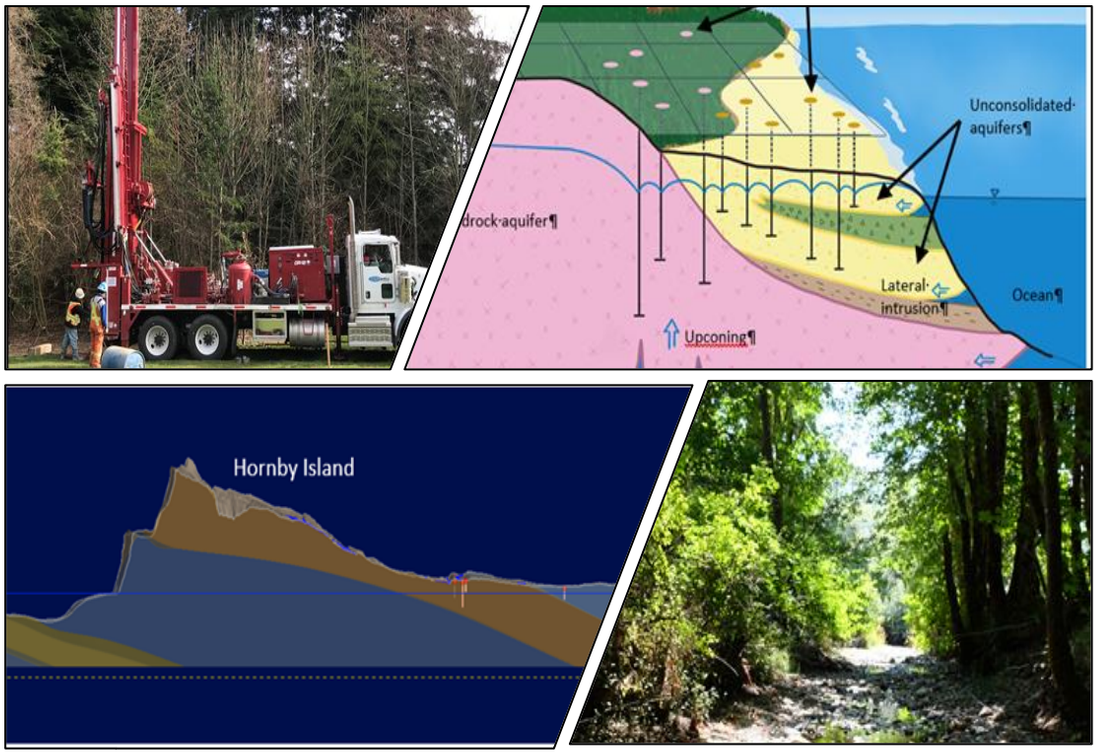
WATER SCIENCE SERIES

Compendium of Provincial Groundwater Science and Monitoring Projects: 2020-21



October 2021

BRITISH COLUMBIA

No. 2021-08

The **Water Science Series** are scientific technical reports relating to the understanding and management of B.C.'s water resources. The series communicates scientific knowledge gained through water science programs across B.C. government, as well as scientific partners working in collaboration with provincial staff. For additional information visit: http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-science-series.

ISBN: 978-0-7726-8048-8

Citation:
Ishikawa, J. (ed.), 2021. Compendium of Provincial Groundwater Science and Monitoring Projects: 2020-21. Water Science Series 2021-08. Province of British Columbia, Victoria.

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Cover Images:
Clockwise from upper left:
1) Drilling of OW498 with rotary drill rig in Mission Point Park, Sechelt. Photo: B. Jackson
2) Mechanisms of intrusion of saltwater in coastal unconsolidated and bedrock aquifers. Source: Western Water Associates Ltd.
3) Glenora Creek, a tributary to the Koksilah River in August 2019. Photo: S. Barroso
4) Cross-section generated by Leapfrog showing the nature of the bedrock geology across Denman and Horny Islands. Source: Islands Trust and GW Solutions.

Acknowledgements

This compendium was compiled through the efforts of members of the B.C. Provincial Groundwater Science and Monitoring Oversight Team (GSMOT): Michele Lepitre, Skye Thomson, Johanna Wick, Jessica Doyle, and Dave Wilford of the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development; Neil Goeller, Amy Sloma and Julie-Ann Ishikawa of the B.C. Ministry of Environment and Climate Change Strategy; and, Elizabeth Johnson of the B.C. Ministry of Energy, Mines and Low Carbon Emissions. We would also like to acknowledge all the project managers, field staff and authors of the various projects who are noted individually as part of each project summary. A full list of partners and outside agencies that have supported the various individual projects has been included at the end of this document.

EXECUTIVE SUMMARY

The BC Provincial Groundwater Program originated in 1961 when the *Water Act* was revised to enable the licensing of groundwater. The primary goal of the groundwater program has been to increase the understanding of the groundwater resources in British Columbia, and to ensure the sustainable management and protection of the resource. As the Province moves forward with the implementation of groundwater licensing under the new *Water Sustainability Act* (*WSA*) which was brought into force in 2016, there is an even greater need to improve the level of scientific knowledge of aquifers, groundwater availability and the interactions between surface water and groundwater. This knowledge is critical to support the sustainable management of groundwater and to support science-based decision making. The Ministry of Environment and Climate Change Strategy (ENV) and the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) share joint responsibility for the Groundwater Program. Currently, groundwater science and monitoring projects are primarily funded out of three main funding envelopes:

- The Strategic Water and Air Monitoring Planning Process (SWAMPP), administered by the Knowledge Management Branch (KMB) within ENV;
- The Groundwater Science Program, administered by the Water Protection & Sustainability Branch (WPS) within ENV; and,
- Water Research Portfolio funding, administered by FLNRORD.

In some cases, the Province also partners with other agencies such as the BC Oil and Gas Commission (OGC), the Geological Survey of Canada (GSC), universities and local governments to fund groundwater-related studies.

This compendium is published under the *Water Science Series* to bring together a compilation of short summaries of the groundwater science and monitoring projects supported by the Province during the 2020-21 fiscal year. The intent is to communicate to a wide audience the nature of the projects undertaken and to provide a quick overview of the project results. Links to key personnel and additional reporting are provided within each summary for anyone who might require more detailed information.

The projects outlined in this compendium meet some of the objectives of FLNRORD's strategic priorities. Specifically, the installation of new groundwater observation wells and the remapping of aquifers provides provincial groundwater staff with the ability to sustainably manage groundwater resources in British Columbia. These projects also support ENV's Service Plan and the critical work needed to interpret the state of the province's environmental health so that all British Columbians will continue to benefit from the wise and prudent management of natural resources.

CONTENTS

1. AQUIFER MAPPING

To effectively manage groundwater resources and the impacts of land development on groundwater availability and quality, it is essential to understand the existence and characteristics of B.C.'s aquifers. Identifying and mapping aquifers is often the first step in developing this understanding. The Groundwater Wells and Aquifers (GWELLS) application is the primary information source on groundwater resources across the province. The GWELLS aquifer catalogue is currently utilized for: i) tracking and informing the management of groundwater rights; ii) prioritizing management; iii) protection and remedial efforts; and, iv) increasing public understanding. It is also used as a resource by several provincial government ministries including the Ministries of Environment and Climate Change Strategy (ENV), Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), Health (HLTH), Energy, Mines and Low Carbon Innovation (EMLI), and Agriculture, Food and Fisheries (AGRI).

As of August 2021, the database contained over 1,200 aquifers. The Province continues to conduct new aquifer mapping projects to expand and refine the database. The need for mapping aquifers is ongoing as communities expand and/or new resource development projects are proposed. In addition, previously mapped aquifers are revisited periodically and updated as new information becomes available or a more detailed level of assessment is required. Aquifer mapping studies are prioritized based on a number of factors, including, but not limited to: (i) the local knowledge of emerging issues that regional offices have identified through their work with communities and in supporting water authorizations; (ii) the locations of water wells in the provincial GWELLS database that are not yet associated with a mapped aquifer; and, (iii) the locations of major resource development projects (e.g. mines, oil and gas).

In 2020/21, aquifers were mapped in the Houston area in northeast B.C. This information will be utilized as a reference to inform groundwater licensing under the *Water Sustainability Act* and is available to the public to inform well protection and land use planning.

Spatial information about mapped aquifers can be accessed using the following tools, supporting a range of user needs:

- GWELLS – The Provincial database for storing and retrieving water well records and aquifer information;
- Groundwater Level Data Interactive Map Portal – a user friendly map-based tool to view and access information from the Provincial Groundwater Observation Network (PGOWN); and,
- iMapBC – an application to view and analyze mapped aquifers along with hundreds of other data layers compiled from across the BC Government and other agencies.

Aquifer Mapping Studies, Houston Area

Project Description

Phase 2 of the North Area aquifer mapping project focused on the Houston area located in the Bulkley River Valley approximately 260 kilometres northwest of Prince George. The Bulkley River is internationally renowned for fishing and is considered one of the most heavily fished rivers in B.C. and an economic driver for the region.

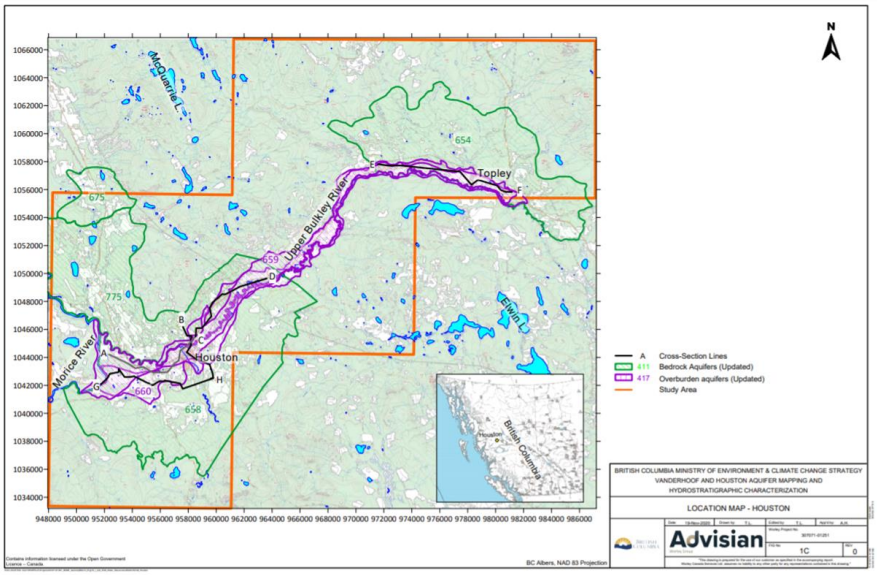
This project integrated water well records from the GWELLS database with mapping of geology, topography, streams and springs to map new, and update existing, aquifers in the Houston area.

Summary of Project Outcome

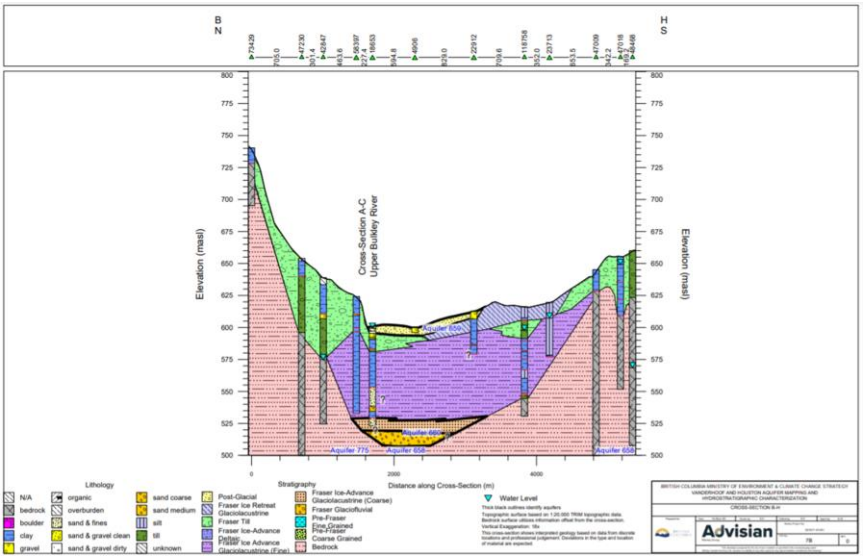
Mapping of the spatial extents and character of unconsolidated and bedrock aquifers provides a resource for water licensing decisions and water management planning. The four existing bedrock aquifers were retained in the study area with some revisions to the extents. Of the six unconsolidated aquifers, only two remain, with four being merged based on the same geologic unit.

Relevance

Results will inform groundwater licensing under the *Water Sustainability Act*. Results may also be used to assist in future assessment of hydraulic connections with surface waters; aquifer hydraulic properties; local or regional groundwater budget analyses; and, development of numerical groundwater models.



Map of study area located along the Upper Bulkley River near Houston, BC.



Cross-Section B-H′ presents the hydrostratigraphy of the Bulkley River Valley.

References

Hinnell, A.C., T. Lengyel, S.P. Funk, J.J. Clague, and Z.M. Hammond. 2020. Vanderhoof and Houston Study Aquifer Mapping Hydrostratigraphic Characterization. Water Science Series, WSS2020-07. Prov. B.C., Victoria, B.C.

Project Contacts

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Funding Acknowledgements:
Groundwater Science,
Water Research Portfolio,
North Area Regional Operations

2. WATER MONITORING

Groundwater Monitoring

The Provincial Groundwater Observation Well Network (PGOWN) monitors groundwater conditions in aquifers across British Columbia through provincially managed, groundwater monitoring wells. The water level measurements and water chemistry data collected through the network helps inform water resource management decisions across the province. Collection, interpretation and reporting of high quality, reliable groundwater level and baseline chemistry data in a timely fashion is important for sustainable water management in BC.

The objectives of the network include:

1. Understanding local and regional hydrogeological processes.
2. Supporting sustainable use of the groundwater resource and minimizing conflicts between multiple groundwater users or between groundwater and surface water users.

The data collected through the PGOWN is publicly available through several Provincial portals:

- *Interactive Map tool - Groundwater Level Data Interactive Map;*
- *Real-time Water Data -Aquarius Time-Series database and,*
- *Water chemistry data - Environmental Monitoring System (EMS) web reporting.*

The PGOWN was formally established in 1961 and the network has evolved over the years with new observation wells added, while monitoring at other wells has been discontinued as priorities, staffing levels and funding levels have fluctuated.

As of June 2021, there are 220 active observation wells in the PGOWN. During the 2020-21 fiscal year, a total of five new observation wells were drilled. The new observation wells are described in the following project summaries.

Surface Water Monitoring

The Province co-manages the Federal-Provincial Hydrometric Network with the Water Survey of Canada that operates 460+ hydrometric stations across the province. Network operations costs are shared between the provincial and federal governments and 3rd parties. The majority of the stations are operated on larger systems for a variety of uses such as public safety, trans-boundary water management, utilities, transportation and resource management. The network focuses on the primary hydrometric parameters of stage and discharge with auxiliary parameters at select locations. Stations are operated in both real-time (telemetry) and non-real-time. Data are published through the federal Water Office website (https://wateroffice.ec.gc.ca/).

In addition, some regions conduct additional local hydrometric measurements to fill in data gaps on smaller stream systems to support licencing decisions. Monitoring of surface water helps to provide insight into the interactions between aquifer-stream systems and provides a more complete picture of the water exchanges between the surface and sub-surface required for assessing water resources.

Observation Well #495, Bowen Island, B.C.

Project Description

This project involved collaborating with the Municipality of Bowen Island and private property owners to identify existing, unused water wells that could be incorporated into the Provincial Groundwater Observation Well Network (PGOWN). From there the project evaluated the identified wells, drafted third-party agreements, collected water quality samples, and added monitoring instrumentation.

The objective of this project was to provide locations for the long-term monitoring of groundwater levels and chemistry within aquifers on Bowen Island.

View of OW495 on Bowen Island.
Photo: B. Jackson

Summary of Project Outcome

Observation Well #495 (OW495) was officially added to the PGOWN in 2020, however, groundwater level data has been collected from this site since 2018. This well is located on private land and is situated in a bedrock aquifer (Aquifer #746). This site is not suitable for telemetry due to heavy forest cover, however, data from the site is downloaded manually every six months.

All groundwater level data are publicly available through the Groundwater Level Data Interactive Map and the provincial Aquarius time-series database. Groundwater samples were also collected for laboratory analyses, and the results are publicly available through the Environmental Monitoring System (EMS).

Relevance

The intent of adopting OW495 was to expand on the collection of long-term water levels and groundwater chemistry data in key South Coast locations. The data will be used to support implementation of the *Water Sustainability Act* through licensing and to inform management decisions that promote the protection and sustainability of this resource which will be especially important for Bowen Island as this community will likely come to rely further on groundwater to supply its future needs.

Learnings and Recommendations

Based on the available data, the groundwater levels at OW495 are shallowest in January and February and deepest in August and September, with levels as shallow as 1.12 m below ground surface (mbgs) to as deep as 3.39 mbgs. The groundwater levels also appear to be tidally influenced, meaning that they fluctuate daily with the oceanic tides.

Previously, this project resulted in the adoption of Observation Well #473 on Bowen Island in 2017. There is ongoing work to identify further existing wells for potential inclusion in the PGOWN in the coming years.

Partners and Linkages

The owner of this private property allowed for the adoption of this pre-existing, unused bedrock well into the PGOWN. Research and identification of existing unused wells on Bowen Island were conducted by the municipality.

References

Province of British Columbia. 2021. Well Record for OW495. GWELLS, Well Tag Number 120711.

Project Contacts

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Funding Acknowledgements:
Strategic Water and Air Monitoring Planning Process,
South Coast Regional Operations

Observation Well #498 & #499, Sechelt, B.C.

Project Description

The Provincial Groundwater Observation Well Network (PGOWN) monitors groundwater conditions in aquifers across British Columbia. The intention of this project was to better understand the hydrogeology of southern Sechelt to support statutory decision-makers and the shíshálh First Nation. This was achieved by installing two observation wells at the same site (one shallow and one deep) to provide for the long-term monitoring of groundwater levels and chemistry of Aquifer #566, an unconfined sand and gravel aquifer. This area has complex hydrogeology, including potentially multiple unconsolidated aquifers, artesian conditions, groundwater-surface water connectivity, and potential saltwater intrusion.

This project involved researching and selecting sites, an archaeological assessment, establishing a third-party agreement, drilling, and adding monitoring instrumentation.

Drilling of OW498 with rotary drill rig in Mission Point Park, Sechelt.
Photo: B. Jackson

Summary of Project Outcome

These wells were drilled and installed between March 8 and March 11, 2021. Observation Well #498 (OW498) has a depth of 43.6 metres below ground surface (mbgs), while OW499 has a depth of 16.5 mbgs. Full satellite telemetry will be added to these wells in the summer of 2021. All groundwater level data will be publicly available through the Groundwater Level Data Interactive Map and the provincial Aquarius time-series database. Groundwater samples will also be collected for laboratory analyses, and the results will be publicly available through the Environmental Monitoring System (EMS).

Relevance

Aquifer #566 is relied on by various local users, including a nearby hatchery, a water bottling facility, and shíshálh Nation. Monitoring of this aquifer will be used to support implementation of the *Water Sustainability Act* through licensing and to inform management decisions that promote the protection and sustainability of this resource.

Learnings and Recommendations

At this time, the groundwater level and chemistry data for these wells are not yet available online. However, the drilling of these wells revealed artesian pressure increasing with depth. The proximity of the two wells will allow for direct comparison of gradients and pressure differences. Future groundwater level and chemistry data collection at these wells will help improve our understanding of the hydrogeology of this area.

Partners and Linkages

The District of Sechelt provided a location within a municipal park (Mission Point Park) for the installation of OW498 and OW499 and agreed to the long-term use of this location for groundwater monitoring.

References

Province of British Columbia. 2021. Well Records for OW498 and OW499. GWELLS, Well Tag Number 123008 and 123004, respectively.

Project Contacts

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Funding Acknowledgements:
Strategic Water and Air Monitoring Planning Process,
South Coast Regional Operations

Observation Well #501, Kitimat

Project Description

With the approval of LNG Canada, the Kitimat River valley has had an increase in industrial activity over the last two years. The Kitimat River supplies water to the the Town of Kitimat and supplies water for most of the regions's industrial activity. Aquifers #1079 and #1081 are unconfined sand and gravel aquifers which are in hydraulic connection to the Kitimat River. Additionally, Aquifer #1085 is a deeper confined sand and gravel aquifer underlying and in connection to Aquifer #1081.

This observation well was drilled into Aquifer #1085 to better understand the impacts of water withdrawals on the regional groundwater system.

View of OW501, Kitimat.
Photo: B. Watson

Summary of Project Outcome

Observation Well #501 (OW501) was drilled to a depth of 42 metres and screened in Aquifer #1085. The lithology encountered at that depth was consistent with that of other regional wells that were used to delineate Aquifer #1085. Aquifer #1081 was not identified during drilling, however, it may be thin at this location or was perhaps not readily apparent using an air-rotary drill. OW501 is in the process of being brought into the provincial monitoring network.

Relevance

Kitimat, located in the Skeena natural resource district, is a region with significant groundwater extraction. This is the first observation well located in the area and it will provide insight into seasonal and long-term trends in the groundwater level. It will also contribute to understanding the impacts of groundwater withdrawals on the aquifer, including extractions related to industrial development in the area.

Learnings and Recommendations

The uppermost, unconfined Aquifer #1081 was not identified at this location. In order to monitor this aquifer, a new location may need to be chosen or a different form of drilling with better lithological resolution may be required.

Partners and Linkages

The Town of Kitimat provided the necessary authorization to locate the monitoring well on their property.

References

Province of British Columbia. 2021. Well Record for Observation Well #502. GWELLS, Well Tag number 123333.

Project Contacts

Johanna Wick | e-mail: Johanna.Wick@gov.bc.ca | Phone: 778-693-2671
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Funding Acknowledgements:
Strategic Water and Air Monitoring Planning Process
North Area Regional Operations

Observation Well #502, Valemount

Project Description

Aquifer #800 is a semi-confined, fine sand aquifer straddling the height of land between the Columbia River and Fraser River watersheds at Valemount. Ongoing research has identified the fine sands, silts and clays in this region as a fan emanating from the Rocky Mountains. Water levels can be very shallow near the watershed divide, draining towards Kinbasket Lake to the south and Fraser River to the north. Artificial wetlands located near the divide may contribute to aquifer recharge. Deeper groundwater flowing through a lower confined aquifer may be influenced directly by the Fraser River and water levels of the Kinbasket Lake Reservoir.

Observation Well #502 (OW502) was drilled in Aquifer #800 over the buried Rocky Mountain trench in order to better understand groundwater flows near the Columbia River and Fraser River water divide.

View of completed well OW502, Valemount.
Photo: S. Bryson

Summary of Project Outcome

OW502 was drilled to a depth of 27 metres. The lithology encountered was consistent with that of the regional wells used to delineate Aquifer #800. A surficial confining layer with a slightly higher concentration of silts and clays was identified, however, no deeper confining layers were discernable above the developed aquifer. Steps are ongoing to bring the well into the provincial monitoring network.

Relevance

Valemount region has the third highest levels of groundwater extraction in the Omineca natural resource region following Prince George and Vanderhoof. This is the first observation well located in the area and will help understand the impact of aquifer withdrawals as well as seasonal and long-term trends. It will also contribute to understanding groundwater behaviour at the divide between the Fraser and Columbia River watersheds.

Learnings and Recommendations

While the lithology largely matched expectations, the surficial gravels and red sands noted in the aquifer report and in many area wells, were not found. Lithological variability was more subtle than expected and resolving the finer details of the location will require a different style of drilling. To understand deep groundwater flows potentially influenced by the Fraser River and Kinbasket Lake Reservoir, a much deeper monitoring well may be required.

Partners and Linkages

The Ministry of Transportation and Infrastructure provided the necessary authorization to locate the monitoring well on highway right-of-way.

References

Province of British Columbia. 2021. Well Record for Observation Well #502. GWELLS, Well Tag number 123098.

Project Contacts

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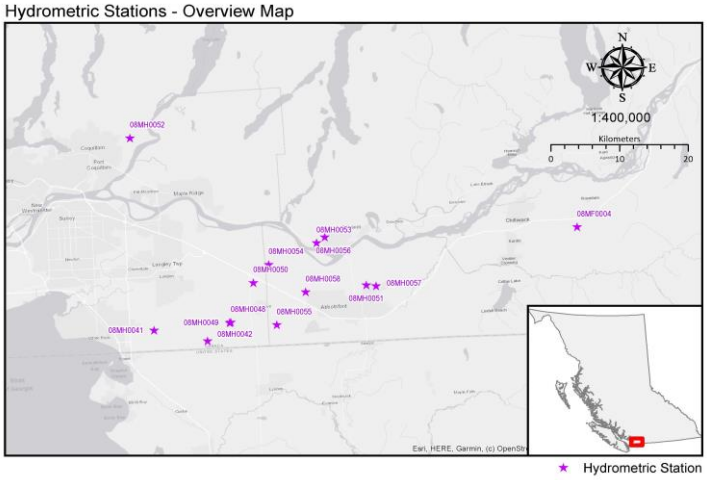
Funding Acknowledgements:
Strategic Water and Air Monitoring Planning Process,
North Area Regional Operations

South Coast Natural Resource Region Hydrometric Network

Project Description

At the beginning of 2019, the South Coast Region designated one full time staff member and used regional funds to design and implement a hydrometric network specific to the region. The goal of the network is to provide authorizations staff with additional information regarding availability of water resources within the region as well as to support the groundwater program by providing additional confidence in groundwater licensing decisions and long-term sustainable resource planning.

Since the inception of the network, a total of sixteen stations have been installed in twelve different watersheds. The data collected at each station will be used to inform both groundwater and surface water management decisions throughout the region.



Hydrometric Stations in the South Coast Region.

Summary of Project Outcome

Each station is outfitted with dataloggers that are downloaded monthly. At each station, hydrographs, rating curves, water temperature charts, and mean monthly/annual discharge tables are being created to provide summaries of stream monitoring efforts. All published data are available on the provincial Aquarius WebPortal.

Relevance

The South Coast regional hydrometric network supplements the existing Federal-Provincial hydrometric monitoring program by collecting data on smaller order streams which are high priority for water licensing. Monitoring water quantity in streams is important as it provides insight into the interactions between groundwater and surface water and provides a better understanding of the water resources in advance of allocation.

Learnings and Recommendations

The collection of local hydrometric data in the South Coast Region has provided a better understanding of the GW-SW interactions in high priority areas and supports water authorizations under the *Water Sustainability Act* related to both licensing decisions as well as water scarcity concerns. This project demonstrates a potential model for a broader Provincial hydrometric monitoring program that could be used to supplement the existing Federal-Provincial hydrometric monitoring program that services regional priorities. Presently, there is no dedicated funding at the provincial level supporting this program. Funding was provided at the regional level with some equipment being provided by the Knowledge Management Branch. Hydrometrics is extremely labour and capital intensive, having dedicated staff and funding for a provincial network would allow for operations to expand and address more regional priorities.

Partners and Linkages

Local governments and organizations within the region have accommodated the installation of hydrometric stations and have, in some cases, provided additional hydrometric data. For example, the Greater Vancouver Zoo has allowed the Province to install a station on the Salmon River as it flows through their property. Also, A Rocha, a local stewardship group, has allowed the installation of a station on the Little Campbell River located on their property.

Project Contacts

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Funding Acknowledgements:
South Coast Regional Operations
Knowledge Management Branch

3. GROUNDWATER CHARACTERIZATION AND RESEARCH

The projects in the following section highlight the variety of groundwater science and research projects undertaken by the Province in 2020-21.

The projects undertaken in 2020-21 can be broadly categorized into three main themes. The first theme consists of studies that characterize the interaction between aquifers and hydraulically connected streams. Under the *Water Sustainability Act*, water is managed as one, interconnected resource and understanding surface water - groundwater interactions continues to be a high priority for resource managers and licensing staff. Projects undertaken used a variety of tools and approaches, including:

- Field-based studies (An Ecological Assessment of Aquifer-Stream Connectivity in the Lower Fraser Valley; Interaction study of Upper Bulkley River in Houston, B.C.); and,
- Desktop assessments (Identifying Drought Susceptible and Drought Resilient Aquifer-Stream systems).

The second theme consists of projects that focus on aquifer and groundwater characterization. These projects aim to advance knowledge and understanding of the groundwater resources. Projects included:

- Groundwater quality assessments (Sea water intrusion risk assessment in coastal B.C.);
- Mapping studies (Surficial materials mapping study; Recharge potential mapping on the Northern Gulf Islands); and,
- Assessment tools for characterizing Aquifer properties (Applying the extended Drawdown Method to Interpret Pumping Tests).

The third theme consists of a project to directly supporting water managers and groundwater resource management decisions. This project focussed on:

- Groundwater management support (Water Use Management in the Koksilah River Watershed; Water Supply & Options Feasibility Project in the Koksilah watershed).

Several of the larger projects listed above are being conducted over multiple years. In cases where the projects are ongoing, an update summary has been provided to report on progress or learnings achieved to date.

An Ecological Assessment of Aquifer-Stream Connectivity in the Lower Fraser Valley (Phase 3)

Project Description

Environmental flow needs (EFN) must be considered for groundwater licensing decisions in BC under the *Water Sustainability Act* (WSA). Groundwater pumping near a stream can potentially alter aquifer-stream exchange and cause streamflow depletion, yet little is known about how aquatic ecosystems rely on groundwater, and the ecological impacts of groundwater pumping. This multi-year study (2018-2021) of Bertrand Creek at Otter Park in Langley, BC is evaluating the ecological role of aquifer-stream exchange to support aspects of EFN determination related to groundwater.

SFU field program; data collection and field investigations.
Photos collage courtesy of SFU

Summary of Project Outcome

Stream channel habitat variables (e.g., stream depth, velocity and substrate), water quality variables (e.g., pH, electrical conductivity and dissolved oxygen), and benthic macroinvertebrates were sampled at the Otter Park site over the summer of 2020. As streamflow conditions got drier over the summer, groundwater discharge maintained stagnant pools and some streamflow in riffles further downstream, despite flows declining to zero at the upstream hydrometric station. This allowed some macroinvertebrates to persist through a prolonged dry period in September 2020. Habitat models were constructed to model macroinvertebrate responses to changes in hydraulic-habitat and water quality variables. The Hunt (1999) analytical streamflow depletion model was integrated with the habitat models for macroinvertebrates (built from data collected onsite) and for the endangered Nooksack Dace (built from literature-derived data) to model how groundwater pumping scenarios might impact instream habitat for these organisms during different flow conditions. Other EFN assessment methods (e.g., wetted perimeter) were evaluated against the habitat models.

Relevance

Previous research at Otter Park identified that groundwater pumping altered aquifer-stream exchange and caused streamflow depletion (Allen et al., 2020). An assessment of ecological responses to flow variability and an evaluation of potential tools to model ecological responses are critical future steps for understanding pumping impacts.

Learnings and Recommendations

Data are being collected over Summer 2021 and will be compared with the Summer 2020 results. A BC Water Science Series report will be forthcoming in Spring 2022.

Partners and Linkages

Dr. Diana Allen of the Department of Earth Sciences at SFU supervised a master's student (Adam Mitton) to undertake this research. The Township of Langley provided the study location on their park land.

References

Allen, D.M., B. Johnson, A. Garnet, K. Howe, M. Lepitre, and M. Simpson. 2020. Assessment of Aquifer-Stream Connectivity Related to Groundwater Abstraction in the Lower Fraser Valley Stream Vulnerability Mapping. Water Science Series Report, WSS 2020-03. Prov. B.C., Victoria B.C.

Hunt, B. 1999. Unsteady stream depletion from ground water pumping. Groundwater, 39(1): 98-102.

Project Contacts

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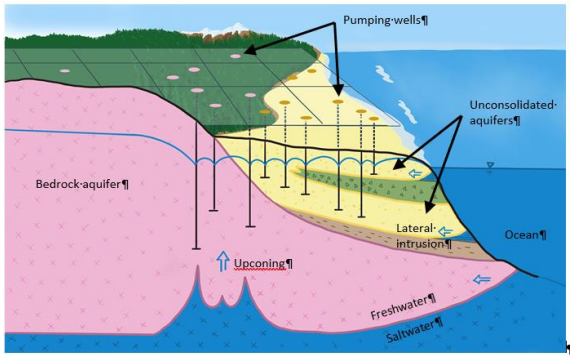
Funding Acknowledgements:
Groundwater Science Program

GIS Modelling of Sea Water Intrusion Risk along British Columbia's Coast

Project Description

Aquifers in coastal B.C. may be vulnerable to the intrusion of sea water due to natural physiographic or hydrogeologic factors, coastal morphology and groundwater use. Where this natural vulnerability is present, over-development can compromise the quality of groundwater relied upon for potable and other purposes. Once sea water intrusion occurs, remedial measures can be slow and costly. Mapping sea water intrusion risk helps to ensure that at-risk areas are appropriately managed and provides a better understanding of the factors contributing to risk.



Mechanisms of intrusion of saltwater in coastal unconsolidated and bedrock aquifers.

Summary of Project Outcome

A sea water intrusion risk assessment was prepared for coastal B.C. for both unconsolidated and fractured bedrock aquifers. This assessment expands and extends the Geographic Information Systems modelling approach developed by Klassen and Allen (2016). Areas with known sea water intrusion issues and groundwater sampling information stored in the Province's Environmental Monitoring System are generally in agreement with this study's assessment.

Relevance

Under the *Water Sustainability Act* S. 58 it is not permitted to operate a well in a manner that causes "…intrusion of saline groundwater, sea water or contaminated water…" into a freshwater aquifer. This work will support statutory decisions, informing technical assessment requirements (e.g., baseline sampling) and authorization conditions (monitoring and reporting) when adjudicating groundwater licenses and approvals having the potential for sea water intrusion. Well drillers and consultants can apply best practices when drilling, equipping or testing wells in higher risk areas. Higher risk areas may also be targeted for more detailed characterization and monitoring, development of area-based plans and/or regulations.

Learnings and Recommendations

As a follow-up to this study, communication materials should be developed to promote awareness of coastal aquifer vulnerability and sea water intrusion risks associated with natural physiographic factors and human activities, and to encourage implementation of best practices to reduce sea water intrusion occurrence in coastal settings. Further work to improve this assessment could involve a more refined analysis of future drinking water needs and climate change scenarios. The maps should be updated in the future when additional water use information becomes available through groundwater licensing under the WSA.

Partners and Linkages

The project was a collaboration between the Province, Islands Trust and Simon Fraser University.

References

Klassen, J. and D.M. Allen. 2016. Risk of saltwater intrusion in coastal bedrock aquifers: Gulf Islands, BC. Department of Earth Sciences, Simon Fraser University.

Province of B.C. 2016. Best Practices for the prevention of saltwater intrusion. Victoria, B.C.

Sivak, T. and M. Wei. 2021. GIS Modelling of Sea Water Intrusion Risk along British Columbia's Coast. Water Science Series, WSS 2021-06. Province of B.C.: Victoria, B.C.

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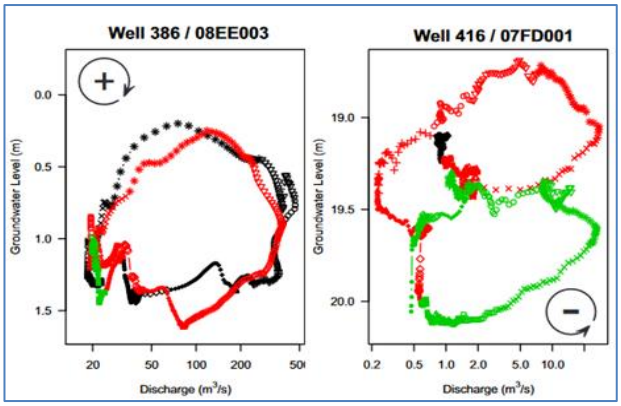
Funding Acknowledgements:
Groundwater Science Program,
Resource Operations Coast Area,
Islands Trust

Identifying Drought Susceptible and Drought Resilient Aquifer-Stream Systems in B.C.

Project Description

Understanding how drought affects the linkages between groundwater levels and connected surface water flows in nearby streams is central to decision-making surrounding water use and the protection of water resources during periods of drought. The main purpose of this project is to develop and test approaches for determining the susceptibility of aquifer-stream systems to drought in B.C. This multi-year project aims to: 1) develop quantitative drought indicator thresholds for groundwater levels; 2) evaluate these indicators and decision-support tools used during water scarcity in the Okanagan Basin and Fraser Valley; and 3) to identify susceptibility of aquifers to drought in the Okanagan Basin and the Fraser Valley.



Relationships between paired hydrometric streamflow and observation well water levels.

Summary of Project Outcome

During the second year of this multi-year project, research efforts focused on classifying the dominant response mechanism of the Provincial Observation Wells as either recharge-driven or streamflow-driven. The observation wells were paired with nearby hydrometric stations and the groundwater levels were compared to stream discharge using statistical cross correlation and graphical hysteresis plots. Of the 220 provincial observation wells, 123 wells were classified (the remaining wells either had no nearby hydrometric stations or had indeterminate results), with 66% of these wells determined to be streamflow-driven and 34% considered to be recharge-driven. Further analyses were initiated to determine if late-summer drought can be predicted in the Okanagan using selected observations wells and climatic information. In addition, SFU has also been conducting a field study in the Bertrand Creek watershed in the Fraser Valley to characterize the relationship between streamflow depletion, aquatic species habitat, and aquifer-stream connectivity to better understand the relationship between drought, groundwater and environmental flow needs.

Relevance

The results of the classification report can be used for a variety of purposes including interpreting the groundwater level response at an observation well and in inferring the degree of hydraulic connection between an aquifer and a stream. The results of this phase of the project are intended to help develop approaches to identify observation wells which might serve as early indicators of drought and identify those aquifers which may be susceptible to drought.

Partners and Linkages

Dr. Diana Allen of the Department of Earth Sciences at SFU supervised two MSc students, April Gullacher and Adam Mitton, and two undergraduate students, Alex Nott and Kira Howe, to undertake this research. Project funding was provided by the Canadian Mountain Network and the BC ENV Groundwater Science Program. Project support was provided by the BC River Forecast Centre, ENV Water Protection and Sustainability and Knowledge Management Branches, FLNRORD, the Okanagan Basin Water Board, the Okanagan Nation Alliance, and the University of Victoria.

References

Gullacher, A., D.M. Allen, and J.D. Goetz. 2021. Classification of Groundwater Response Mechanisms in Provincial Observation Wells Across British Columbia. Water Science Series, 2021-03. Province of British Columbia, Victoria.

Project Contacts

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Funding Acknowledgements:
Groundwater Science Program,
Canadian Mountain Network

Upper Bulkley Groundwater Interaction Project, Houston, B.C.

Project Description

Seepage meter installed under water to measure flux through the stream bed. Photo: J. Wick

Groundwater and surface water are a single system and when groundwater is withdrawn there can be implications for streamflow. The Upper Bulkley River watershed near Houston, B.C., is a classic sand and gravel valley fill aquifer with strong connections between groundwater and surface water. There is considerable interest around hydraulic connectivity and Environmental Flow Needs (EFN) in the Upper Bulkley River watershed. This interest is due, in part to the watershed's natural propensity for drought and low flow conditions, and high water temperatures. The river also serves as a critical spawning and rearing area for pacific salmon and steelhead trout, and as a source of water for a variety of users. This project began in 2018 and is intended to be a 4-year study that includes: a desktop and scoping exercise (Phase 1); field data collection which involves a drone overflight with infrared instrumentation, monitoring and recording of discharge, water levels, and the analysis of water for a range of water quality parameters (Phase 2); and report writing and data sharing with stakeholders, First Nations and water management staff (Phase 3).

Summary of Project Outcome

The intended outcome of the project is to strategically collect and synthesize groundwater and surface water data to further inform management of the water resources in the Upper Bulkley River watershed into the future.

To date, data loggers have been installed in volunteer wells, and ortho- and thermal-imagery from drone flights have been compiled to inform site selection. This field season, piezometers and seepage meters will be installed at selected sites to monitor and record discharge and water levels and a water quality analysis will be completed to further understand the connection between surface water and groundwater.

A thorough grasp of groundwater resources, existing water allocation pressures, the interplay between groundwater and surface water, and Environmental Flow Needs (EFN) must be understood by Water Managers in order to make informed and durable water allocation decisions. This project aims to fill current knowledge gaps, particularly where there are implications for EFN.

Partners and Linkages

Project development and data sharing partners will include: The Office of the Wet'suwet'en; The Wet'suwet'en First Nation; The Upper Bulkley River Streamkeepers; The District of Houston; The Regional District of Bulkley-Nechako; Fisheries and Oceans Canada; local residents who volunteered wells and the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Project Contacts

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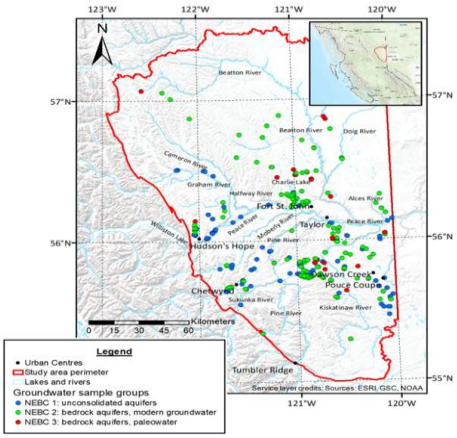
Funding Acknowledgements:
Water Research Portfolio

Characterization of Baseline Groundwater Chemistry, Northeast B.C.

Project Description

This project is being undertaken in collaboration with Simon Fraser University to better understand the variability and natural controls on groundwater chemistry in the Peace Region of northeast BC. The project uses multivariate statistical analysis to define distinct groundwater types, GIS mapping to display the distribution of chemically distinct groundwater, and numerical geochemical modeling to define the natural chemical evolution of the groundwater along regional flow paths.

The data supporting the analysis includes; 1) a hydrochemical dataset consisting of approximately 520 water samples; 2) well records from the BC GWELLS database and from the newly installed Energy and Environment Research Initiative (EERI) groundwater monitoring well network (Allen et al. 2021); and 3) X-ray diffraction, bulk chemistry and microscopy data from sediments and bedrock samples.



Distribution of sampling location.

Summary of Preliminary Results

Three distinct groundwater types occur in the regional near-surface bedrock groundwater system; these include Na-HCO_3, Na-HCO_3-SO_4, and Na-Ca-Mg-HCO_3-SO_4 type groundwater, which have total dissolved solids (TDS) values ranging from approximately 1,000 to 3,000 mg/L. The changes in composition and salinity reflect the chemical evolution of the groundwater through water-rock interactions along the flow path. Reaction path and reactive transport modeling indicates that the major controls on groundwater composition in the bedrock include gypsum dissolution and cation exchange between calcium and sodium with a minor contribution from mineral weathering.

The unconsolidated groundwater system in the region contains primarily Ca-Mg-HCO_3 type groundwater which has a TDS ranging from 300 to 1,000 mg/L. Like the bedrock-sourced groundwater, the changes in chemical composition and salinity are through reactions with the minerals that the water encounters from recharge in the unsaturated zone and along the flow paths in the aquifers. Reactive transport modeling indicates that gypsum and carbonate dissolution are the major controls on groundwater composition. Preliminary maps show the distribution of the hydrochemical groups based on water samples in the database. Final maps will include extrapolation of the zones to regions where few or no water analyses are available.

Relevance

Establishing regional groundwater chemistry baselines will aid the interpretation of local groundwater analytical results and help distinguish groundwater that has been perturbed from its natural chemical state, should such concerns evolve in the future. Determining mean groundwater residence times will help determine groundwater flow rates and provide timeframes over which remediation and reclamation programs may be effective. Mapping of distinct groundwater types will enhance knowledge of the character and distribution of groundwater throughout the Peace Region.

Partners and Linkages

Project partners include; Simon Fraser University; University of British Columbia; University of Calgary; BC Oil and Gas Research and Innovation Society; BC Oil and Gas Commission; Geoscience BC; Geological Survey of Canada; Ministry of Forests, Lands, Natural Resource Operations and Rural Development; Ministry of Energy, Mines and Low Carbon Innovation.

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Funding Acknowledgements:
Water Research Portfolio

Water Use and Management in the Koksilah River Watershed, Vancouver Island, B.C.

Project Description

Within recent years, streamflow in the Koksilah River and tributaries including Patrolas, Kelvin and Glenora Creeks, has been declining during summer periods reducing the quality of aquatic habitat and threatening the survival of fish populations. This study examined how water use in the watershed has changed over time, and summarized management tools under the *Water Sustainability Act (WSA)* that could be applied during periods of critically low stream flow.

Summary of Project Outcome

Historical and present water demand from surface and groundwater sources was examined. Groundwater use was estimated based on registered wells and land use. Licensed surface water use and estimated water demand is highest during the dry season, coincident with periods of naturally low stream flow. Approximately 65% of daily water use during the summer period is for agricultural irrigation. Annually, municipal waterworks and private domestic use represents 17% of consumptive water demand, mainly supplied from groundwater sources. A groundwater curtailment model was developed to identify water diversions that could be curtailed to improve stream flows during critical periods, providing insight into surface and groundwater interactions within the watershed.

Glenora Creek, a tributary to the Koksilah River, in August 2019.
Photo: S. Barroso

Relevance

A Temporary Protection Order was issued in the Koksilah watershed in August 2019 under S. 88 of the WSA. This was the first time in B.C. that selected water users were curtailed to prevent declines in streamflow below a critical threshold. Maintenance of minimum flows is crucial to prevent impacts to Indigenous interests, including the right to fish, and to use the stream and riparian areas for social or cultural practices.

Learnings and Recommendations

Groundwater flux, from unconsolidated (sand and gravel) and bedrock aquifers that are hydraulically connected to the stream, provides baseflow and helps maintain beneficial in-stream conditions such as cooler water temperatures. Unregulated groundwater development increased in the watershed after restrictions on surface water licences were imposed in the early 1980's. Continued investment in monitoring and engagement with water user communities is essential to address water challenges in this area.

Partners and Linkages

Cowichan Tribes, in partnership with FLNR, are leading the Koksilah Watershed Water Sustainability Plan Scoping Project. This study and other technical work contribute to an understanding of the watershed and present options to maintain environmental flows while preserving adequate supplies for drinking water, irrigation and other needs.

References

Barroso, S., and M. Wainwright. 2020. Water Use and Management Options in the Koksilah River Watershed: Preliminary analysis and recommendations for future work. Water Science Series, WSS 2020-02. Prov. B.C., Victoria B.C.

Project Contacts

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Funding Acknowledgements:
Regional Operations Coast Area

Koksilah Water Supply and Options Feasibility Project, Koksilah Watershed, Vancouver Island, B.C.

Project Description

In recent years, streamflow within the Koksilah River and its tributaries during the low flow summer period has been declining, reducing the quality of aquatic habitat and threatening survival of fish populations. This study examined the feasibility of alternate water supply options required to meet summertime demands, and maintain adequate environmental flows, while supporting the economy and wellbeing of the community.

Options were examined that could provide water for agricultural irrigation and other uses, such as this parcel which uses a pivot irrigation system.

Summary of Project Outcome

Options to meet water demands for agriculture, domestic, commercial and non-potable (industrial) uses were identified and evaluated according to impact (ability of option to meet the demand), affordability, ease of implementation and use, and reliability. Water sources considered included greywater reuse, cisterns, dugouts, water storage tanks, extraction pits, natural features, municipal water supplies, municipal wastewater reuse, water from existing lakes or manufactured reservoirs, aquifer storage and recovery, and forest management.

Relevance

In many areas of B.C., development pressures, changes in land use, and impacts of climate change on the timing and quantity of precipitation inputs will require creative solutions for water provision. Development of a variety of water sources, including water quality that is fit-for-purpose, is needed to ensure adequate water supplies while preserving environmental stream flows.

Learnings and Recommendations

Long term sustainable solutions in the Koksilah watershed require both demand management and increases in supply/storage. Water supply options that ranked most highly were those that provided the largest volumes but also require significant financial investment, such as dugouts, water tanks, lakes, and aquifer storage and recovery. Further work is needed to engage the community and assess the feasibility of the best options. Ultimately, more than one supply alternative may be required to address the difference between seasonal supply and demand.

Partners and Linkages

This study was funded and partnered by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development and the Ministry of Agriculture, Food and Fisheries. Cowichan Tribes, in partnership with the provincial government, are leading the Koksilah Watershed Water Sustainability Plan Scoping Project. This and other technical work contribute to an understanding of the state of the watershed and options to maintain environmental flows while preserving adequate supplies for drinking water, irrigation and other purposes.

References

Elucidate Consulting Inc. 2021. Koksilah Water Supply & Options Feasibility Project (Report and Appendices). Prepared for Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Report available from: www.koksilahwater.ca

Project Contacts

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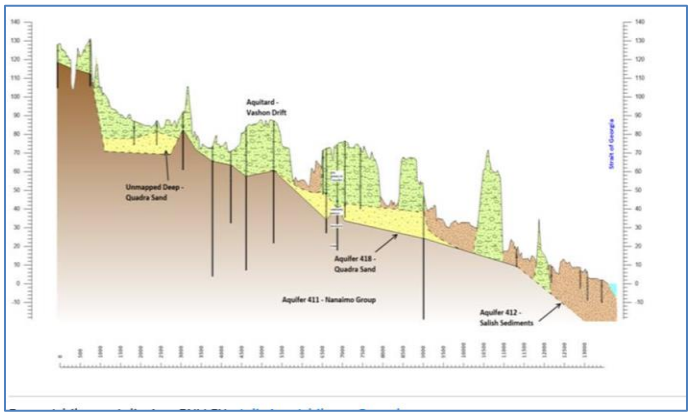
Funding Acknowledgements:
West Coast Region, Authorizations
Agriculture Resource Division

Oyster River and Black Creek Watersheds: Preliminary Desktop Assessment of Hydraulic Connection

Project Description

In this desktop GIS-based study, a conceptual understanding was developed for the main aquifers within the Oyster River and Black Creek watersheds and how and where hydraulic connection between groundwater and surface water likely occurs. This understanding was then applied to delineate preliminary Groundwater Management Areas (GWMAs) within the watersheds to allow any stream depletion impacts from well pumping to be managed in sub-areas related to key stream reaches.



Schematic cross-section of the Oyster Watershed.

Summary of Project Outcome

The delineation of the GWMAs corresponded to those reaches of the streams which were considered to be likely hydraulically connected to adjacent aquifers and were delineated separately for Black Creek and Oyster River to facilitate depletion calculations when evaluating potential impacts to the streams. In the Oyster River area, separate GWMAs were identified for the shallowest aquifers, the deeper Quadra Sands aquifers, and the Nanaimo Group sedimentary bedrock aquifer. Two separate GWMAs were delineated for the Black Creek area, one for the Quadra Sands and one for bedrock. Significant portions of the study area were excluded from GWMA delineation because the confined aquifers in these areas were not considered to be likely hydraulically connected to the streams, with deeper groundwater likely flowing through the watershed.

Relevance

Oyster River and Black Creek, two fully recorded streams located on the east coast of Vancouver Island between the communities of Courtenay and Campbell River support important fisheries and aquatic habitats. Determining the likelihood of hydraulic connection of wells to streams in the Oyster River and Black Creek watersheds is vital to effective management of environmental flows within the stream while maintaining adequate supply for water users.

Learnings and Recommendations

GIS mapping of the water table in the Black Creek watershed indicates hydraulic connection between surface water and groundwater is likely for many of the stream reaches. Well pumping in provincial Aquifer #412 and in a shallow unconsolidated aquifer unit are expected to impact flow in the nearest stream reaches. Confining sediments (till, silt, and clay) underlie nearly all stream reaches at depth, restricting hydraulic connection with the deeper confined Quadra Sands aquifers and Nanaimo Group sedimentary bedrock aquifer. Hydraulic connection appears likely only along three reaches of Oyster River: near the mouth, downstream of the confluence with the Little Oyster River, and upstream of Doyle Road. These open stream reaches are where depletion of streamflow from well pumping can occur. Field work and further enhanced mapping is recommended to improve the preliminary understanding of the nature of hydraulic connection in the study area.

References

Sivak, T. and M. Wei. (Western Water Associates Ltd.). In prep. Oyster River and Black Creek Watersheds: Preliminary Assessment of Hydraulic Connection.

Project Contacts

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Funding Acknowledgements:
Groundwater Science Program,
West Coast Region, Authorizations

Northern Gulf Islands Recharge Potential Mapping: Denman, Hornby and Gabriola Islands

Cross-section generated by Leapfrog showing the nature of the bedrock geology across Denman and Horny Islands.

Project Description

Groundwater management areas (also referred to as groundwater regions) were delineated for Denman, Hornby and Gabriola Islands as part of the Recharge Potential Mapping project. Islands Trust has been working with a consultant to collate groundwater information and spatial data to estimate recharge potential across the Islands Trust Area. Groundwater management areas are based on factors including watersheds boundaries, aquifers, major fault structures, areas of groundwater development (well location, density), and the potential for interconnectivity between groundwater and surface water. Groundwater and surface water are managed as "one water" in B.C., therefore groundwater management areas incorporate the potential and degree of interconnectivity between groundwater and surface water. Accurate delineation of aquifer boundaries, especially for unconsolidated aquifers is critical as their location and geometry influence groundwater flow. The Province contributed funds to the Islands Trust project so it could include the assessment of hydraulic connection between groundwater and surface water for the groundwater management areas on Denman and Hornby Islands and to update the mapping of unconsolidated aquifers on Denman Island, which had not been revised since 2006.

Summary of Project Outcome

Outcomes from the Northern Gulf Islands Recharge Potential Mapping project included: 3D Leapfrog models of Denman, Hornby and Gabriola Islands; updated aquifer mapping on Denman Island; delineated groundwater management areas which indicate degree of hydraulic connection between groundwater and surface water; recharge potential mapping; and estimated monthly and annual recharge rates for the study area.

Relevance

This project is the first phase of the Islands Trust's Groundwater Sustainability Strategy which aims to determine the carrying capacity of the islands' groundwater resources by identifying the water needs of communities and ecosystems, including an estimation of regional water balances. This work will inform future updates of the Province's Water Allocation Plan for Denman and Hornby and enable the inclusion of groundwater in the plan.

Learnings and Recommendations

Aquifer #739 was remapped and now extends further north across Komass Bluffs, along the north-east side of Denman Island. Groundwater management areas were delineated to identify the areas of the aquifers and watersheds that contribute baseflow to hydraulically connected streams year-round.

Partners and Linkages

This work was a partnership between the Province of B.C. and Islands Trust.

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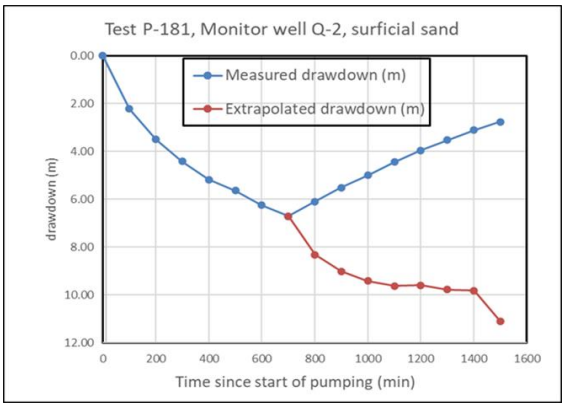
Funding Acknowledgements:
Islands Trust,
Groundwater Science Program,
West Coast Region, Resource Management

Applying the Extended Drawdown Method to Interpret Pumping Tests in British Columbia

Project Description

Pumping tests are often done to estimate well performance, assess the hydraulic properties of an aquifer, and potentially identify flow boundaries. These tests require 24 to 72 hours of monitored constant rate pumping, followed by several hours of recovery measurements. The van der Kamp (1989) extended drawdown method applies the principle of superposition to extrapolate well drawdown measurements beyond the actual period of the test using well recovery data.

This project evaluates the applicability of the van der Kamp method to analyzing pumping tests in the British Columbian context by applying the approch to various aquifer types across the province.



Extended drawdown of a pumping test.

Summary of Project Outcome

The method was found to be generally applicable to BC so long as the principle of superposition applies, and pumping was at a truly constant rate. Where pumping is believed to have dewatered the aquifer (negating the principle of superposition), a downward shift is visible in superimposed drawdown vs. time graphs. An upward spike on these same graphs is attributed to the limited accuracy of drawdown and flow measurements at the beginning of pumping tests. These discrepancies can form a check on assumptions inherent in the interpretation of pumping tests.

Relevance

Pumping tests are regularly conducted in British Columbia in support of licence applications and project feasibility studies. By applying this method, additional information can be drawn from testing results without collecting significant additional data. It also serves as a check on assumptions made during the interpretation of pumping test data, which can be very important when assessing locations where data may be limited.

Learnings and Recommendations

1) Changes in static water level during testing impact the drawdown and extended drawdown calculations. The static water level must have fully recovered from previous step tests before initiating the pumping test. During testing, pumping rates should be measured and recorded both immediately prior to and after changing the pumping rate. Any unavoidable changes in pumping rate need to be accounted for.
2) Recovery measurements should be taken for as long as possible. Guidelines that suggest achieving a minimum 90% recovery should be clarified to mean at least 90% aquifer recovery and exclude any recovery attributed to well loss.
3) Calculated extended drawdown serves as a check on assumptions inherent to pumping test analysis and could be adopted as normal practice by professionals to help with interpretation of pumping tests.
4) The Province of British Columbia could consider making pumping test data available with the associated well record in the GWELLS database.

References

Van der Kamp, G., A. Grunsky, M. Wei. In prep. Applying the Extended Drawdown Method to Interpret Pumping Tests in British Columbia. Water Science Series, Prov. B.C.

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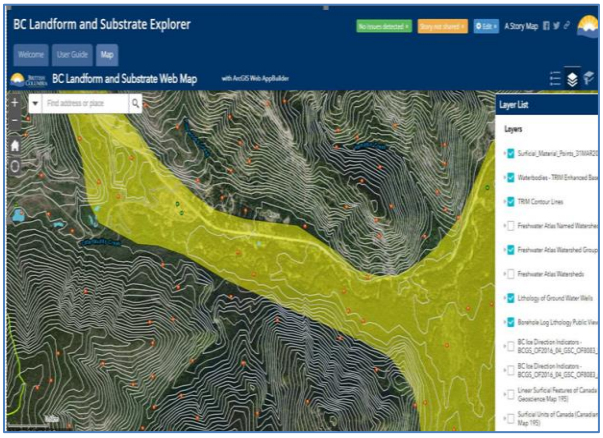
Funding Acknowledgements:
Groundwater Science Program,
North Area Reginal Operations

Surficial Material Mapping Project – 2020/2021 Pilot Project

Project Description

Understanding B.C.'s complex surficial materials is crucial to the understanding of groundwater and surface water resources throughout the province. This study was a two-year pilot study. The overall goal for year 2 (2020/2021) was to produce a set of predictive maps for the entire province with spatially accurate areas that fill the scale gap between physiographic regions and inventory polygons for soils, surficial geology, aquifers, and terrain mapping. Mid-scale mapping of the substrate, landforms and inventory is required to support resource allocation and decision making.

A parallel initiative of this project was to compile existing mapping inventory layers to inform the expert interpreted training points needed for machine learning and to create a map application summarizing all spatial layers related to surficial material.



Screenshot of BC Landform and Substrate Explorer.

Summary of Project Outcome

As part of this project a broad classification scheme for surficial materials was developed in order to predict surficial material type based on expert interpreted points and a machine learning mapping approach. The results of this work included:

- The development of criteria, classes, and a template for data collection for machine learning training points;
- Testing and feedback from applying the classification of surficial materials;
- The development of a method for classifying surficial materials and Broad Landform Classes;
- The identification of training points used by machine learning to model mid-scale mapping of surficial material in B.C.; and,
- The development of a draft map application for accessing surficial material information in B.C.

Relevance

The overall intent of this project was to improve and expand the availability of surficial mapping across BC to support decision making related to water resource management. The reconnaissance mapping layers developed as part of this pilot project can be used to prioritize areas across the province needing additional detailed mapping.

Learnings and Recommendations

The project team is excited to move forward based on the results of this pilot project. Recommendations for future work include:

- running the model with additional training points from different regions in the province;
- field validation of model outputs; and,
- evaluation of the model outputs by regional experts.

Further research on optimizing the location and distribution of remotely sensed training points and further consideration on the broad classifications used for mapping should be undertaken. In addition, the results of this project should be shared with staff, professionals, and academic partners to seek feedback and refine the results.

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Funding Acknowledgements:
Groundwater Science Program

4. ACKNOWLEDGEMENTS

The Province would like to acknowledge all the partners that have supported and contributed to advancing these groundwater projects over the last year. These partnerships have spanned ministries, academic institutions, municipal governments, federal agencies, First Nations, and stewardship groups including:

- Ministry of Environment and Climate Change Strategy - Water Protection and Sustainability and Knowledge Management Branches
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Ministry of Transportation and Infrastructure
- Ministry of Agriculture, Food and Fisheries
- Ministry of Energy, Mines and Low Carbon Innovation
- B.C. River Forecast Centre
- The Islands Trust
- Geological Survey of Canada
- Geoscience BC
- BC Oil and Gas Commission
- BC Oil and Gas Research and Innovation Society
- Fisheries and Oceans Canada
- Okanagan Basin Water Board
- Bowen Island Municipality
- The District of Sechelt
- The Town of Kitimat
- The Township of Langley
- The District of Houston
- The Okanagan Nation Alliance
- Cowichan Tribes
- The Wet'suwet'en First Nation
- The Office of the Wet'suwet'en
- Canadian Mountain Network
- University of British Columbia
- University of Calgary
- University of Victoria
- Simon Fraser University
- The Upper Bulkley River Streamkeepers
- The Greater Vancouver Zoo
- A Rocha