WELL DRILLING & OPERATION ADVISORY
Risk of Sea Water Intrusion
Delta and Richmond, B.C.

There is risk of sea water intrusion in Delta and Richmond, B.C. Well drillers, pump installers, well operators and well owners should be aware of potential complications and costs associated with sea water intrusion into aquifers.

Where can sea water intrusion occur?

Areas at risk of sea water intrusion are located throughout Delta and Richmond, B.C. Risk of sea water intrusion generally increases near the ocean, with areas of high well density and low-lying topography (narrow bays, inlets, and bedrock peninsulas) having increased vulnerability. Sea water intrusion has been observed in coastal wells where pumping has drawn sea water landward towards the well and in wells that have been drilled to depths at or near the interface between freshwater and saline groundwater.

What is sea water intrusion?

Sea water intrusion occurs when saline (salty) water from the ocean is drawn into a freshwater aquifer (groundwater source). Freshwater aquifers along the coast may be vulnerable to sea water intrusion due to physiographic and hydrogeologic conditions (Figure 1A). Sea water intrusion can affect a single well or multiple wells.

Pumping and changes in sea level and/or groundwater levels can cause sea water to migrate landward (Figure 1B). A large portion of a freshwater aquifer could be impacted if a single well is over-pumped or if multiple wells are pumping. Sea water intrusion may be permanent or take many years to reverse.

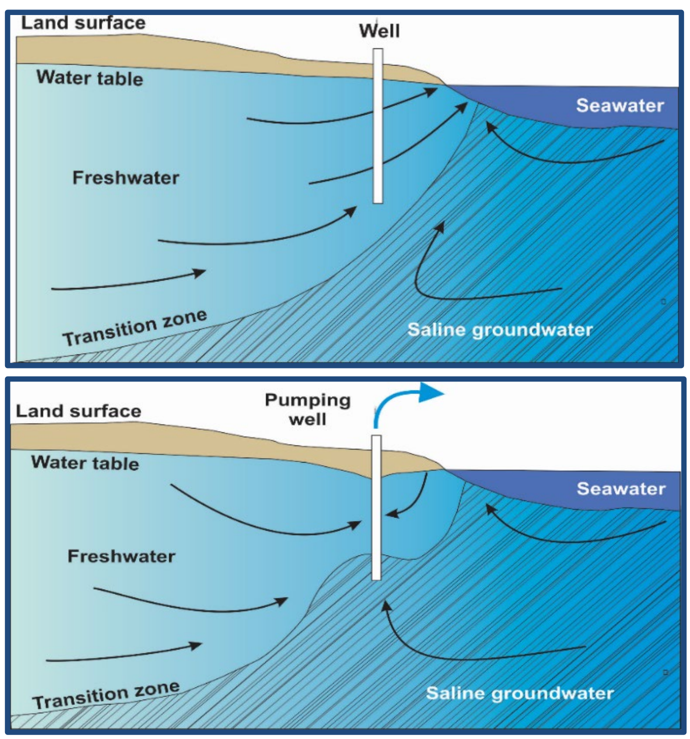

Figure 1: Freshwater and saline groundwater has a natural equilibrium (A; top). Pumping or other disturbances can lead to landward migration of the interface between freshwater and saline groundwater (B; bottom). (British Columbia , 2016)

Why is sea water intrusion a concern in Richmond and Delta?

Sea water intrusion is a concern in Richmond and Delta because groundwater is both a drinking water source and an irrigation source for agriculture. Too much sodium in the diet can pose a health risk, while plant health and soil fertility can be negatively impacted if irrigated with saline groundwater. Furthermore, dewatering is often required in Richmond and Delta during land development, due to the flat topography and shallow groundwater table which can also induce intrusion conditions.

Sand and gravel aquifers located near the ocean are particularly susceptible to sea water intrusion. Aquifers # 42, 43, 44, 62, 63, 64, and 65 underlie the areas of Delta and Richmond and are comprised of sands and gravels deposited within the Fraser River delta (Figure 2). Delta and Richmond are bordered by the ocean to the west and south. Additionally, a saltwater wedge is present at the mouth of the Fraser River, between Richmond and Delta. The extent of the saltwater wedge is dependent on seasons and tides but has been documented to extend as far upstream as Annacis Island (Leung, Stronach, & Matthieu, 2018).

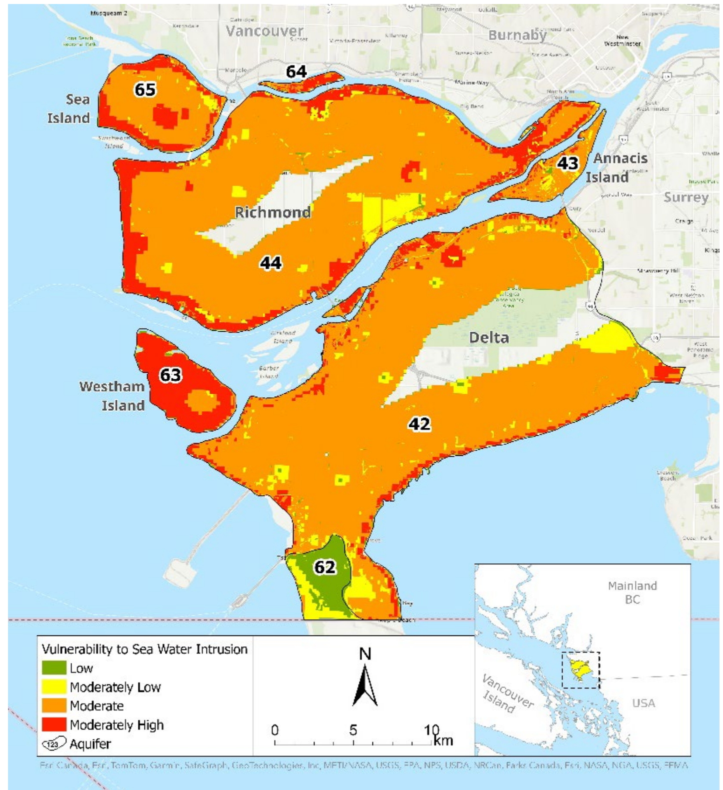

Figure 2: Vulnerability map of sea water intrusion risk in unconsolidated aquifers in Delta and Richmond.

This area is at risk of sea water intrusion due to its low elevation, shallow permeable sediments, and proximity to the ocean and river. Vulnerable areas extend throughout the majority of these two areas.

Areas with elevated risk of sea water intrusion:

- Tsawwassen /Tilbury/ North Delta, Delta (Aquifer 42).
- Annacis Island (Aquifer 43)
- Thompson/Seafair/ Steveston, Richmond (Aquifer 44).
- Bridgeport/Finn Slough/ Queensborough, Richmond (Aquifer 44).
- Westham Island (Aquifer 63).
- Mitchell Island (Aquifer 64)
- Sea Island (Aquifer 65)

Where are the greatest risks of sea water intrusion in the Richmond and Delta?

Vulnerability to sea water intrusion has been assessed on a scale Low to High across Richmond and Delta (Sivak & Wei, 2021), as shown in Figure 2.

As indicated on the map, locations with high vulnerability to sea water intrusion include:

- Sea, Mitchell, Annacis, and Westham Islands,
- Richmond, and
- Delta.

Excavation dewatering can also cause sea water intrusion.
As advised for wells, a cautious excavating approach, monitoring, and management for sea water intrusion should be applied to all dewatering activities in risky areas.

Whereas all areas at risk for sea water intrusion should be approached with caution for any well drilling operations or excavation dewatering, several areas have ongoing water quality issues associated with sea water intrusion and are of elevated concern. Well drilling and operation in these areas should be approached with extreme caution and, as with other areas, best management practices must be used. Areas with elevated risk will likely increase with ongoing development, climate change, and demand on our aquifers.

What are indicators of sea water intrusion?

Sea water intrusion is typically indicated by elevated electrical conductivity value, chloride concentration, and Total Dissolved Solids (TDS) concentration. These indicators of salinity are easy to measure and may vary seasonally or in relation to groundwater pumping. Wells containing groundwater with chloride concentration greater than 150 mg/L, electrical conductivity (measured as specific conductance) greater than 1000 µS/cm, or TDS concentration greater than 700 mg/L are considered affected by sea water intrusion (Klassen & Allen, 2016). These numeric values are used as operational thresholds and wells may only be operated if chloride concentration, electrical conductivity, and TDS are less than these values.

Who is responsible if saline water is detected in a well?

Under Section 58 of the *Water Sustainability Act*, a person must not operate a well in a manner that causes or is likely to cause the intrusion of saline groundwater, sea water, or contaminated water. Well owners are responsible for hiring qualified professionals to drill their well and not operate their well if saline water is detected, as described above.

In addition, under Section 23 of the *Drinking Water Protection Act*, a person must not allow anything to be introduced into a domestic water system, a well recharge zone, a drinking water source or an area adjacent to it, if it is likely that this would result in a drinking water health hazard or that the owner would have to limit use of the water due to this risk.

How can the risk of sea water intrusion be managed?

Anyone constructing a well[1] in B.C. (with some exceptions for shallow excavated wells) must be registered as a well driller or be working under the supervision of a registered well driller or a qualified professional.

[1] A well is defined in the *Water Sustainability Act* as: an artificial opening in the ground made for the purpose of exploring for or diverting groundwater, testing or measuring groundwater, recharging or dewatering an aquifer, groundwater remediation, use as a closed loop geoexchange well, or use as a geotechnical well.

Hiring a registered well driller or a qualified professional is the first step in managing sea water intrusion risk.

Well drillers or excavators should always conduct a pre-drilling assessment when drilling in coastal areas. This may include examining well records from the provincial GWELLS database and the provincial Sea Water Intrusion Risk layer shown in iMapBC and the B.C. Water Resources Atlas.

Considerations for Well Owners

- Ensure the driller or professional you hire is registered with the Province, qualified and experienced with sea water intrusion. Obtain multiple quotes.
- Recognize the risks and your liability to neighbours and others if your well causes sea water intrusion.
- Sample groundwater from wells annually for chloride, electrical conductivity and TDS.

Well owners in coastal areas should analyse a sample of groundwater from their well annually for chloride, electrical conductivity, and TDS, preferably during the dry season, and track water quality changes over time. Operators of wells used to supply drinking water systems can coordinate this testing with their annual testing for other contaminants as recommended or required by the Regional Health Authority. Well owners may also use hand-held meters or automated in-line sensors to monitor the electrical conductivity of their well. In-line monitoring can be paired with an automated shut off for the pump if the electrical conductivity rises above a specified value or the groundwater level falls below a specified depth.

Risk of sea water intrusion in coastal area can be mitigated by following these best practices:

Best practices when drilling or excavating in areas with sea water intrusion risk:

- Ensure you have experience and equipment to deal with sea water intrusion.
- Avoid drilling in locations with moderately high to high sea water intrusion risk.
- Avoid drilling within 50 m of the coast.
- When unsure of the risk, work with a professional to avoid drilling overly deep for a particular area.
- Avoid technologies such as hydrofracturing within 100 m of the coast.
- Use a calibrated hand-held meter to measure electrical conductivity during drilling.
- Consider stopping drilling and testing for chloride if an increase in electrical conductivity is observed.

Best practices <u>when well testing</u> in areas with sea water intrusion risk:

- Hire a qualified professional to evaluate the risk of sea water intrusion.
- For pumping tests, monitor water quality during the test with either a calibrated hand-held meter or a continuous monitoring device such as a conductivity or chloride sensor.
- Collect at least three water samples before, during, and after pumping. Analyze for chloride, electrical conductivity, and TDS. Compare characteristics of sample to those of sea water.
- Reduce the estimate of safe available drawdown to limit drawdown below sea level.
- Measure downhole electrical conductivity to identify fractures or zones where saline water is encountered to inform well construction, operation, or alteration.

Best practices <u>when operating a well</u> in areas with sea water intrusion risk:

- Monitor the well for long-term decline in water levels or well supply. If observed, stop using the well and have the well assessed by a qualified professional. Avoid deepening the well in response to declining well supply.
- Hire a registered well pump installer to modify the pump set up. Raise the pump to obtain water from shallower depths and reduce drawdown during pumping. Install a dole valve to limit well pumping rates. Install automation controls to limit the duration and increase the frequency of well pumping.
- Practice water conservation by installing low water use appliances and irrigation systems, drought resistant gardens and consider options for water re-use.
- If water quality in the well is fresher in winter, add capacity to store pumped water from the wet season for use in drier periods and supplement well water use with water from other sources (bulk hauling, rainwater collection) following health guidelines for water storage and disinfection (B.C. Ministry of Health, 2020).
- Install water meters or alarms to detect leaks and fix leaks quickly once detected.
- If needed, consult a qualified professional to assess sea water intrusion risk, interpret water quality tests, design a well monitoring and management program or for advice on well alteration.

What if a well is impacted by sea water intrusion?

It may be necessary to temporarily discontinue, alter, or permanently decommission a well if it has been impacted by sea water intrusion. Alteration of a well may involve infilling the well below a certain depth or sealing fractures within bedrock aquifers to prevent saline groundwater from entering the well and contaminating shallower aquifers. A qualified professional can help to assess your well, aquifer and water system to determine how best to approach this issue and how/if it can be mitigated or managed.

Unusable wells or wells that are no longer needed must be decommissioned by a registered driller in accordance with the Groundwater Protection Regulation, as abandoned wells can allow vertical migration of contamination and saline groundwater.

Legislation and regulatory information

To learn more about the applicable regulations, please see:

- *Water Sustainability Act*, Section 58: https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/14015#section58
- Ground Water Protection Regulation Guidance Manual (June 2019): https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-licensing-and-rights/gwpr_guidance_manual_signed.pdf

Additional Information

For additional information on managing sea water intrusion risk refer to the:

- Province of B.C.'s brochure on Sea Water Intrusion: www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-wells/saltwaterintrusion_factsheet_flnro_web.pdf
- GIS Modelling of Sea Water Intrusion Risk along British Columbia's Coast. Sivak, T. and M. Wei, Western Water Associates Ltd. 2021. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=59164
- Chemical indicators of saltwater intrusion for the Gulf Islands, British Columbia. By J. Klassen, D. Allen and D. Kirste, Department of Earth Sciences, Simon Fraser University. 2014. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=50327
- Registry of qualified well drillers/pump installers, GWELLS database and other groundwater resources: Groundwater Wells and Aquifers - Province of British Columbia (gov.bc.ca)
- Individual Registrant Directory of Engineers and Geoscientists, EGBC: http://www.egbc.ca/app/Registrant-Directory
- Risk of saltwater intrusion in coastal bedrock aquifers: Gulf Islands, B.C. By J. Klassen and D. M. Allen. Department of Earth Sciences, Simon Fraser University. 2016. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=50332
- Saltwater intrusion process, investigation and management: Recent advances and future challenges. By A.D. Werner, M. Bakker, V. E. A. Post, A. Vandenbohede, C. Lu, B. Ataie-Ashtiani,

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