788,211	1,503,411	1,549,917	435,561	175,425	60,108	52,307	5,792,912	5,792,912
2016	49,907	246,235	124,717	1,754,646	367,352	401,256	1,173,064	1,615,126	416,758	147,521	78,011	92,113	6,366,693	6,466,707
2015	61,409	48,807	112,416	186,326	377,753	634,889	1,183,866	1,411,498	388,554	263,637	280,239	51,407	5,000,801	5,000,801
2014	44,506	76,811	262,237	210,129	272,938	693,197	1,183,666	1,347,789	486,568	262,937	125,418	94,713	5,060,910	5,060,910
2013	41,406	50,907	100,914	147,321	312,944	376,753	1,108,655	1,186,666	347,849	199,628	56,408	81,511	4,010,962	4,010,962
2012	67,709	54,108	110,415	161,423	230,432	299,642	1,048,247	1,309,884	351,149	156,822	82,512	46,306	3,918,649	3,918,649
2011	54,508	42,106	96,814	173,924	225,632	499,570	1,053,448	1,452,004	374,753	265,137	112,016	83,812	4,433,722	4,433,722
2010	108,815	120,617	612,486	348,049	500,170	412,758	1,278,879	1,248,975	301,742	142,420	118,017	55,508	5,248,436	5,248,436
2009	33,605	-	177,125	209,929	300,642	574,181	1,207,169	1,301,382	370,552	223,131	175,625	175,925	4,749,266	4,749,266
2008	474,267	127,418	127,618	122,517	370,152	567,580	1,523,814	828,616	333,847	140,120	82,312	80,311	4,778,570	4,778,570
2007	115,016	75,411	145,220	229,032	283,040	377,053	1,118,257	1,275,679	275,939	122,417	64,809	57,808	4,139,680	4,139,680
2006	82,412	64,609	129,918	180,825	228,232	350,749	1,085,452	1,299,582	321,045	165,423	84,512	64,609	4,057,369	4,057,369
2005	56,808	103,424	232,524	160,432	263,528	343,448	1,082,152	1,116,957	266,237	128,418	139,620	214,730	4,108,276	4,108,276
2004	84,212	73,610	163,823	247,835	372,552	432,561	1,085,870	1,053,930	260,537	138,019	127,518	109,015	4,149,482	4,149,482
2003	157,822	135,719	215,030	346,849	295,041	460,465	1,281,880	1,248,834	303,984	208,729	163,023	126,418	4,943,793	4,943,793
2002	605,785	155,322	223,031	182,126	298,242	476,776	1,060,140	1,236,082	319,836	309,043	153,021	166,323	5,185,727	5,185,727
2001	104,815	78,411	163,223	192,827	266,737	354,750	916,028	1,000,440	300,942	167,924	120,217	128,618	3,794,932	3,794,932
2000	123,417	126,618	120,617	216,330	188,126	352,131	972,455	1,044,046	334,847	190,127	99,214	101,114	3,869,043	3,869,043
1999	119,285	140,720	262,428	371,270	239,593	363,983	965,067	1,201,878	160,304	192,209	203,019	122,208	4,341,959	4,341,963
1998	100,696	85,380	168,642	261,178	316,253	506,762	967,577	1,133,077	385,704	214,989	114,898	121,626	4,376,782	4,376,782

Monthly Consumption Statistics 1998-2023 (Litres)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (reported)	Annual (calc)
10th Percentile	46,156	51,387	111,216	147,271	229,332	351,440	970,016	1,048,988	271,088	139,070	62,459	53,908	3,964,806	3,964,806
25th Percentile	57,758	66,409	124,717	175,650	268,288	376,828	1,065,643	1,190,469	307,947	149,846	82,762	80,611	4,142,131	4,142,131
Average	120,421	103,106	193,146	299,377	401,271	539,885	1,280,119	1,329,447	405,598	209,040	122,735	127,018	5,111,403	5,119,769
Median	83,312	78,411	166,123	210,480	314,599	488,173	1,178,365	1,300,482	360,851	191,168	113,857	97,914	4,861,182	4,861,182
75th Percentile	118,218	127,418	226,432	329,248	522,660	654,525	1,392,995	1,475,257	473,816	260,061	149,671	128,068	5,750,381	5,771,259
90th Percentile	156,256	149,481	262,351	420,159	738,704	851,769	1,722,742	1,656,391	657,092	296,612	189,322	195,327	6,813,726	6,822,329

SSID Monthly consumption data 1998 - 2023 (Cubic metres)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	% of Long-term average (1998-2023)	% Change since 1998	Year	Connections serviced	% Increase in connections since 1998
1997																		
1998	101	85	169	261	316	507	968	1,133	386	215	115	122	4,377	-14%	0%	1998	106	0%
1999	119	141	262	371	240	364	965	1,202	160	192	203	122	4,342	-15%	-1%	1999	110	4%
2000	123	127	121	216	188	352	972	1,044	335	190	99	101	3,869	-24%	-12%	2000	114	8%
2001	105	78	163	193	267	355	916	1,000	301	168	120	129	3,795	-26%	-13%	2001	114	8%
2002	606	155	223	182	298	477	1,060	1,236	320	309	153	166	5,186	1%	18%	2002	118	11%
2003	158	136	215	347	295	460	1,282	1,249	304	209	163	126	4,944	-3%	13%	2003	129	22%
2004	84	74	164	248	373	433	1,086	1,054	261	138	128	109	4,149	-19%	-5%	2004	130	23%
2005	57	103	233	160	264	343	1,082	1,117	266	128	140	215	4,108	-20%	-6%	2005	137	29%
2006	82	65	130	181	228	351	1,085	1,300	321	165	85	65	4,057	-21%	-7%	2006	135	27%
2007	115	75	145	229	283	377	1,118	1,276	276	122	65	58	4,140	-19%	-5%	2007	140	32%
2008	474	127	128	123	370	568	1,524	829	334	140	82	80	4,779	-7%	9%	2008	143	35%
2009	34	-	177	210	301	574	1,207	1,301	371	223	176	176	4,749	-7%	9%	2009	143	35%
2010	109	121	612	348	500	413	1,279	1,249	302	142	118	56	5,248	3%	20%	2010	144	36%
2011	55	42	97	174	226	500	1,053	1,452	375	265	112	84	4,434	-13%	1%	2011	146	38%
2012	68	54	110	161	230	300	1,048	1,310	351	157	83	46	3,919	-23%	-10%	2012	146	38%
2013	41	51	101	147	313	377	1,109	1,187	348	200	56	82	4,011	-22%	-8%	2013	143	35%
2014	45	77	262	210	273	693	1,184	1,348	487	263	125	95	5,061	-1%	16%	2014	147	39%
2015	61	49	112	186	378	635	1,184	1,411	389	264	280	51	5,001	-2%	14%	2015	149	41%
2016	50	246	125	1,755	367	401	1,173	1,615	417	148	78	92	6,367	25%	45%	2016	153	44%
2017	78	77	113	211	750	788	1,503	1,550	436	175	60	52	5,793	13%	32%	2017	157	48%
2018	48	66	232	147	728	536	1,394	1,750	497	143	84	82	5,623	10%	28%	2018	158	49%
2019	65	52	226	134	583	915	1,389	1,483	701	176	54	86	5,865	15%	34%	2019	163	54%
2020	61	77	-	403	530	696	1,885	1,777	734	327	231	131	6,852	34%	57%	2020	160	51%
2021	138	249	335	438	750	980	2,370	1,620	614	284	163	280	8,221	61%	88%	2021	160	51%
2022	155	131	206	276	587	661	1,644	1,693	760	440	113	582	7,232	41%	65%	2022	164	55%
2023	100	120	166	472	797	982	1,801	1,380	504	251	106	115	6,776	33%	55%	2023	164	55%
2024																		

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
10th Percentile	46	51	111	147	229	351	970	1,049	271	139	62	54	4,140
25th Percentile	58	66	125	176	268	377	1,066	1,190	308	150	83	81	4,142
Average	120	103	193	299	401	540	1,280	1,329	406	209	123	127	5,111
Median	83	78	166	210	315	488	1,178	1,300	361	191	114	98	4,861
75th Percentile	118	127	226	329	523	655	1,393	1,475	474	260	150	128	5,750
90th Percentile	156	149	262	420	739	852	1,723	1,656	657	297	189	195	6,814

Conversions and constants

Litres	Imp.gallon	m^3
1	0.22	0.001
4.55	1	0.00455
1000	220	1

Monthly percentage of annual usage

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Long-term average (monthly percent of use)	2%	2%	4%	6%	8%	10%	25%	26%	8%	4%	2%	2%

Savary Shores Improvement District Water Use Per Active Connection

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	365
2023	22022	26292	36542	103761	175250	215970	396180	303556	110880	55308	23210	25256	1494227
Dwellings occupied	35	42	62	77	126	131	157	151	120	83	45	61	164
Per dwelling (Imp.gallons/month)	629	626	589	1348	1391	1649	2523	2010	924	666	516	414	9111
Per dwelling (m^3/month)	2.9	2.8	2.7	6.1	6.3	7.5	11.5	9.1	4.2	3.0	2.3	1.9	41.4
Per dwelling (litres per day)	92	102	86	204	204	250	370	295	140	98	78	61	113

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2022	34027	28864	45379	60810	129043	145415	361720	372398	167156	96756	24816	128128	1594512
Dwellings occupied	31	38	65	89	109	130	151	147	126	91	50	27	164
Per dwelling (Imp.gallons/month)	1098	760	698	683	1184	1119	2395	2533	1327	1063	496	4745	9723
Per dwelling (m^3/month)	5.0	3.5	3.2	3.1	5.4	5.1	10.9	11.5	6.0	4.8	2.3	21.6	44.2
Per dwelling (litres per day)	161	123	102	104	174	170	351	372	201	156	75	***696***	121
Per dwelling (L/d)(exc Dec)	161	123	102	104	174	170	351	372	201	156	75	-	111

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2021	30448	54758	73744	96272	164956	215556	521393	356312	134970	62511	35900	61600	1808420
Dwellings occupied	46	43	73	66	80	120	147	155	131	99	56	46	160
Per dwelling (Imp.gallons/month)	662	1273	1010	1459	2062	1796	3547	2299	1030	631	641	1339	11303
Per dwelling (m^3/month)	3.0	5.8	4.6	6.6	9.4	8.2	16.1	10.5	4.7	2.9	2.9	6.1	51.4
Per dwelling (litres per day)	97	207	148	221	302	272	520	337	156	93	97	196	141

Notes: ***Potential outlier***

SSID Number of active connections (dwellings occupied) per month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Average
2021	46	43	73	66	80	120	147	155	131	99	56	46	160	
2022	31	38	65	89	109	130	151	147	126	91	50	27	164	
2023	35	42	62	77	126	131	157	151	120	83	45	61	164	
Average connections active	37	41	67	77	105	127	152	151	126	91	50	45	163	
Average water use per connection (2021-2023)	117	144	112	176	227	231	414	334	166	115	84	318	125	203
Average water use per connection (2021-2023) (excluding Dec 2022)	117	144	112	176	227	231	414	334	166	115	84	129	125	187

Total lots in service area	213		
Lots with connections	172	81%	of total lots
Max. annual active connections (2021-2023)	164	95%	of non-vacant lots within service area

Percentage of serviced lots connected per reporting period

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2021	27%	25%	42%	38%	47%	70%	85%	90%	76%	58%	33%	27%	93%
2022	18%	22%	38%	52%	63%	76%	88%	85%	73%	53%	29%	16%	95%
2023	20%	24%	36%	45%	73%	76%	91%	88%	70%	48%	26%	35%	95%
Average	22%	24%	39%	45%	61%	74%	88%	88%	73%	53%	29%	26%	95%

Notes and assumptions

Savary Shores encompasses 213 lots, of which 172 are currently serviced with water connections (SSID, 2024)
Assume one dwelling per parcel or connection (i.e. number of occupied dwellings equivalent to number of connections serviced)
Occupancy of each dwelling variable (assume highest in July and August)
Irrigation period for domestic gardens June-August (accounting for some of the observed increase in summer use), mainly on permanent/full time resident lots.
December 2022 water use potential outlier (leak or maintenance issue)

APPENDIX D

SAVARY ISLAND WATER DEMAND - ADDITIONAL TABLES

		January	February	March	April	May	June	July	August	September	October	November	December	Year	
	(Note	31	28	31	30	31	30	31	31	30	31	30	31	365	Days per month
Seasonal occupancy factor (% developed lots occupied per month)	(3)	10%	10%	20%	35%	40%	50%	80%	80%	50%	25%	15%	15%		% Occupancy
Residential use (daily volume per lot, litres)	(4)	200	200	200	200	250	250	400	400	200	200	200	200	240	Average (L/d)

Scenario 1: Savary Island Water Demand, Litres Per Month (2025 Actual Use, Seasonal Occupancy)

January	February	March	April	May	June	July	August	September	October	November	December	Year	Comment
62,620	56,560	125,240	212,100	313,100	378,750	1,001,920	1,001,920	303,000	156,550	90,900	93,930	3,796,590	
-	-	-	-	-	-	-	-	-	-	-	-	-	
3,720	3,360	7,440	12,600	18,600	22,500	59,520	59,520	18,000	9,300	5,400	5,580	225,540	
930	840	1,860	3,150	4,650	5,625	14,880	14,880	4,500	2,325	1,350	1,395	56,385	
1,860	1,680	3,720	6,300	9,300	11,250	29,760	29,760	9,000	4,650	2,700	2,790	112,770	
620	560	1,240	2,100	3,100	3,750	9,920	9,920	3,000	1,550	900	930	37,590	
182,280	164,640	364,560	617,400	911,400	1,102,500	2,916,480	2,916,480	882,000	455,700	264,600	273,420	11,051,460	
-	-	-	-	-	-	-	-	-	-	-	-	-	
16,740	15,120	33,480	56,700	83,700	101,250	267,840	267,840	81,000	41,850	24,300	25,110	1,014,930	
1,240	1,120	2,480	4,200	6,200	7,500	19,840	19,840	6,000	3,100	1,800	1,860	75,180	
36,580	33,040	73,160	123,900	182,900	221,250	585,280	585,280	177,000	91,450	53,100	54,870	2,217,810	
3,720	3,360	7,440	12,600	18,600	22,500	59,520	59,520	18,000	9,300	5,400	5,580	225,540	
-	-	-	-	-	-	-	-	-	-	-	-	-	
620	560	1,240	2,100	3,100	3,750	9,920	9,920	3,000	1,550	900	930	37,590	
4,340	3,920	8,680	14,700	21,700	26,250	69,440	69,440	21,000	10,850	6,300	6,510	263,130	
-	-	-	-	-	-	-	-	-	-	-	-	-	
15,500	14,000	15,500	15,000	28,900	28,400	28,900	28,900	28,400	15,500	15,000	15,500	249,500	
-	-	-	-	-	-	-	-	-	-	-	-	-	
9,920	8,960	19,840	33,600	49,600	60,000	158,720	158,720	48,000	24,800	14,400	14,880	601,440	
-	-	-	-	-	-	-	-	-	-	-	-	-	
1,240	1,120	2,480	4,200	6,200	7,500	19,840	19,840	6,000	3,100	1,800	1,860	75,180	
930	840	1,860	3,150	4,650	5,625	14,880	14,880	4,500	2,325	1,350	1,395	56,385	
1,240	1,120	2,480	4,200	6,200	7,500	19,840	19,840	6,000	3,100	1,800	1,860	75,180	
-	-	-	-	-	-	-	-	-	-	-	-	-	
620	560	1,240	2,100	3,100	3,750	9,920	9,920	3,000	1,550	900	930	37,590	
94,860	85,680	189,720	321,300	474,300	573,750	1,517,760	1,517,760	459,000	237,150	137,700	142,290	5,751,270	Modelled (not included in total)
-	-	-	-	-	-	-	-	-	-	-	-	-	
620	560	1,240	2,100	3,100	3,750	9,920	9,920	3,000	1,550	900	930	37,590	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
120,420	103,110	193,150	299,380	401,270	539,890	1,280,120	1,329,450	405,600	209,040	122,730	127,020	5,131,180	Measured (long-term average)
73,160	66,080	146,320	247,800	365,800	442,500	1,170,560	1,170,560	354,000	182,900	106,200	109,740	4,435,620	
-	-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	-	
4,960	4,480	9,920	16,800	24,800	30,000	79,360	79,360	24,000	12,400	7,200	7,440	300,720	
930	840	1,860	3,150	4,650	5,625	14,880	14,880	4,500	2,325	1,350	1,395	56,385	
5,580	5,040	11,160	18,900	27,900	33,750	89,280	89,280	27,000	13,950	8,100	8,370	338,310	

	620	560	1,240	2,100	3,100	3,750	9,920	9,920	3,000	1,550	900	930	37,590
	620	560	1,240	2,100	3,100	3,750	9,920	9,920	3,000	1,550	900	930	37,590
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-

Total estimated demand (Litres/month)

A	69,750	63,000	139,500	236,250	348,750	421,875	1,116,000	1,116,000	337,500	174,375	101,250	104,625	4,228,875
B	261,020	235,760	506,540	846,600	1,256,500	1,513,400	3,957,220	3,957,220	1,216,400	629,300	371,400	383,780	15,135,140
C	-	-	-	-	-	-	-	-	-	-	-	-	-
D	13,330	12,040	26,660	45,150	66,650	80,625	213,280	213,280	64,500	33,325	19,350	19,995	808,185
E	121,660	104,230	195,630	303,580	407,470	547,390	1,299,960	1,349,290	411,600	212,140	124,530	128,880	5,206,360
F	85,870	77,560	171,740	290,850	429,350	519,375	1,373,920	1,373,920	415,500	214,675	124,650	128,805	5,206,215
All	551,630	492,590	1,040,070	1,722,430	2,508,720	3,082,665	7,960,380	8,009,710	2,445,500	1,263,815	741,180	766,085	30,584,775

Scenario 1: Savary Island Water Demand by Area (2025 land use, seasonal occupancy)

Total estimated demand (m³/month)														Lots with water use (2025)
A	70	63	140	236	349	422	1,116	1,116	338	174	101	105	4,229	112
B	261	236	507	847	1,257	1,513	3,957	3,957	1,216	629	371	384	15,135	392
C	-	-	-	-	-	-	-	-	-	-	-	-	-	0
D	13	12	27	45	67	81	213	213	65	33	19	20	808	21
E	122	104	196	304	407	547	1,300	1,349	412	212	125	129	5,206	173
F	86	78	172	291	429	519	1,374	1,374	416	215	125	129	5,206	138
All	552	493	1,040	1,722	2,509	3,083	7,960	8,010	2,446	1,264	741	766	**30,585**	836

Scenario 2: Savary Island Water Demand, Cubic Meters Per Month (Projected, full time occupancy all 2025 non-vacant lots, 240 L/d average use, current fire protection use)

Total estimated demand (m³/month)														Lots with water use (2025)
A	833	753	833	806	833	806	833	833	806	833	806	833	9,811	112
B	2,925	2,642	2,925	2,830	2,938	2,844	2,938	2,938	2,844	2,925	2,830	2,925	34,501	392
C	-	-	-	-	-	-	-	-	-	-	-	-	-	0
D	156	141	156	151	156	151	156	156	151	156	151	156	1,840	21
E	1,287	1,163	1,287	1,246	1,287	1,246	1,287	1,287	1,246	1,287	1,246	1,287	15,155	173
F	1,027	927	1,027	994	1,027	994	1,027	1,027	994	1,027	994	1,027	12,089	138
All	6,228	5,625	6,228	6,027	6,241	6,040	6,241	6,241	6,040	6,228	6,027	6,228	**73,396**	836

Scenario 3: Savary Island Water Demand, Cubic Meters Per Month (Projected, Full time occupancy all residential habitable lots, 240 L/d average use, current fire protection use)

Total estimated demand (m³/month)														Lots with water use (projected)
A	1,138	1,028	1,138	1,102	1,138	1,102	1,138	1,138	1,102	1,138	1,102	1,138	13,403	153
B	5,067	4,577	5,067	4,904	5,081	4,917	5,081	5,081	4,917	5,067	4,904	5,067	59,730	680
C	-	-	-	-	-	-	-	-	-	-	-	-	-	0
D	171	155	171	166	171	166	171	171	166	171	166	171	2,015	23
E	1,607	1,452	1,607	1,555	1,607	1,555	1,607	1,607	1,555	1,607	1,555	1,607	18,922	216
F	1,920	1,734	1,920	1,858	1,920	1,858	1,920	1,920	1,858	1,920	1,858	1,920	22,601	258
All	9,903	8,945	9,903	9,584	9,917	9,597	9,917	9,917	9,597	9,903	9,584	9,903	**116,670**	1330

Scenario 1 Validation

Population and occupancy (reference values)		January	February	March	April	May	June	July	August	September	October	November	December	Year
SSID serviced lots connected per month	Average (2021-2023) (%)	22%	24%	39%	45%	61%	74%	88%	88%	73%	53%	29%	26%	95%
BC Hydro (2011, 2012)	Monthly percent occupancy	13%	13%	33%	44%	60%	73%	92%	93%	67%	45%	22%	16%	
	Average (SSID, BC Hydro, %)	17%	18%	36%	44%	61%	73%	90%	90%	70%	49%	26%	21%	
	BC Hydro estimated monthly population	364	364	806	1023	1381	1622	2041	2092	1539	1051	551	443	
Modelled population (comparison to published values)														
	Non-vacant residential lots within & outside SSID (2025)	836												
	Average persons per lot (per month)	2	2	2	2	2.5	2.5	3	3	2.5	2	2	2	
	% lots occupied per month	10%	10%	20%	35%	40%	50%	80%	80%	50%	25%	15%	15%	
	Estimated monthly population (persons per lot times % occupancy)	167	167	334	585	836	1045	2006	2006	1045	418	251	251	
	% Difference SSID modelled vs metered use	-21%	-17%	-2%	7%	18%	6%	19%	14%	13%	13%	12%	12%	12%

Notes

(1) Land use categories and lot estimates from BC Assessment Authority (2025) Assessment Roll updated following Sept 2024 field audit.
(2) Water use categories: R=Residential RM=Residential use with multiplier NW=No water use G=Government use (e.g. firehall) SSID=Savary
(3) Seasonal occupancy factor (% developed lots occupied per month) based on SSID average (2021-2023), BC Hydro (2011) estimated monthly
(4) Water use per residential category lot based on long-term monthly average in SSID (1998-2023)
(5) Water for practicing firefighting reported from Savary Island Fire Department as 20,000 - 30,000 US Gallons/year. Active groundwater license
(6) Savary Island Store lots are categorized by BC Assessment as residential and residential outbuilding. Assume use equivalent to one residence per
(7) Water use for lots inside SSID incorporated within average water use data from purveyor (except General Store).

APPENDIX E

SAVARY ISLAND WATER BALANCE MODEL - ADDITIONAL FIGURES & TABLES

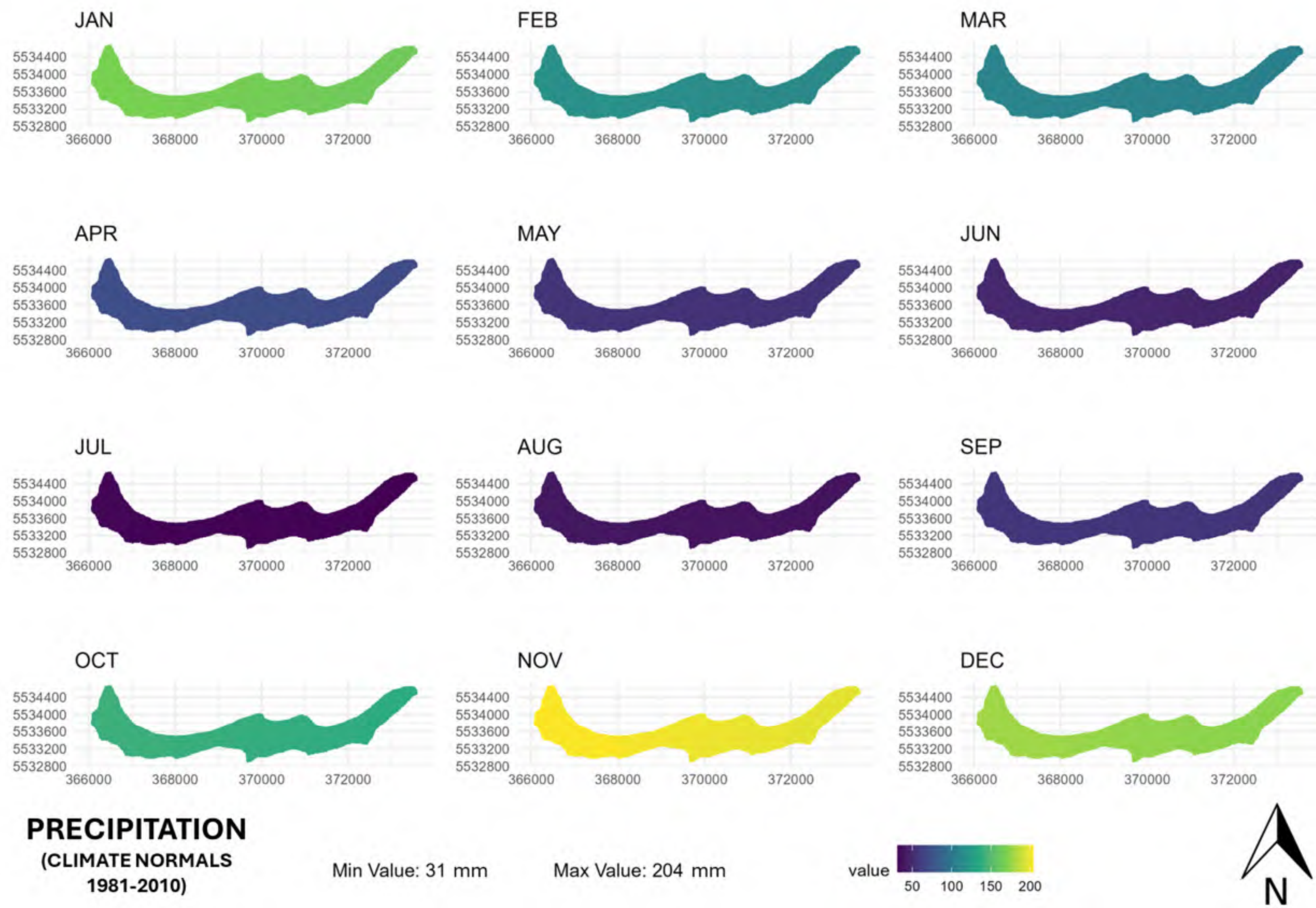


Figure E1. Annual precipitation (mm) (Climate Normal 1981-2010) (water balance model input).

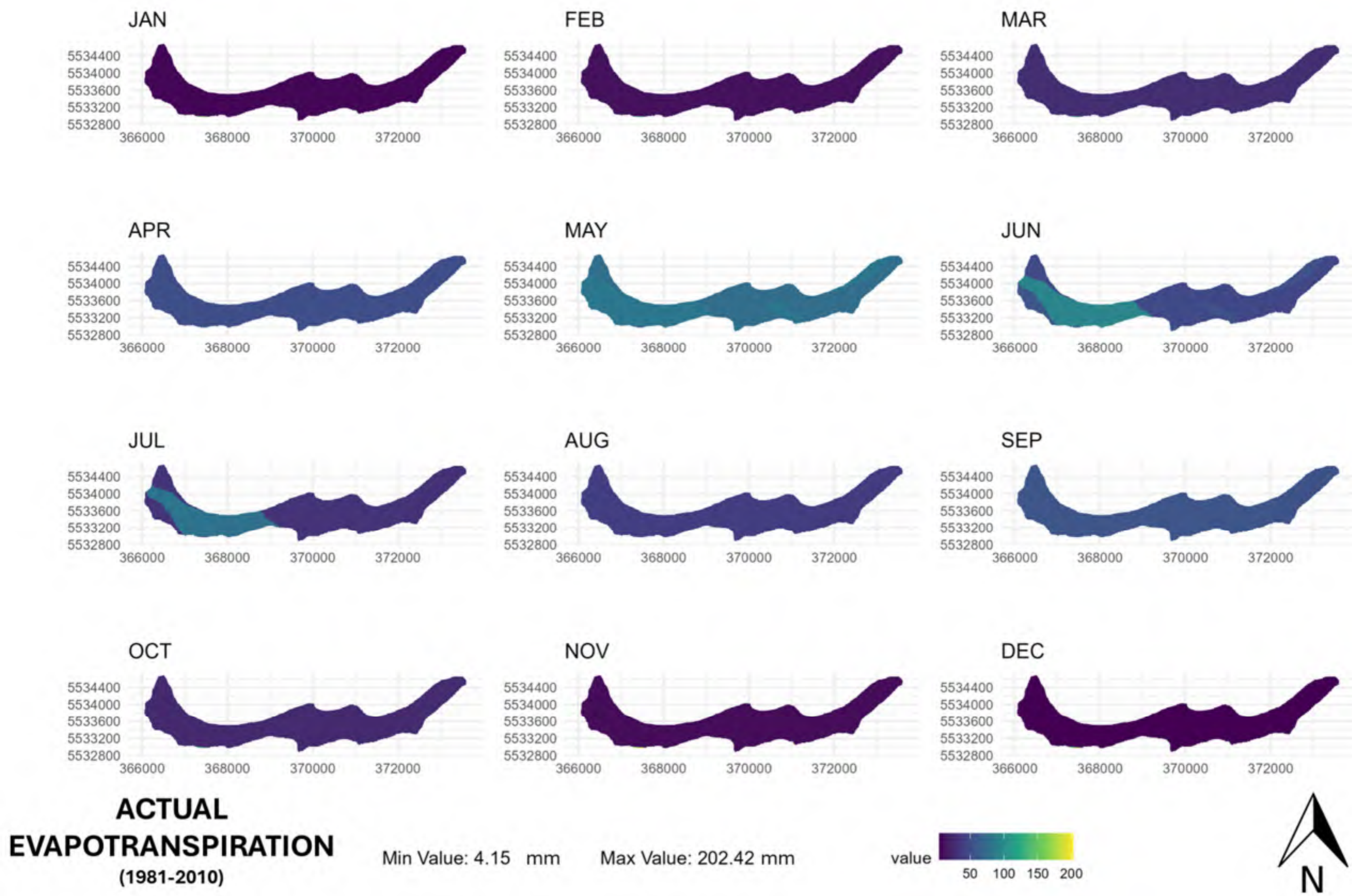


Figure E2. Annual actual evapotranspiration (mm) (Climate Normal 1981-2010) (water balance model output).

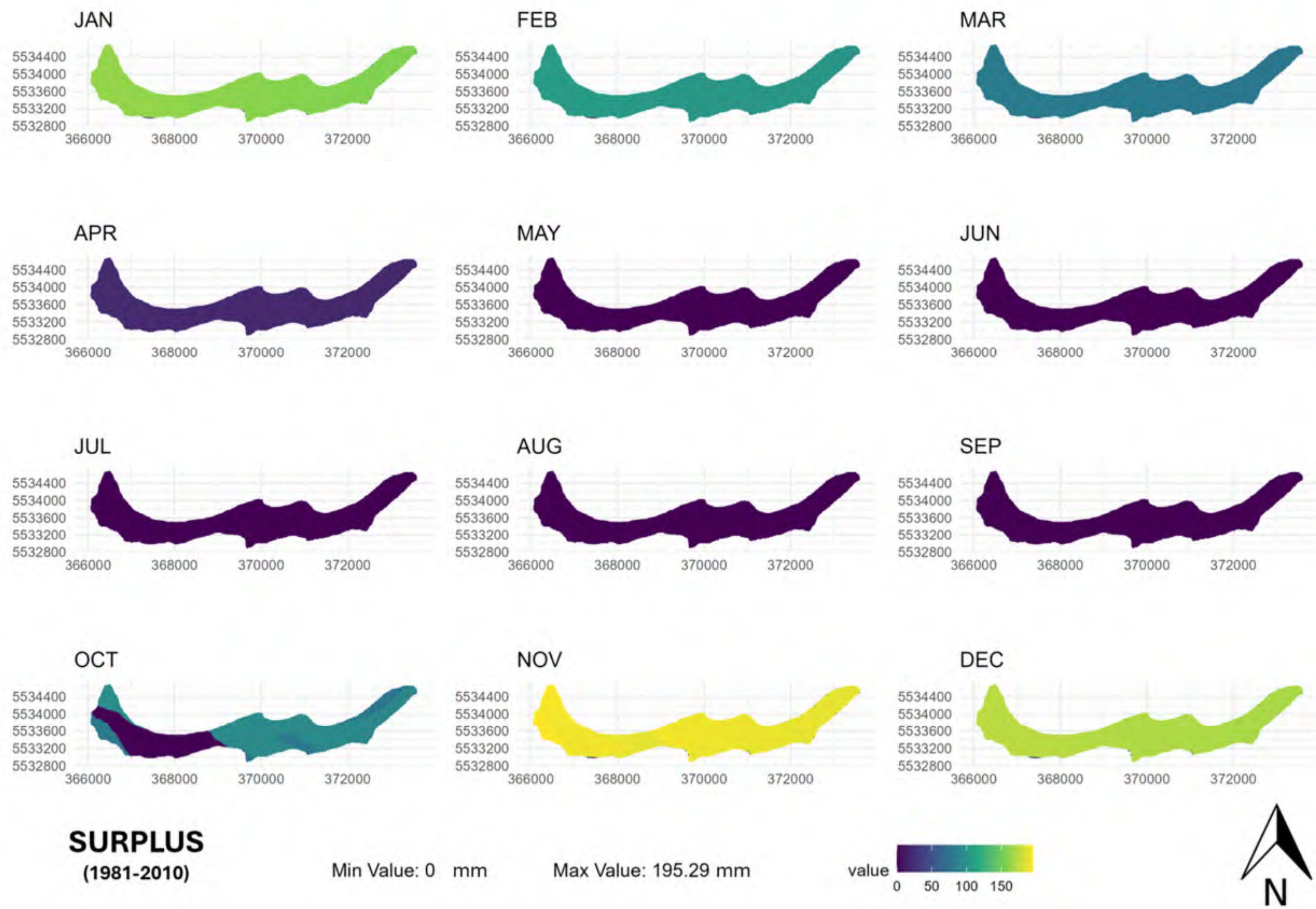


Figure E3. Calculated annual water surplus (mm) (water balance model output).

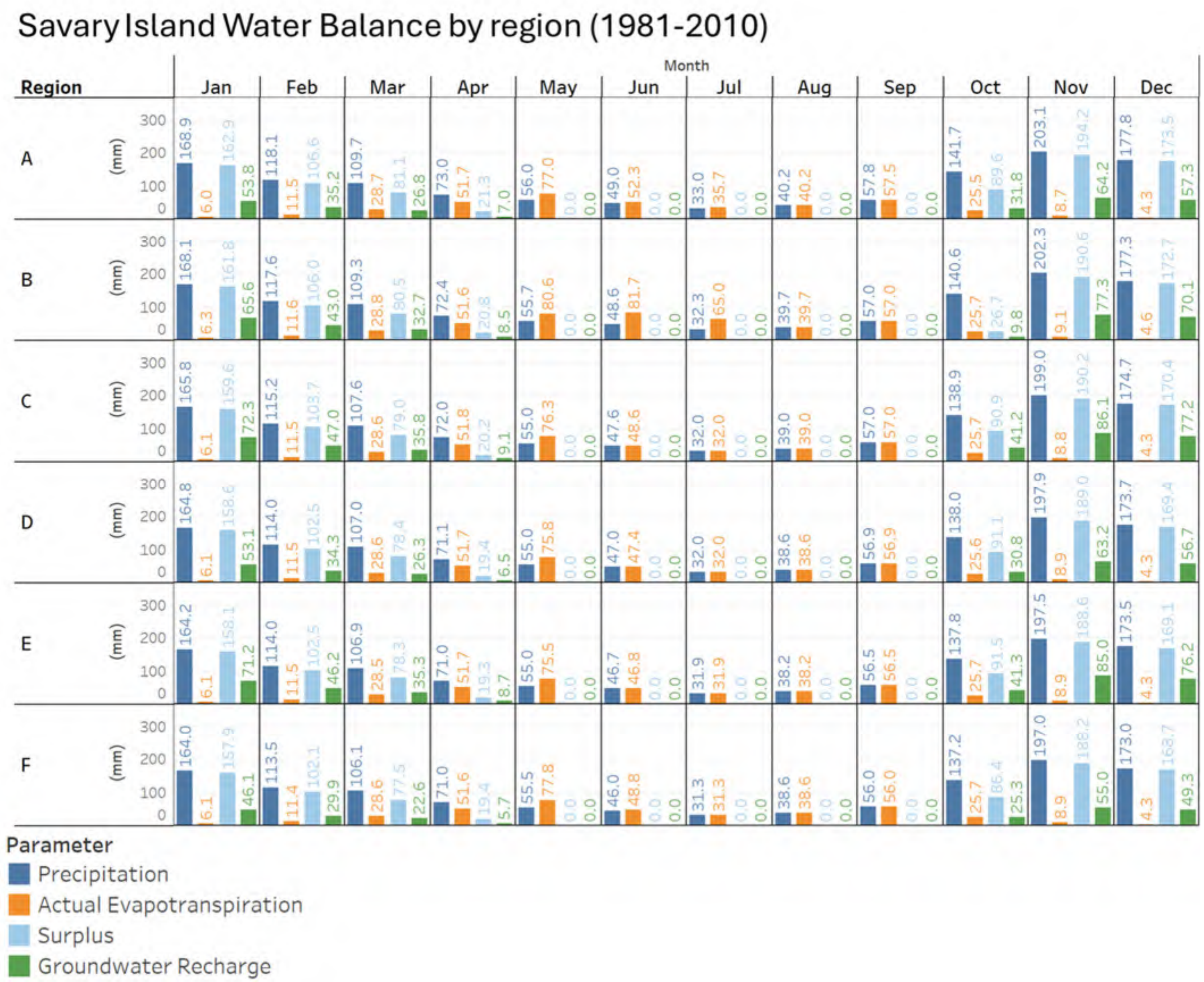


Figure E4. Savary Island water balance outputs by region (1981-2010 Climate Normals).

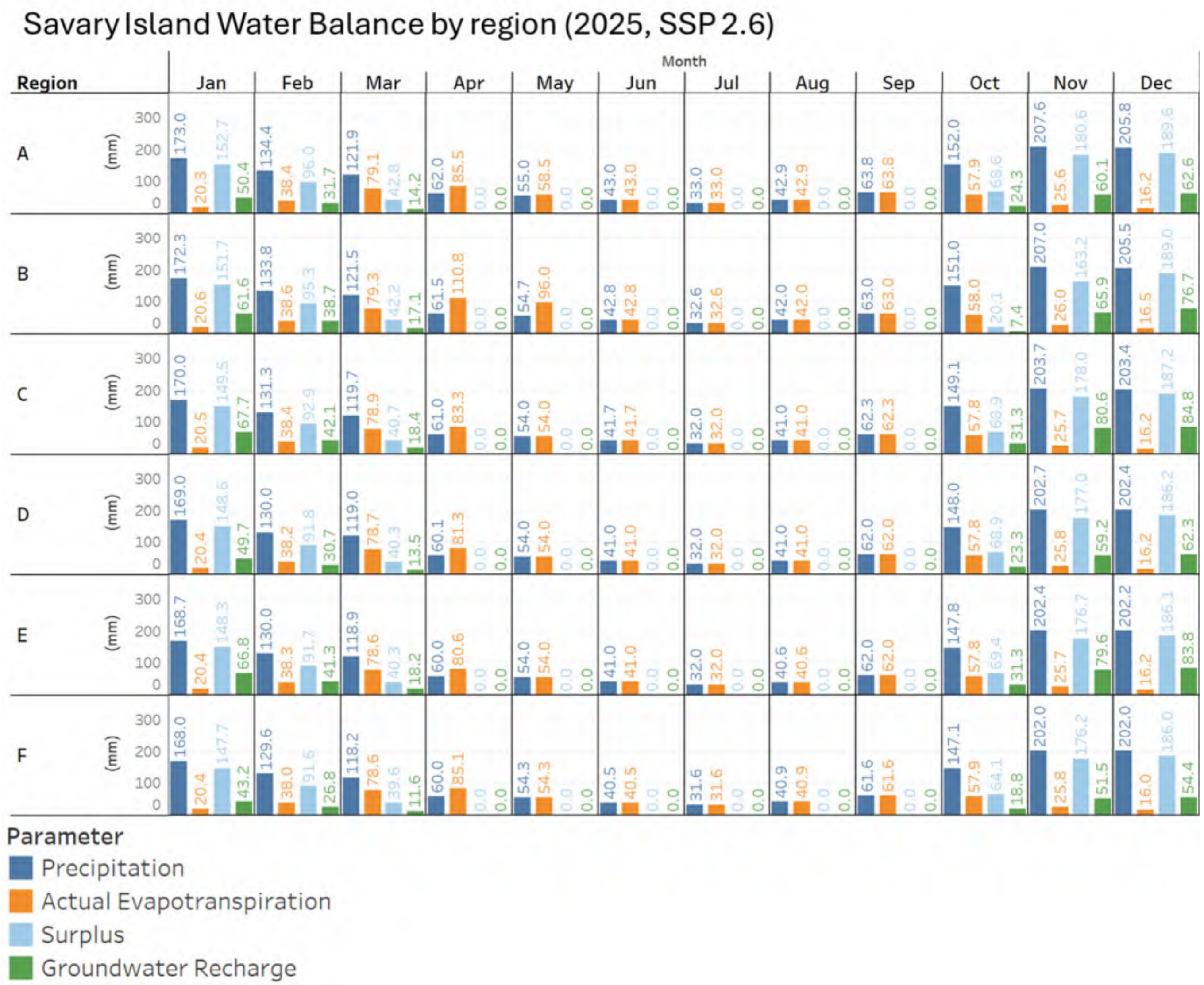


Figure E5. Savary Island water balance outputs by region (2025 SSP 2.6).

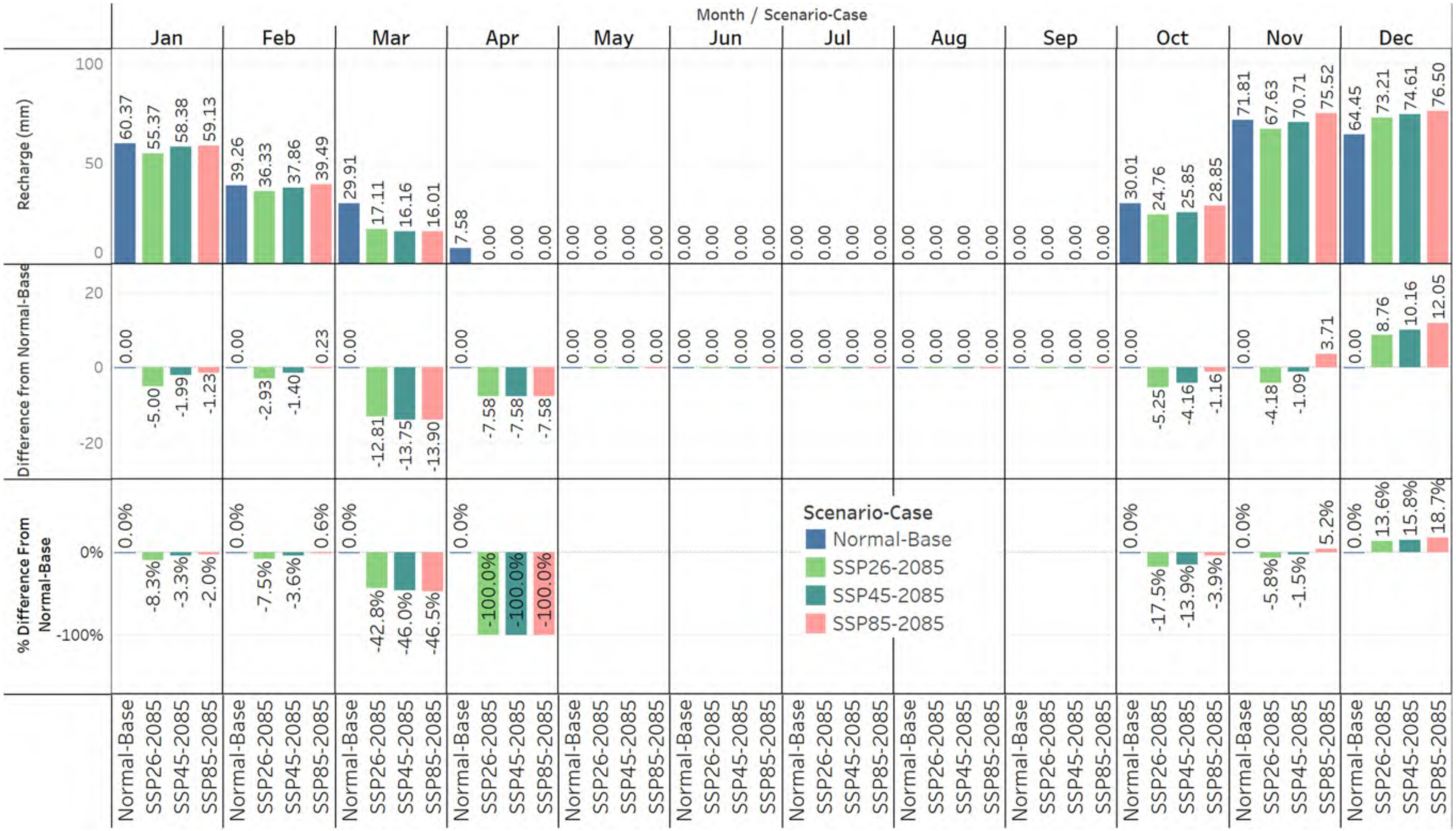


Figure E6. Estimated recharge and change in 2085 relative to 1981-2010 climate normals, summarized by month for Savary Island, SSP 2.6, 4.5 and 8.5.

APPENDIX F

FIELD SURVEY WELL CONSTRUCTION OBSERVATIONS

Table F1. Well construction field observations summary

Category or requirement	Number	%	Regulation requirements and rationale
Construction method			
Drilled	40	74%	Wells must be constructed by or under direct supervision of a registered qualified well driller who is trained and knowledgeable of well construction requirements.
Driven (sand point)	12	22%	
Dug	2	4%	
Total	54	100%	
Class, subclass, status, purpose of use			
Monitoring well (permanent, active)	3	6%	GWELLS database categorizes the class, subclass, and purpose of well use. Improperly abandoned "inactive" wells can cause aquifer contamination. If there is no intent to use it, an inactive well should be decommissioned within 10 years.
Water supply, domestic (active)	45	83%	
Water supply, domestic (inactive)	1	2%	
Water supply, domestic (new, not in use)	3	6%	
Water supply, water system (active)	2	4%	
Location			
Outside	52	96%	Pumphouses commonly installed to protect the water pipes from freezing or to house the pressure tank, treatment system, etc. Hazardous materials and foreign matter including sources of contamination must not be stored in the well pump house. Wells sited outside typically have water lines installed below the frost line and connected to pump via a pitless adapter.
In pump house	2	4%	
Pump type			
Hand pump	6	11%	Pumps must be installed by or under direct supervision of a registered qualified well driller or well pump installer trained and knowledgeable of well pump installation requirements. Jet pumps and hand pumps were mainly in use in area A - Thah teq (Indian Point).
Jet pump	5	9%	
Hand pump and jet pump	4	7%	
Submersible pump	30	56%	
Unknown	3	6%	
No pump	6	11%	
Well Identification (ID) Plate			

Category or requirement		Number	%	Regulation requirements and rationale
	Has identification plate	20	37%	Physical metal plate attached to well in the field. Required to be installed by driller for all water supply wells drilled since 2005.
	No identification plate	34	63%	
Well registered in GWELLS				
	Registered (has Well Database Tag Number)	12	22%	Inspected sites were cross-referenced to registered wells based on location, depth, owner name, ID plate, and diameter. Drillers are required to register all permanent wells including water supply, monitoring, and geothermal wells (since 2016).
	Not registered	42	78%	
Secure cap and/or cover				
	Yes	52	96%	A well cap prevents entry into the well of contaminants, flood water and vermin.
	No	2	4%	
Surface seal				
	Yes	5	9%	A bentonite clay surface seal prevents well contamination by filling the void space between well casing and surrounding ground. Bentonite should also fill the gap between multiple well casings (if used). Required for all water supply wells since 2005. If seal material is removed during pump installation, it must be restored by well pump installer. A shallow surface seal can be retrofitted in shallow wells lacking a surface seal e.g. if contamination is reoccurring or unfilled anulus is visible.
	No (no bentonite observed, or unfilled annulus visible)	16	30%	
	Unknown (likely no seal)	33	61%	
Unfilled annular space				
	Annular space filled (not exposed)	46	85%	An unfilled opening around the well casing can create a pathway for contaminants to easily infiltrate to the aquifer. The area around the well must be backfilled and sloped so that surface water flows away from it. Trenches installed for buried water lines can also create a pathway for preferential flow of contaminants toward the well and should be backfilled (material re-compacted to density of native fill or soil).
	Open annulus, uneven stickup or subsidence observed around well	8	15%	
Foreign matter within 3 m of well head				
	No foreign matter within 3 m	46	85%	Keeping the area around the well clean and accessible protects it from contamination. Foreign matter must be kept a minimum of 3 m away from the well. Foreign matter includes garbage,

Category or requirement		Number	%	Regulation requirements and rationale
				waste, pesticides/fertilizers, materials from construction or demolition, fuel or other potential contaminants.
	Foreign matter observed within 3 m of well	8	15%	Examples observed: Generators and fuel, laundry washing table, garbage and recycling storage, construction waste, vehicle parking.
Well maintenance concerns (general observations)				
	Hand pump discharging at well head with no spill guard or drain. Unfilled annular space (e.g. around exterior steel casings and between riser pipe and PVC of sand point wells). Unfilled depression or need for re-grading so ground slopes away from well. Vehicle parking or other sources of hydrocarbon contaminants near well (e.g. generators). Proximity of sewage sources (outhouses less than 30 m from well). Inactive wells that should be decommissioned if not in use. Old, rusty or corroded casings, and casings with stickup <0.30 m. Pumphouse in poor repair with rodents (one site).			

APPENDIX G

TLA’AMIN NATION QƐYƐ QʷƏN (SAVARY ISLAND) MAP

GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

English Place Name	ʔayʔaǰuθəm Place Name	Pronounciation	Meaning	Additional Info
Savary Island	qɛyɛ qʷən	Qaye qwun	Fresh Water Spring. It is called this because of the 3 places on the island that have water.	There are indications this was a place for ceremonial and spiritual gatherings. There are lots of clam digging areas on both sides of the island. It was a herring spawning area in the past, near the reef. The cedar trees are good for root digging, and there are lots of berries on the island. Good hunting. This is the term given to Savary Island after in was changed by the Transformer. It is called this because of the 3 places on the island that have water.
	ṫi: ṫi: may	T'eet'ee may	Many Wild Cherry Trees	The Tla'amin people used to camp here when they wew digging clams around Savary Island. There is evidence of partial homes, and it has a strong spiritual snece.
Indian Point	θatɛq	Thah teq	Broken Off	At 0 tide you can walk across to Hernando. There are coho fishing spots on both sides of the reef. There is lots of plankton feed, and a strong tide.
Beacon Point	χɛχaǰeyıs	XeX yales	Little rocks on south side of Savary Island, half way down island. known in sechelt as χaχiʔalɛs	The reef goes out far. When the tide goes out, there are a lot of tidal pools ranging from shallow to feet deep. There are cockles and little clams.

APPENDIX H

DIGITAL FILES (DATABASE AND SPATIAL LAYERS)

APPENDIX I

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT
This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT
This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS
During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY
The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY
GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision

of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT
The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE
Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES
The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES
The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE
The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT
Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.