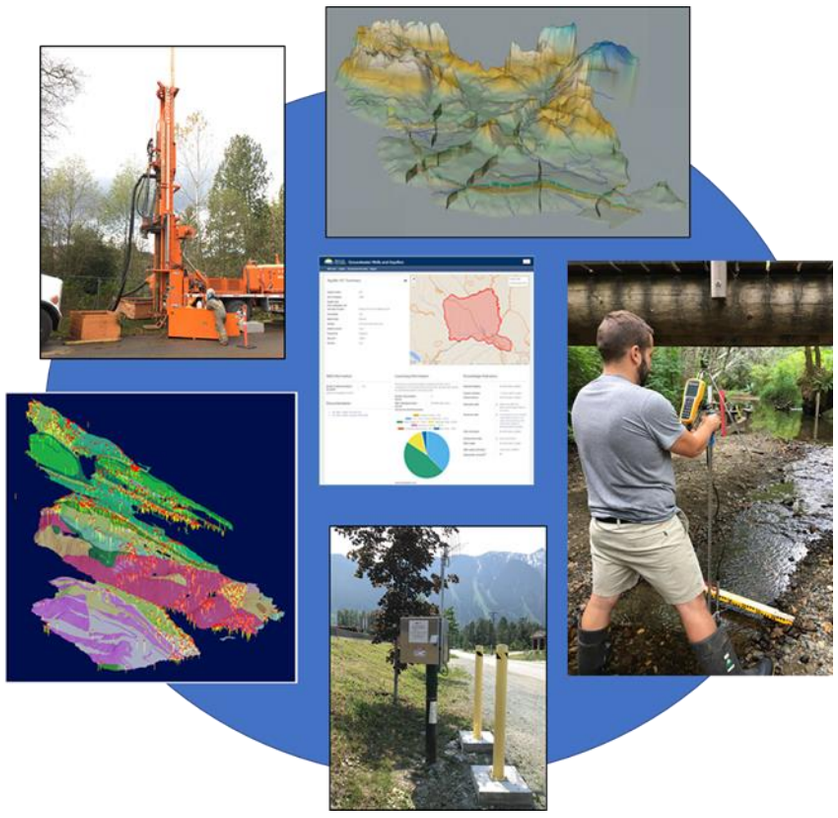
WATER SCIENCE SERIES

Compendium of Provincial Groundwater Science and Monitoring Projects: 2018-19

Julie-Ann Ishikawa (editor)



November 2019

BRITISH COLUMBIA

No. 2019-08

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: 978-0-7726-7288-9

Citation:
Ishikawa J. (editor), 2019. Compendium of Provincial Groundwater Science and Monitoring Projects: 2018-19. Water Science Series, WSS2019-08. Prov. B.C., Victoria B.C.

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Cover Images:
Middle image, followed by upper left photo then clockwise
1) Screen shot of GWELLS Aquifer Summary page for Aquifer #451
2) Topographic visualization of the Shawnigan Lake Area, B.C.
3) View of dual rotary drill rig at Observation Well 479 in Maple Ridge, BC. Photo credit: Bryan Jackson
4) Measuring Streamflow, Mill Bay, BC. Photo credit: Julie-Ann Ishikawa
5) View of Observation Well 476 in Pemberton., BC. Photo credit: Bryan Jackson
6) 3-D visualization of the geology and wells on Salt Spring Island, B.C.

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, Jun Yin, Pat Lapcevic, and Dave Wilford of the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development; Tarik Dessouki, 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 Petroleum Resources. 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. Also, thank you to Klaus Rathfelder and Robin Pike for review and formatting assistance. 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 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 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 Intended Outcome (WIO) research funding, administered by FLNRORD

In some cases, the province also partners with other agencies such as Geoscience BC, 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 2018-19 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 Ministry Strategic Roadmap. 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 use 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 resource of this screening level, groundwater resource information throughout 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)and Agriculture (AGRI).

As of August 2019, 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 initiated. 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 2018/19, aquifers were mapped or revised in several areas of the province including Langley, the Northern Okanagan, the Sunshine Coast, Haida Gwaii, Ucluelet, Salt Spring Island, Hope and Eastern Vancouver Island. 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.

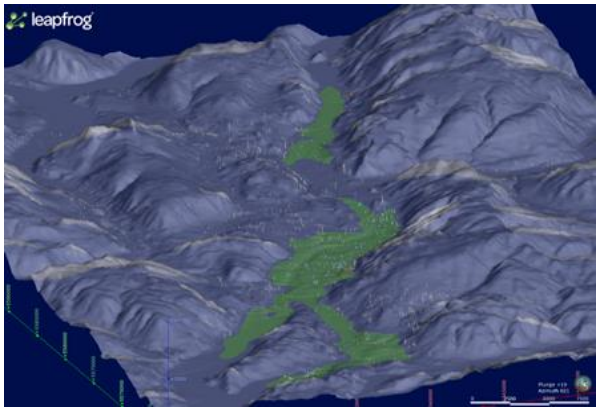
Spatial information about mapped aquifers can be accessed using the following tools, supporting a range of user needs:

- 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 – view and analyze mapped aquifers along with hundreds of other data layers compiled from across the BC Government and other public-sector agencies.

North Okanagan Aquifer Mapping & Geologic Modelling Phase III: Okanagan Valley Update

Project Description

Phase III of the North Okanagan project included refinement to the hydrostratigraphic model of the Okanagan Valley aquifers building on the initial model developed in Phase I (BC Water Science Series document WSS2017-03). This update focused on improving the resolution of aquifers in the Okanagan Valley (Vernon to Mara Lake).



Hydrostratigraphic Model View.

Summary of Project Outcome

A more precise interpretation of the extent and thickness of the upper confined aquifers, and aquifer subdivisions was developed. The deep confined aquifer 1155 is now mapped in the West Vernon area. Three subdivisions were assigned to the deep confined aquifer (1155, 1226 and 1227) and two subdivisions were assigned to the shallow confined aquifer (1153 and 1225) based on an updated bedrock surface and re-characterizing of the borehole stratigraphy.

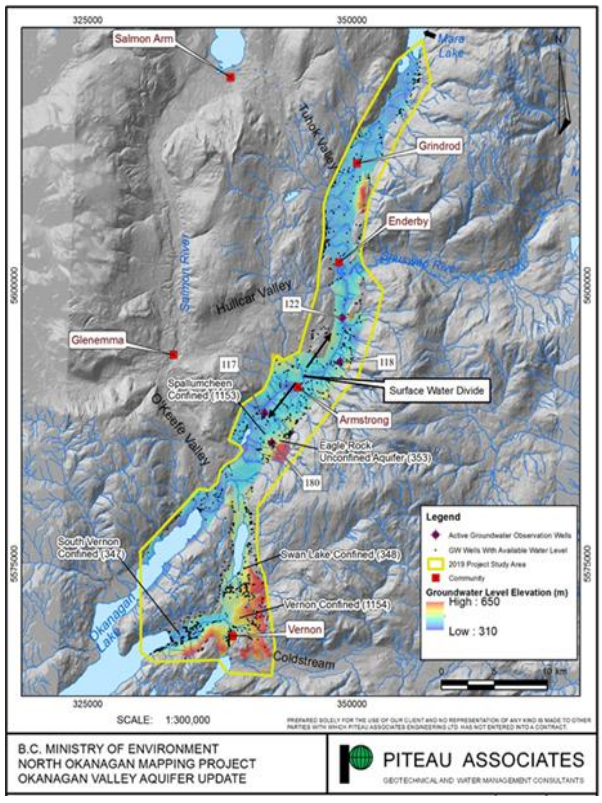
The updated Leapfrog™ geological model presented in this report includes available groundwater well data, geophysical interpretations and water level information

Relevance

The updated model and mapping provide a framework for assessing aquifer utilization, water resource planning and groundwater exploration.

Learnings & Recommendations

Recommendations for future studies to enhance the hydrogeologic understanding of the Northern Okanagan include field studies to characterize the seasonal variations in the flow regime by measuring water levels and geochemistry, installation of additional monitoring wells and development of a numerical groundwater flow model.



Groundwater Elevation Map.

References

Hassan, S., M. Stewart, and R. Allard. 2019. North Okanagan Aquifer Mapping and Geologic Modelling Phase III: Okanagan Valley Aquifer Update. Water Science Series, WSS2019-03. Prov. BC, Victoria BC

Project Contacts

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Dave Thomson | e-mail address: David.Thomson@gov.bc.ca | Phone number: 250-260-4641

Acknowledgements:
Groundwater Science Program

Detailed Aquifer Mapping Study: Shawnigan Lake Area, Vancouver Island, B.C.

Project Description

This project included an assessment of the hydrostratigraphy of the Shawnigan Lake area and surrounding communities (Mill Bay, Cobble Hill). This area is a priority for aquifer characterization based on known concerns with water availability, increasing demand for water related to expanding development, and local dependency on groundwater. The study improves the Province's understanding of the physical hydrogeology and provides a basis for further studies of water quantity and quality.

Study area.

Summary of Project Outcome

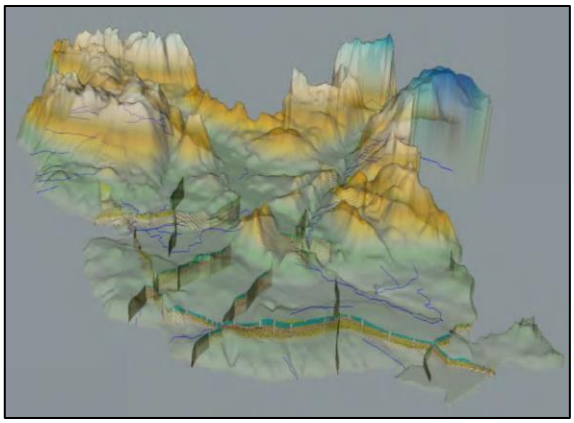
A conceptual site model of the hydrogeology of the area was created including evaluation of the geology, topography and surface water drainage, hydrostratigraphy of overburden and bedrock units, groundwater flow, and recharge and discharge zones.

Relevance

An improved understanding of the hydrogeology of the area supports science-based decision making for sustainable water management and implementation of the Water Sustainability Act. In particular, the hydrostratigraphic frameworks developed can inform groundwater licensing and assist in future assessment of hydraulic connections with surface waters; aquifer hydraulic properties to inform groundwater development potential; local or regional groundwater budget analyses; and, development of numerical groundwater models.

Recommendations & Next Steps

Potential next steps towards further hydrogeological characterization within the study area include: improving the density of groundwater level monitoring and establishing groundwater quality monitoring sites to understand seasonal and long term trends; mapping of seeps and springs to improve the understanding of groundwater discharge zones; identification of probable groundwater recharge and discharge zones along the Koksilah River and Patrolas Creek through geochemical studies and additional hydrometric monitoring; and, development of a numerical groundwater model to assess future water availability through simulation of future growth and potential changes to the hydrogeologic cycle as a result of climate change.



Visualization of topography and cross sections.

References

Hammond, Z.M., A.C. Hinnell, J.J. Clague. 2019. Detailed Aquifer Mapping Study: Shawnigan Lake Area, Vancouver Island, B.C. Water Science Series, WSS2019-02. Prov. BC, Victoria, BC.

Project Contacts

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Acknowledgements:
Groundwater Science Program

2. GROUNDWATER MONITORING

The Provincial Groundwater Observation Well Network (PGOWN) monitors groundwater conditions in aquifers across British Columbia through a series of 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.

The objectives of the network include:

- understanding local and regional hydrogeological processes and characteristics;
- supporting groundwater licensing and sustainable resource management;
- flood forecasting;
- drought monitoring;
- climate change monitoring;
- cumulative effects monitoring; and,
- minimizing groundwater conflicts between users.

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

- *Map tool - Groundwater Level Data Interactive Map;*
- *Real-time water level data - Aquarius web portal; and,*
- *Water quality 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 August 13, 2019, there are a total of 213 active PGOWN wells in the network. With the implementation of licensing of groundwater users in 2016, understanding the availability of provincial groundwater resources has been a priority. During the 2018-19 fiscal year, a total of 15 new observation wells were either drilled or adopted to become part of the PGOWN. Ten new monitoring wells were drilled in key areas and four existing wells were adopted. Summary pages for the new PGOWN wells are available in the following section.

Observation Wells, Koksilah River Watershed, Cowichan Station

Project Description

The Provincial Groundwater Observation Well Network (PGOWN) monitors groundwater conditions in aquifers across British Columbia. This project involved site selection, drilling, pumping tests, sampling for water quality and the instrumentation of two new monitoring wells. The sites in Cowichan Station were selected for their proximity to Koksilah River and to groundwater production wells. The first phase of this project included the two new monitoring wells described below. A second phase of the project is planned for 2019-20 to drill a third shallow well in the surficial aquifer and a bedrock aquifer well in close proximity to Koksilah River. Area residents rely on the Koksilah River and groundwater from both aquifers for domestic and agricultural purposes.

Installation of well screen at Uphill Road.
Photo: G. Henderson

Summary of Project Outcome

Observation wells OW488 and OW489 were instrumented with water level monitoring equipment in March 2019. Groundwater levels collected hourly are publicly available on the provincial real-time water data website (Province of British Columbia, 2019a). Water chemistry samples were collected from both wells during a pumping test and the results are publicly available online through the Environmental Monitoring System (EMS) web reporting tool (Province of British Columbia, 2019b).

Relevance

Koksilah River watershed has been identified as a watershed to watch for drought conditions and conservation measures. This project will result in long-term water level data from aquifers #197 and #198 to support authorization and management of groundwater, particularly during times of water scarcity. The project will also provide the opportunity to better understand hydraulic connectivity, aquifer response to curtailment, and how water moves through layered aquifer systems.

Learnings & Recommendations

Water levels in OW488 on Koksilah Rd ranged from 14.3-14.7 m below ground surface between March and May 2019. Water levels in OW489 on Uphill Rd ranged from 4.8-6.2 m below ground surface in the same period. Pumping interference can be seen in OW489 on Uphill Rd.

Partners and Linkages

Staff from Cowichan Station Area Association were consulted to determine Koksilah Road drilling locations and to observe water level changes from their well during the OW488 pumping test. The Ministry of Transportation and Infrastructure provided the permits to install monitoring wells in the road right-of-way.

References

Province of British Columbia, 2019a. *Real-time water data:* http://aqrt.nrs.gov.bc.ca. [Accessed May 2019].
Province of British Columbia, 2019b. *EMS Web Reporting*: https://a100.gov.bc.ca/pub/ems/indexAction.do [Accessed August 2018].

Project Contacts

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Acknowledgements:
Strategic Water and Air Monitoring Planning Process
FLNRORD WSA Special Projects Funding

Drilling of New PGOWN Well OW481, Fort Nelson, B.C.

Project Description

A site was selected to monitor water levels and water quality in aquifer 1041, located adjacent to the Fort Nelson River south of Fort Nelson, B.C. Aquifer 1041 is a shallow unconfined aquifer consisting of post-glacial fluvial sand and gravel, likely deposited by the modern Fort Nelson River. This is one of the major aquifer types identified in a recent report supporting the implementation of the Mackenzie River Basin Bilateral Water Management Agreement. This project involved site selection, drilling, a pumping test, and sampling for water quality.

Casing for OW481, Fort Nelson, B.C.
Photo: J. Yin

Summary of Project Outcome

Observation well 481 was installed to a total depth of 13.7 m below ground surface on October 2, 2018. Satellite telemetry equipment has not been installed due to an ongoing land use agreement between the BC and federal governments on behalf of Fort Nelson First Nation. A 24-hour pumping test was conducted from November 19 to 20, 2018. Due to the high yield of the well and the limited pumping capacity of the 4-inch pump, the drawdown was too small to warrant any pumping test analysis. Water chemistry samples were collected before and after the pumping test. The results of the analysis identified a small amount of methane in the groundwater samples. The well water level is currently monitored using a Solinst Levelogger.

Relevance

The project will enable the collection of long-term water level and water chemistry in the shallow unconfined aquifer in the area. The data will be used to support licencing and management decisions, as well as provide insight into the impact of flood and drought conditions on the aquifer. In the Fort Nelson area, groundwater quality concerns related to the development of unconventional gas production have been raised by the Fort Nelson First Nation and the public. This well can also serve the purpose of monitoring potential industrial impacts to the groundwater.

Learnings & Recommendations

Small amounts of dissolved methane were detected in the water samples. It is recommended that further studies be conducted to identify the source of the dissolved methane.

Partners and Linkages

Fort Nelson First Nation participated in the site selection, provided the site access, and provide ongoing support in the operation of OW481.

References

Levson, V.M., H. Blyth, T. Johnsen and M. Fournier. 2018. Liard and Petitot Sub Basins Transboundary Groundwater Resources Assessment. Water Science Series, WSS2018-01. Prov. BC, Victoria B.C.

Project Contacts

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Acknowledgements:
FLNRORD Water Intended Outcome
Geoscience BC

Drilling of New PGOWN Well OW482, Fort Nelson, B.C.

Project Description

A site was selected to monitor water levels and water quality in aquifer 1040, located adjacent to the Muskwa River south of Fort Nelson, BC. Aquifer 1040 is a deep paleovalley aquifer confined by thick low permeability clays, silty clays and tills. The aquifer is likely the predominant drinking water supply in the area where water quality is potable or treatable. This is one of the major aquifer types identified in a recent report in supporting the implementation of the Mackenzie River Basin Bilateral Water Management Agreement. This project involved site selection, drilling, and sampling for water quality.

Drill rig setting up to drill OW482, Fort Nelson BC.
Photo: J. Yin.

Summary of Project Outcome

Observation well 482 was installed to a total depth of 116.6 m below ground surface from October 3 to 6, 2018. Due to the thick and hard confining layer, the casing was left intact and a well screen was not installed. Because the well has no screen, groundwater moves into the well vertically through the 6-inch opening at the bottom of the well. A pumping test, which assumes horizontal flow into the well, was therefore not conducted. Full satellite telemetry equipment was installed on June 5, 2019 to monitor water levels in the well. Prior to the installation of the telemetry equipment, the water level was being recorded by a Solinst Levelogger. A water chemistry sample was collected on June 5, 2019.

Relevance

The project will enable the collection of long-term water level and water chemistry in a paleovalley aquifer in the area. The data will be used to support licencing and management decisions, as well as provide insight into the impact of flood and drought conditions on the aquifer. In the Fort Nelson area, groundwater quality concerns related to the development of unconventional gas production have been raised by the Fort Nelson First Nation and the public. This well can also serve the purpose of monitoring potential industrial impact to the groundwater.

Learnings & Recommendations

The dissolved methane concentration in the collected sample on June 5, 2019 was 23.6 mg/L. It is recommended that further studies be conducted to identify the source of the dissolved methane.

Partners and Linkages

Fort Nelson First Nation is supporting the operation of OW482.

References

Levson, V.M., H. Blyth, T. Johnsen and M. Fournier. 2018. Liard and Petitot Sub Basins Transboundary Groundwater Resources Assessment. Water Science Series, WSS2018-01. Prov. BC, Victoria B.C.

Project Contacts

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Acknowledgements:
FLNRORD -Water Intended Outcome
Geoscience BC

Drilling of New PGOWN Wells OW475 and OW476 – Pemberton, B.C.

Project Description

Two monitoring locations were selected in Pemberton, BC, to monitor groundwater levels in aquifer 326; an unconfined sand and gravel aquifer.

The intention of these wells was to provide locations for the long-term monitoring of groundwater levels and groundwater chemistry within the aquifer. This project involved researching and selecting sites, drilling the monitoring wells and adding telemetry and monitoring instrumentation to the wells. With the data collected from these observation wells we can better understand the state of aquifer 326 and properly inform decision makers in the Water Authorizations group.

View of OW476 in Pemberton.
Photo: B. Jackson.

Summary of Project Outcome

Observation wells 475 and 476 were drilled to total depths of 24.4 and 36.6 metres below ground surface (m bgs), respectively, in August 2018. OW475 was screened at a depth of 21.6 – 24.7 m bgs while OW476 was screened from 33.5 – 36.6 m bgs. Full satellite telemetry was added to both of these wells to automate collection of water level measurements. All groundwater level data will be publicly available through the provincial Aquarius time-series database and the provincial Groundwater Level Data Interactive Map. Water samples were also collected for laboratory analyses, and the results are publicly available through the Environmental Monitoring System (EMS).

Relevance

Aquifer #326 was identified as a high priority aquifer for monitoring due to the dependence of the local community on this aquifer, primarily for domestic, irrigation and water supply system wells. The intent of monitoring is to collect long-term water level data. The data will be used to support implementation of the *Water Sustainability Act* (*WSA*) through licensing and to inform management decisions that promote protection and sustainability of the resource.

Learnings & Recommendations

Water levels in OW475 ranged from 1.30 to 2.63 m bgs between August 2019 and June 2019 while water levels in OW476 ranged from 1.21 to 2.49 m bgs in the same time period.

Partners and Linkages

The Village of Pemberton provided drilling locations on park land and a road right-of-way for the installation of these observation wells.

Project Contacts

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Michele Lepitre | e-mail address: Michele.Lepitre@gov.bc.ca | Phone number: 778-572-2168

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

Drilling of New PGOWN Well OW478– Whistler, B.C.

Project Description

A monitoring location was selected in Whistler, B.C., to monitor groundwater levels in aquifer 387, an unconfined sand and gravel aquifer.

The intention of this well was to provide a location for the long-term monitoring of groundwater levels and groundwater chemistry within the aquifer. This project involved researching and selecting sites, drilling the monitoring well and adding telemetry and monitoring instrumentation to the well. With the data collected from this observation well we can better understand the state of aquifer 387 and properly inform decision makers in the Water Authorizations group.

View of OW478 in Whistler.
Photo: B. Jackson

Summary of Project Outcome

Observation well 478 was drilled to a total depth of 20.1 metres below ground surface (m bgs) on August 30th, 2018. The well screen was installed at a depth of 12.2 – 13.7 m bgs. Full satellite telemetry was added to this well to automate collection of water level measurements. All groundwater level data will be publicly available through the provincial Aquarius time-series database and the provincial Groundwater Level Data Interactive Map. Water samples were also collected for laboratory analyses, and the results are publicly available through the Environmental Monitoring System (EMS).

Relevance

Aquifer 387 was identified as a high priority aquifer for monitoring due to the dependence of the local community on this aquifer, primarily for water supply system wells. The intent of monitoring is to collect long-term water level data. The data will be used to support implementation of the *Water Sustainability Act* (*WSA*) through licensing and to inform management decisions that promote protection and sustainability of the resource.

Learnings & Recommendations

Water levels in OW478 ranged from 5.89 to 6.59 m bgs between August 2018 and June 2019.

Partners and Linkages

The Resort Municipality of Whistler provided a location on a road right-of-way for the installation of this observation well.

Project Contacts

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

Drilling of New PGOWN Well OW479 – Maple Ridge, B.C.

Project Description

A monitoring location was selected to monitor water levels in aquifer 19 (Grant Hill aquifer), which is a partially confined bedrock aquifer located in Maple Ridge, B.C.

The intention of this well was to provide a location for the long-term monitoring of groundwater levels and groundwater chemistry within the aquifer. This project involved researching and selecting sites, drilling the monitoring well and adding telemetry and monitoring instrumentation to the well. With the data collected from this observation well, we can better understand the state of aquifer 19 and properly inform decision makers in the Water Authorizations group.

View of dual rotary drill rig at OW479 in Maple Ridge.
Photo: B. Jackson

Summary of Project Outcome

Observation well 479 was drilled to a total depth of 121.0 metres below ground surface (m bgs) on November 6th to November 8th, 2018. The well was cased to 29.2 m bgs, with the remainder left as an open-hole bedrock well. Full satellite telemetry will be added to this well. All groundwater level data will be publicly available through the provincial Aquarius time-series database and the provincial Groundwater Level Data Interactive Map. Water samples were also collected for laboratory analyses, and the results are publicly available through the Environmental Monitoring System (EMS).

Relevance

Aquifer 19 was identified as a high priority aquifer for monitoring due to the dependence of the local community on this aquifer, primarily for domestic and agricultural needs, as well as ongoing complaints from this area regarding potentially falling groundwater levels. The intent of monitoring is to collect long-term water level data. The data will be used to support implementation of the *Water Sustainability Act* (*WSA)* through licensing and to inform management decisions that promote protection and sustainability of the resource.

Learnings & Recommendations

Water levels in OW479 ranged from 13.21 to 14.41 m bgs between November 2018 and April 2019 (telemetry has not yet been added as of date of publication).

Partners and Linkages

The District of Maple Ridge provided a location on a road right-of-way for the installation of this observation well.

Project Contacts

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Michele Lepitre | e-mail address: Michele.Lepitre@gov.bc.ca | Phone number: 778-572-2168

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

Drilling of New PGOWN Wells – Dewdney and Deroche, B.C.

Project Description

Two monitoring locations were selected in Dewdney and Deroche, B.C., to monitor groundwater levels in aquifer 12; an unconfined sand and gravel aquifer.

The intention of these wells was to provide locations for the long-term monitoring of groundwater levels and groundwater chemistry within the aquifer. This project involved researching and selecting sites, drilling the monitoring wells and adding telemetry and monitoring instrumentation to the wells. With the data collected from these observation wells, we can better understand the state of aquifer 12 and properly inform decision makers in the Water Authorizations group.

View of sonic drill rig at Observation Well 485 in Dewdney.
Photo: B. Jackson

Summary of Project Outcome

Observation wells 485 and 486 were both drilled to a total depth of 24.4 metres below ground surface (m bgs) in January 2019. OW485 was screened at a depth of 20.0 – 21.5 m bgs while OW486 was screened from 18.0 – 21.0 m bgs. Both wells were equipped with full satelite telemetry. All groundwater level data will be publicly available through the provincial Aquarius time-series database and the provincial Groundwater Level Data Interactive Map. Water samples were also collected for laboratory analyses, and the results are publicly available online through the Environmental Monitoring System (EMS). In addition, a clustered well was added next to OW485, installed to a shallower depth of 7.6m bgs to allow for a more accurate understanding of the shallow groundwater quality. This well (well Tag Number 116227) will not be part of the PGOWN).

Relevance

Aquifer 12 was identified as a high priority aquifer for monitoring due to the dependence of the local community on this aquifer, primarily for domestic, irrigation and water supply system wells. The intent of monitoring is to collect long-term water level data. The data will be used to support implementation of the *Water Sustainability Act* (*WSA*) through licensing and to inform management decisions that promote protection and sustainability of the resource.

Learnings & Recommendations

Water levels in OW486 ranged from 2.18 to 2.79 m bgs between January and April 2019. Data from OW485 is not yet available. Telemetry has not yet been added to either of these sites.

Partners and Linkages

The Ministry of Transportation and Infrastructure provided drilling locations on road right-of-ways for the installation of these observation wells.

Project Contacts

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Michele Lepitre | e-mail address: Michele.Lepitre@gov.bc.ca | Phone number: 778-572-2168

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

Four New PGOWN Wells Acquired by Adoption of Existing Wells – South Coast Region, B.C.

Project Description

This project involved collaborating with partners to identify previously drilled monitoring wells that could be incorporated into the Provincial Groundwater Observation Well Network (PGOWN); evaluating the wells; making third party agreements for the selected wells; water quality sampling; and, adding telemetry and monitoring instrumentation to the selected wells, where feasible.

The intention of this project was to provide locations for the long-term monitoring of groundwater levels and groundwater chemistry within the selected aquifers. With such data we can better understand the state of the aquifers and properly inform decision makers in the Water Authorizations group.

View of OW483, east of Squamish.
Photo: B. Jackson

Summary of Project Outcome

The following previously drilled wells were adopted into the PGOWN as a result of this project in 2018-2019: OW474 (in aquifer 25, in Miracle Valley); OW477 (in aquifer 395, in Whistler); OW480 (in aquifer 548, on Keats Island); and, OW483 (in aquifer 397, east of Squamish). OW477 and OW483 had telemetry installed while the other two sites were not suitable for telemetry. Groundwater level data will be manually downloaded periodically from the non-telemetry wells. All groundwater level data will be publicly available through the provincial Aquarius time-series database and the provincial Groundwater Level Data Interactive Map. Water samples were collected from all the wells and submitted for baseline laboratory analyses, and the results are also publicly available online.

Relevance

The intent of adopting these monitoring wells is 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* (*WSA*) through licensing and to inform management decisions that promote protection and sustainability of the resource.

Learnings & Recommendations

Groundwater levels in OW474 in Miracle Valley ranged from 23.58 to 26.04 metres below ground surface (m bgs) between July 2018 to April 2019 (no telemetry). Groundwater levels in OW477 in Whistler ranged from 4.38 to 8.14 m bgs between July 2018 to June 2019. Groundwater levels in OW480 on Keats Island ranged from 2.35 to 11.25 m bgs between June 2018 to February 2019 (no telemetry). Groundwater levels in OW483 in Squamish ranged from 86.58 to 86.96 m bgs between January to June 2019.

Partners and Linkages

Partners for this project included: the District of Mission; the District of Squamish; the Resort Municipality of Whistler; and, the Convention of Baptist Churches of British Columbia.

Project Contacts

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Michele Lepitre | e-mail address: Michele.Lepitre@gov.bc.ca | Phone number: 778-572-2168

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

3. GROUNDWATER RESEARCH AND SCIENCE PROJECTS

The projects in the following section highlight the wide variety of groundwater science and research projects undertaken by the Province in 2018-19. These projects demonstrate the technical ability and expertise of provincial groundwater staff and demonstrate the challenges and complexities of assessing and sustainably managing the groundwater resources of the province.

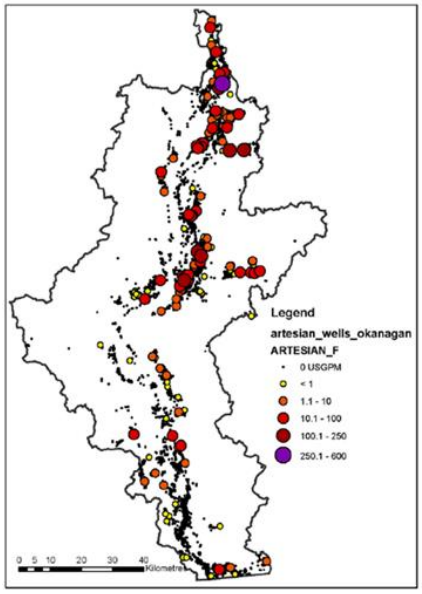
The interaction between surface water and groundwater (SW-GW) is poorly understood and seems to emerge as an overarching theme in many of the projects undertaken in 2018-19. Under the *Water Sustainability Act*, water is to be managed as one interconnected resource and several studies included in this section seek to understand and characterize the interaction between aquifers and hydraulically connected streams. This science is essential for assessing the implications of groundwater pumping on the Environmental Flow Needs (EFN) of connected streams. The range and type of studies undertaken to understand these interactions have included: on-going field studies near a sensitive stream in the Lower Mainland; a hydraulic connectivity study in the Koksilah watershed; projects in Mill Bay, Valemount and the upper Bulkley watershed to assess local SW-GW interactions; and, a desktop analysis comparing the results of analytical models with numerical models in predicting streamflow depletion and lag time. Other projects over the past year have included: mapping of artesian wells to mitigate risk; delineation of spring source areas near Chetwynd; a water budget assessment on Salt Spring Island; two aquifer characterizations projects (Terrace and north-east BC); and, further development of automated tools to analyse and share existing groundwater data.

Many of the following projects are large in scope and are being conducted over multiple years. In cases where the projects are ongoing, an update summary has been provided to report out on progress and any results or learnings achieved to date.

Mapping and Mitigating Risk of Flowing Artesian Wells: Okanagan Basin & Lower Fraser Valley

Project Description

The main goal of this project is to develop a more comprehensive understanding of the factors controlling where flowing artesian conditions occur and where there is elevated risk when drilling into such conditions. This project also examines how current policies and regulatory requirements regarding flowing artesian wells might be improved.



Map showing flowing artesian wells in the Okanagan Basin.

Summary of Project Outcome

This multi-year project is being implemented in phases. Phase 1 (completed) involved carrying out a preliminary geostatistical analysis on the occurrence of flowing artesian wells in the Okanagan Basin and Lower Fraser Valley. Phase 2 (in progress) involves developing an understanding of why and where flowing artesian wells occur. This involves developing conceptual hydrogeological models based on hydrogeological information (e.g., geological cross-sections), groundwater flow modeling, and local knowledge (e.g. well drillers) on the occurrence of flowing artesian wells in mountainous (Okanagan) and low relief (Lower Fraser Valley) settings. Phase 3 will involve mapping the likelihood of encountering flowing artesian wells in each study area, and Phase 4 will focus on developing an information package.

Relevance

Flowing artesian wells are a known problem in many regions of B.C., particularly in the Lower Fraser Valley and the Okanagan. Allowed to flow uncontrolled, these wells can eventually reduce the long-term sustainability of the aquifer, leading to reduced water yield for surrounding wells and springs, and reduced natural groundwater discharge to streams which can impact aquatic habitat. Moreover, flowing artesian wells may significantly increase the risk of land subsidence or formation of sinkholes as evidenced by the recent flowing artesian well in the City of Vancouver. The results may be extensive property damage, loss of property value, and exorbitant costs to the property owner, as well as limiting the future use of the land. Controlling artesian flow is a requirement of the *Water Sustainability Act* (S. 52 and 53).

Learnings & Recommendations

This project will yield insight into the hydrogeological factors that control the occurrence of flowing artesian wells. The maps produced for the Okanagan Basin and Lower Fraser Valley will show areas of high and moderate risk for flowing artesian conditions. These maps can be used for identifying areas that should be more closely examined or monitored, as well as for issuing Flowing Artesian Conditions Advisories. The project is intended to support regulatory requirements for controlling artesian flow by providing better understanding of where such conditions occur, and how B.C. and other jurisdictions are managing the problem through policy and regulation.

Partners and Linkages

The project is being carried out by Diana Allen (Professor) and Brynje Johnson (M.Sc. student) in the Department of Earth Sciences at Simon Fraser University, and Mike Wei (Hydrogeologist) at Hydro Geo Logic.

Project Contacts

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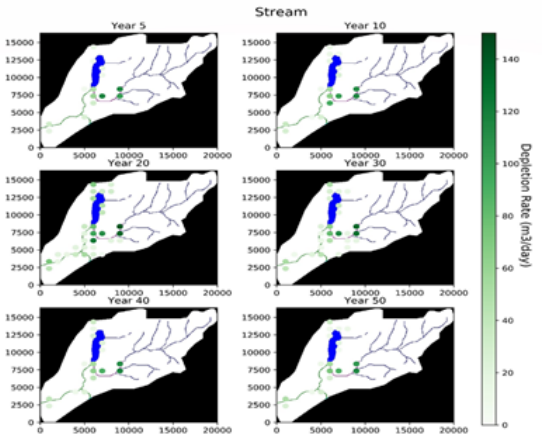
Acknowledgements:
Groundwater Science Program

Analytical Models and Lag Times for Groundwater Pumping Impacts on EFN

Project Description

Groundwater extraction leads to complex hydrologic and ecologic changes that depend on local hydrology, geology and topography. One of the most significant changes can be stream flow depletion and the resulting impacts on environmental flow needs (EFN). Critical information needed to make sustainable water management decisions is the timing and severity of these impacts. Simplified, analytical models have been used to predict stream depletion. The purpose of this project is to assess the validity and accuracy of these models in predicting stream flow across the varying landscapes and climatic regions of BC by comparing them to existing numerical models to; 1) evaluate the applicability and limits of analytical models for estimating groundwater pumping impacts on EFN in order to identify which analytical models are appropriate tools in the various aquifer types of BC; and 2) to test metrics for estimating the lag time between groundwater pumping and streamflow depletion.



Predicted stream depletion over time.

Summary of Project Outcome

During the initial phase of this multi-year project, detailed analysis and comparisons between numerical and analytical models were completed for two domains: BX Creek in the Okanagan region (dry, snowy domain) and the Bevan Wellfield in the South Coast region (rainy domain). Based on learnings from these initial two domains, a work flow has been established for modifying existing numerical models and comparing the output with results from analytical models.

Relevance

The purpose of this project is to determine where and under what conditions analytical models can be used for water management decisions, and how these models can be implemented to support management decisions related to groundwater pumping and environmental flow needs.

Learnings & Recommendations

An important lesson learned during the first phase of this project is the complexity of using and adapting existing numerical models to simulate stream flow depletion. Although numerical models are more detailed with regards to site specific characteristic, initial model design has a large impact on the ability to simulate reasonable streamflow depletion estimates.

Partners and Linkages

The University on Victoria - the research work is being conducted by Tom Gleeson (professor), Sam Zipper (post doc), and Qiang Li (post doc) in the civil engineering department at the University of Victoria

References

Zipper, S.C., T. Dallemagne, T. Gleeson, T. Boerman, & A. Hartmann. 2018. Groundwater pumping impacts on real stream networks: testing the performance of simple management tools. Water Resources Research. Vol 54, issue 8. 5471-5486.

Project Contacts

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Acknowledgements:
Groundwater Science Program

Assessment of Aquifer-Stream Connectivity Related to Groundwater Abstraction in the Lower Fraser Valley (Phase 2)

Project Description

Pumping groundwater from a well, beside a stream can result in depletion of streamflow. Evaluation of hydraulic connectivity is required for water licensing decisions in BC under the *Water Sustainability Act* (*WSA*).

The study was carried out on Bertrand creek at Otter Park in Langley, B.C. Bertrand creek, a creek with critical habitat for Nooksack Dace and Salish Sucker, flows over and is hydraulically connected to the Abbotsford-Sumas aquifer in the park. The purpose of the study was to characterize the aquifer and streambed sediment properties, and to evaluate potential streamflow depletion resulting from groundwater pumping.

Instrumentation and Pumping Test at Otter Park
Photos: M. Lepitre.

Summary of Project Outcome

The aquifer and streambed sediment properties were characterized using various methods including: grain size analysis; slug and bail tests; and, a 30-hour constant rate pumping test. Results indicated that streambed sediments have a hydraulic conductivity of approximately one order of magnitude lower than the aquifer sediments. Hydraulic connectivity between the aquifer and the stream was assessed using stream discharge; vertical hydraulic gradients in nested instream piezometers; and, streambed temperature. Several lines of evidence indicate that streamflow depletion occurred; however, the variation in the streamflow data limits the conclusions that can be made without a longer pumping test.

Relevance

This ongoing multi-year project was designed to build on previous research to improve the understanding of groundwater-surface water interaction, specifically the effect of pumping on streamflow depletion.

Learnings & Recommendations

Future work will include: (1) analyzing a dataset from a longer pumping test to confirm if the pumping test results did in fact indicate initial stages of streamflow depletion or if the observed result were due to natural variation in the streamflow, and (2) completing an Environmental Flow Needs assessment for Bertrand Creek.

Partners and Linkages

Dr. Diana Allen of the Department of Earth Sciences at SFU supervised an honours undergraduate student (Brynje Johnson) to undertake this research. The Township of Langley provided the study location on their park land.

References

Johnson, B. 2018. Aquifer-Stream Connectivity at Otter Park, Langley, BC. Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of B.Sc. (Honours), Department of Earth Sciences, SFU.

Project Contacts

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Acknowledgements:
Groundwater Science Program

Mill Bay Aquifer Characterization and Water Budget

Project Description

Aquifer characterization studies were conducted to support and inform groundwater licensing in the Mill Bay area on southern Vancouver Island. The project objectives were: i) conduct field and desktop studies to address knowledge gaps of groundwater resources, including characterization of groundwater flow, recharge, use, and interaction with surface waters; and, ii) refine and update the Mill Bay aquifer water budget to provide broad estimates of groundwater availability for groundwater allocation and licensing. The project was organized into four tasks:

1) Improve the understanding of GW-SW interactions through hydrometric measurements of streamflow and measurement of shallow groundwater gradients;
2) Improve the understanding of inter-aquifer groundwater movement through geochemical analyses of groundwater and surface water samples;
3) Inventory and update groundwater pumping and groundwater level data to support water budget development and calibration; and,
4) Integrate results of aquifer characterization studies into a revised Mill Bay aquifer water budget to reflect and support use of the water budget for groundwater allocation and licensing.

Hydrometric and shallow groundwater level measurements (top); mapped aquifer extent and groundwater quality sampling (bottom).
Photos: K. Rathfelder

Summary of Project Outcome

A field program of surface water and groundwater data collection was completed to support aquifer characterization. Two hydrometric stations and five flumes were installed to collect continuous streamflow data for assessing groundwater baseflow discharge. Sixteen shallow piezometers were installed along five stream transects to assess surface water–groundwater interactions. Water samples were collected from 30 surficial and bedrock aquifer wells and six stream locations during summer and winter sampling rounds. Geochemical analyses of water samples support the assessment and interpretation of groundwater flow paths, amount of inter-aquifer mixing, and groundwater discharge to streams. Continuous groundwater level data were collected from two bedrock and four surficial aquifer wells. Aquifer characterization data will support refinement and calibration of the aquifer water budget. A final project report is planned for 2020.

Relevance

Groundwater is the main source of water supply for the community of Mill Bay, but the long-term sustainability of groundwater supply is a concern. Declining yields in production wells suggests current groundwater supply is under pressure and demands on future groundwater supplies are expected to increase from development pressures. The outcomes of this project will inform allocation staff who will make determinations on future groundwater license applications.

Partners

Project support was provided by the Cowichan Valley Regional District, the Mill Bay Waterworks, and the Department of Earth Sciences at Simon Fraser University.

Project Contacts

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Acknowledgements:
Groundwater Science Program

Aquifer Information: Factsheets and GWELLS Aquifer Summary Page

Project Description

The purpose of the Aquifer Dashboard project is to "know what we know" about groundwater and aquifers in the province and to make this information easily accessible from a centralized location. Currently, groundwater information is stored in several different databases across a number of different ministries and programs. The objective of the dashboard project is to identify and bring together key groundwater information on an aquifer-based platform through the production of aquifer factsheets (with hyperlinks to source data) and ultimately through the development of an interactive aquifer web tool. The project deliverables will help to tell the "Aquifer Story" for the nearly 1200 provincial aquifers. This is a large multi-year endeavour being worked on by a team of groundwater staff from ENV and FLNRORD.

GWELLS Aquifer Summary page

Summary of Project Outcome

Work completed this year includes the launch of the interactive Aquifer Search & Summary Tool available through GWELLS. This tool currently summarizes information within the GWELLS aquifer application, provides a basic summary of aquifer licensing information and provides links to other key information about each aquifer. The search map and aquifer summary page are a work in progress and will be expanded and improved over the next couple of years. In addition, nearly 1100 aquifer factsheets (about 90% of all provincial aquifers) were produced using the scripting languages R and LaTex to retrieve, clean, analyse and display groundwater data from several different databases into a concise one to two-page factsheet. The factsheets were published through GWELLs and can be accessed through the Aquifer Summary page.

Relevance

Accessibility of groundwater information is more important than ever with the implementation of groundwater licensing under the *Water Sustainability Act*. Streamlined access to information is crucial for Water Authorizations staff in making consistent and informed decisions when adjudicating new groundwater licence applications and transitioning existing groundwater users. This project will save staff time and effort and will also increase public knowledge and awareness about provincial aquifers

Learnings & Recommendations

This project has demonstrated the tremendous value of using scripts to work with large data sets. The scripted output has been effective in highlighting database errors and assisting with targeted data clean-up efforts. Creating an interactive web tool is an iterative process and fixes and upgrade will continue to be incorporated into the GWELLS Aquifer summary page over the coming years.

Partners and Linkages

We are partnering with the Geological Survey of Canada (GSC) to ensure that products are compatible with the National Groundwater Information Network (GIN) portal. The GSC will provide support for this project by contributing information for areas of the province where they have conducted in-depth aquifer studies.

References

- GWELLS aquifer summary page: https://apps.nrs.gov.bc.ca/gwells/aquifers.
- Sample factsheet: https://s3.ca-central-1.amazonaws.com/aquifer-docs/00400/AQ_00451_Aquifer_Factsheet.pdf

Project Contacts

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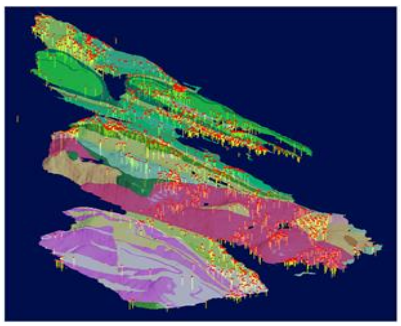
Acknowledgements:
Groundwater Science Program

Aquifer Mapping and Monthly Groundwater Budgets for Aquifers on Salt Spring Island, B.C.

Project Description

Water supplies on Salt Spring Island, the most populous of the southern Gulf Islands, are primarily obtained from wells in low-yielding fractured bedrock aquifers and relatively small lakes such as St. Mary Lake and Maxwell Lake. A geospatial database was developed, including three-dimensional visualization in Leapfrog Hydro, integrating geologic mapping, and subsurface lithology from well records to revise the aquifer boundaries. Monthly groundwater budgets were developed to assess the sustainability of groundwater use in comparison to precipitation, groundwater recharge, surface water discharge and evapotranspiration components of the water cycle.



3D visualization of geology and wells.

Summary of Project Outcomes

Consolidating data obtained from water purveyors and a study of agricultural water use enabled a detailed quantification of monthly water demand for residential, industrial, commercial, and agricultural sectors. Water availability is reliant on precipitation received within the island footprint. Surface water runoff (approximately 54% of total precipitation) and evapotranspiration (35%), are the largest components of the water cycle, compared to groundwater recharge (10%). Local groundwater availability may be limited due to the low storage capacity of the bedrock aquifers, heterogeneous fracture networks delivering water to individual wells, and seasonal exhaustion of supplies in areas of high well density.

Relevance

The viability of communities in the Gulf Islands and other coastal areas of BC relies upon the availability of freshwater. Water budgets support science-based decision-making, including water authorizations under the *WSA*.

Learnings & Recommendations

Results of this analysis suggest there is sufficient freshwater to meet current demands, however, seasonal water shortages are likely, especially due to changes in climate and saltwater intrusion. Understanding of local water deficits could be improved by: increased groundwater level data from spatially distributed monitoring wells; continuous (annual) hydrometric gauging in key basins; and, quantification of the water balance in smaller-scale groundwater management units.

Partners and Linkages

This study was completed by Golder Associates with partners from the Ministry of Environment and Climate Change Strategy, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, the Islands Trust, and the Salt Spring Island Water Protection Alliance. A concurrent study on agricultural water use was completed by the Ministry of Agriculture.

References

Gorski, N.G. and J.P. Sacre. 2019. Aquifer mapping and monthly groundwater budget analysis for aquifers on Salt Spring Island. Water Science Series, WSS2019-01. Province of British Columbia, Victoria, BC

Tam, S. and T. Van der Gulik. 2017. Agricultural Water Demand Modelling for Salt Spring Island. BC Ministry of Agriculture, Victoria, B.C.

Project Contacts

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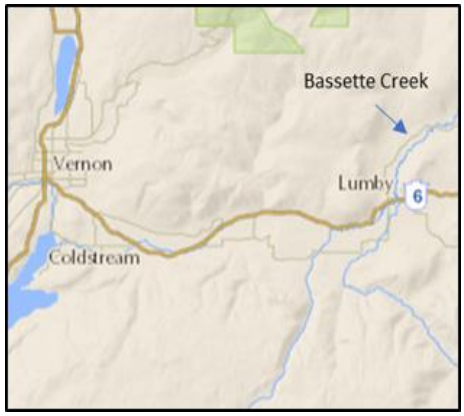
Acknowledgements:
FLNRORD South Area Regional Operations
Groundwater Science Program

Hydrogeology and Environmental Flow Needs Assessment of a Groundwater Licence Application near Lumby, B.C.

Project Description

As part of the adjudication of a groundwater license application for a well near Lumby, B.C., it was determined that a reasonable likelihood of hydraulic connectivity existed between the well and nearby Bessette creek, a stream with high fisheries values and seasonal water shortages. Based on the assessment, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) refused the license. The decision to refuse the license was subsequently appealed by the applicant. An analytical model based on methodologies outlined in Rathfelder (2016), was used to estimate the water demand and hydraulic connectivity in the study area and to estimate the effects of the subject pumping well on Bessette Creek. The model results were important in supporting the decision to deny the licence.



Bessette Creek, near Lumby BC.

Summary of Project Outcome

The decision to deny the licence was ultimately upheld after review by the Environmental Appeal Board (EAB). The development of the analytical model was critical in demonstrating hydraulic connectivity and the environmental impacts of groundwater withdrawal on Bessette Creek. The EAB upheld the Ministry's decision based, in part, on the establishment of hydraulic connection between the well and Bessette Creek, the quantification of the impact of the withdrawal, and a separate water accounting report. The EAB decision is publicly available online (2017-WAT-007).

Relevance

This was the first EAB appeal related to the subject of hydraulic connectivity. The EAB upheld the Ministry's decision to refuse a new groundwater licence application on this oversubscribed system. The analytical model of streamflow depletion was instrumental in providing evidence to support the decision.

Learnings & Recommendations

The outcome of the EAB decision reinforces the importance of science-based decision making, particularly as it relates to the implementation of the *Water Sustainability Act* and quantifying the effects of groundwater withdrawals on surface water. It also underscores the statutory decision-makers' authority to request additional information from an applicant necessary to adjudicate the water licence application.

Partners and Linkages

Richard McLeary, PhD and R.P.Bio, FLNRORD, submitted an expert report in response to the appeal. It addressed environmental flow needs and provided a water use accounting in the watershed.

References

Rathfelder, K.M., 2016. Modelling tools for estimating effects of groundwater pumping on surface waters. Province of BC, Ministry of Environment and Climate Change Strategy, Water Science Series WSS2016-09.

Project Contacts

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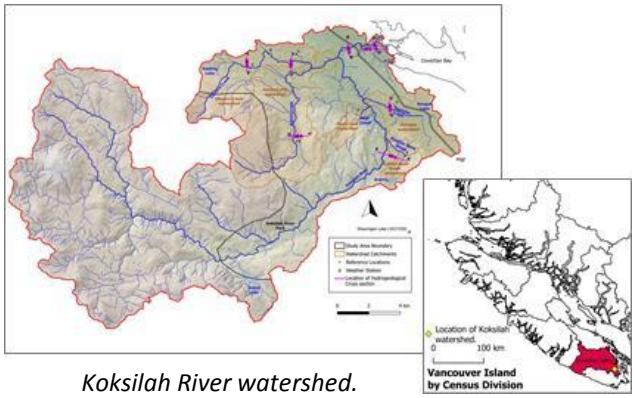
Acknowledgements:
FLNRORD South Area Regional Operations
Groundwater Science Program

Koksilah River Watershed: Preliminary Assessment of Hydraulic Connection, Vancouver Island

Project Description

Koksilah River, on southern Vancouver Island, is vulnerable to low streamflow during the dry season that may affect the quality of aquatic habitat. High surface and groundwater usage in the middle and lower watershed—along with changes in land use and precipitation—are contributing to reductions in river discharge during the summer. The potential hydraulic connectivity between Koksilah River and adjacent wells and aquifers, was examined using a geospatial model developed using well lithology, stream and topographic elevation data and geologic mapping.



Koksilah River watershed.

Summary of Project Outcome

Groundwater elevation, and confining material thickness were mapped, and eight cross-sections were developed. Spatial locations along stream reaches in the watershed were identified as open, perched, or blocked to hydraulic connection with adjacent aquifers. Points of hydraulic connection between a well and the stream were identified on open reaches, where confining sediments were absent, pinched out or were incised by the stream. Stream depletion factors (SDF) were calculated using representative hydrologic properties for wells constructed in four major subtypes of unconsolidated (confined and unconfined) and fractured bedrock (sedimentary and crystalline) aquifers.

Relevance

A modified approach to understanding the hydraulic connection between surface water bodies and adjacent aquifers was developed to support decision-makers in water authorizations (licensing) and issuance of Temporary Protection Orders under sections 86, 87 and 88 of the *Water Sustainability Act*.

Learnings & Recommendations

The majority of wells within the basin were determined to be hydraulically connected to Koksilah River or associated tributaries (Glenora, Kelvin and Patrolas Creeks). Wells in confined, unconsolidated aquifers at further distance from the stream are predicted to have a shorter lag time between when groundwater pumping starts and initiation of streamflow capture compared to unconfined or bedrock wells located closer to the stream. Field surveys of streambed elevation and sediment properties, enhanced flow monitoring and installation of clustered groundwater observation wells are recommended to improve understanding of hydrologic processes in the basin.

Partners and Linkages

This project was carried out by Western Water Associates Ltd. in partnership with the Ministry of Forests, Lands Natural Resource Operations and Rural Development and the Ministry of Environment and Climate Change Strategy. This study supports the development of a *Water Sustainability Plan* to address water quantity and quality issues.

References

Sivak, T. and M. Wei. 2019. Koksilah River Watershed: Preliminary Assessment of Hydraulic Connection. Water Science Series, WSS2019-05. Province of British Columbia, Victoria, B.C.

Project Contacts

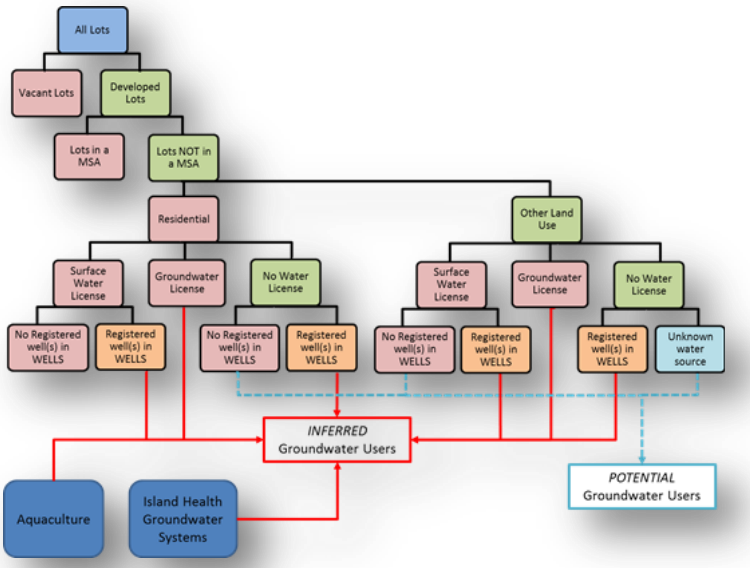
Megan Wainwright | e-mail address: Megan.Wainwright@gov.bc.ca | Phone number: 250-751-7399
Sylvia Barroso | e-mail address: Sylvia.Barroso@gov.bc.ca | Phone number: 250-751-3265

Acknowledgements:
FLNRORD West Coast Regional Operations

Analysis of Current Groundwater Use in the West Coast Region, B.C.

Project Description

A methodology was developed to determine estimates of current groundwater use in the West Coast Region. B.C. Assessment Authority data was used in conjunction with provincial and municipal data sets such as the GWELLS, agricultural demand studies, aquaculture permit data, Island Health water systems data and municipal water service areas, to identify which lots could be using groundwater as a source of freshwater. Groundwater demand was determined for each of the classified aquifers and water precincts and the number of expected license applications under the provisions of the existing-groundwater users program estimated.



Flow chart of inferred and potential groundwater users.

Summary of Project Outcome

The largest use of groundwater in the region is for less than 20 aquaculture operations (52%), followed by water supply systems (25%) and agriculture (15%). Together, these sectors use over 90% of the total anticipated groundwater demand in the West Coast Region.

Relevance

Understanding the demand for groundwater from users, prior to the enactment of the *Water Sustainability Act* in 2016, is critical to ensuring that the majority of the largest users by volume apply for an existing use groundwater licence prior to the March 1st 2022 deadline for transitioning users.

Learnings & Recommendations

This study improved our understanding of groundwater use in the West Coast Region. More confidence in the results will require revisions to some key data layers (e.g., water system service areas), verification of data (e.g., aquaculture operations) and review of assumptions related to estimating water use (e.g., multiple connection waterworks). The developed methodology could be applied to other regions in the province.

Partners and Linkages

This project was carried out by Hatfield Consultants in partnership with the Ministry of Forests, Lands Natural Resource Operations and Rural Development and the Ministry of Environment and Climate Change Strategy. Further refinement of the methodology and databases is currently underway.

References

Bennett, T., I. Bystron, P. Lapcevic, M. Wainwright, and T. Diep. 2019. Analysis of Current Groundwater Use in the West Coast Region, British Columbia. Water Science Series, WSS2019-09 (pending). Prov. BC, Victoria BC

Project Contacts

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Acknowledgements:
FLNRORD West Coast Regional Operations

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

Project Description

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 valley fill aquifer of sand and gravel 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, high water temperatures, importance as a critical spawning and rearing area for pacific salmon and steelhead trout, and its importance as a source of water for a variety of users. This project began in 2018 and is intended to be a 3-year study that includes: a desktop and scoping exercise (Phase 1); field data collection which involves a drone overflight with infrared instrumentation; the monitoring and recording of discharge, water levels, and the analysis of water for a range of parameters (Phase 2); and, report writing and data sharing with stakeholders, First Nations and Water Management staff (Phase 3).

Model from drone-acquired data.

Summary of Project Outcome

The intended outcome of this research project is to increase all levels of government understanding (Federal, Provincial, Regional and First Nations) of the interaction between surface water and groundwater resources in the Upper Bulkley River watershed through strategic collection and synthesis of both groundwater and surface water data.

This project will contribute to a more thorough understanding of groundwater resources, existing allocation pressures, the interplay between groundwater and surface water, and Environmental Flow Needs (EFN), which must now be understood by Water Managers in order to make informed and durable water allocation decisions under the *Water Sustainability Act.*

Relevance

This project will support not only water management decisions in the Upper Bulkley River watershed but will also provide critical information to a multi-year, multi-stakeholder fisheries research project.

Partners and Linkages

Project development and sharing partners will include: the office of the Wet'suwet'en; the Wet'suwet'en First Nation; the Upper Bulkley River Streamkeepers/ A Rocha Canada; the District of Houston; the Regional District of Bulkley-Nechako; Fisheries and Oceans Canada; and the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Project Contacts

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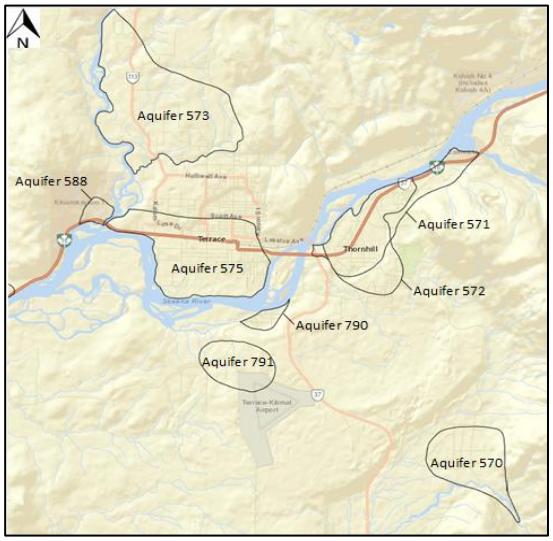
Acknowledgements:
FLNRORD Water Intended Outcome

Terrace Aquifer Characterization Project, Terrace, B.C.

Project Description

The purpose of this study is to identify approaches to characterize aquifers using water chemistry as a primary information source and to improve the understanding of local aquifers and groundwater resources in the Terrace and Thornhill area. A sampling program was developed to evaluate groundwater and surface water quality to provide insight into groundwater recharge zones, interactions between surface water and groundwater, and to aid in estimating the mean groundwater recharge.



Mapped aquifers in the Terrace area.

Summary of Project Outcome

The project is in its final year (2019) of data collection. Three rounds of private well sampling (28 sites) and surface water collection (15 sites) have been completed. Sample analysis included metals, isotopes, and general parameters. In addition, a total of 16 groundwater sites were selected for tritium analysis during the summer of 2017 sampling event. An ongoing collection of precipitation is occurring to establish a local meteoric water line through isotope analysis to complete data comparisons. Data analysis is underway with support from contractors. Outcomes of the final project are expected in the fall of 2020.

Relevance

There is a lack of hydrogeological knowledge and understanding in regards to the recharge areas for aquifers in Terrace and the interactions between groundwater and surface water bodies (i.e. Skeena River). Due to an increase in industrial activities and the potential for future development around Terrace, a better understanding of the groundwater resources is required to ensure groundwater protection and sustainability. In addition, this research will support effective allocation and management of the groundwater resource. The methods developed as part of this project (i.e., natural isotopic tracer) can be applied to other regions.

Learnings & Recommendations

1) This project has provided insight into how water chemistry data can be used as a tool for assessing groundwater flow patterns and for defining aquifer boundaries. This project has also provided insight into the groundwater-surface water interactions in the Terrace Area;
2) Analysis of water samples for tritium isotopes can provide useful information related to aquifer recharge zones but a local meteoric water line needs to be established.

Partners and Linkages

Sampling occurs from volunteer wells across the region, volunteer wells are from the City of Terrace, the Regional District of Kitimat-Stikine, First Nations (Kitselas and Kitsumkalum), and private home owners.

References

A final report will be produced documenting the results of the research.

Project Contacts

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Acknowledgements:
FLNRORD Water Intended Outcome

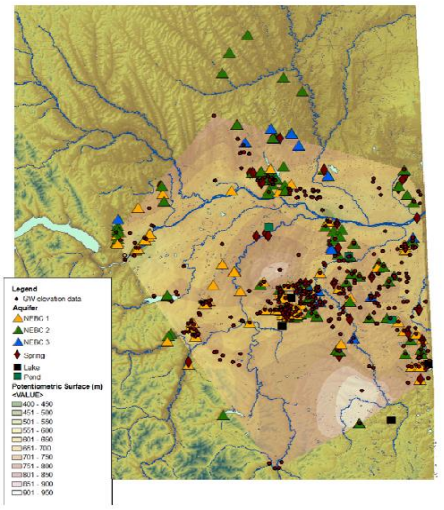
Aquifer Characterization in Northeast British Columbia

Project Description

This project was undertaken to characterize aquifers in the Peace Region of NE BC in collaboration with several different organizations. The objectives of this work are to better understand the groundwater resources by evaluating the distribution of aquifers and to characterize the chemistry and availability of groundwater. To meet these objectives the project has three components: i) water well chemistry survey; ii) expansion of the observation well network; and, iii) geophysical survey of aquifers.

Summary of Project Outcome

The physical and chemical characterization of the groundwater aquifer systems of the Peace Region allowed for the identification of local and regional groundwater flow systems. The geochemistry and geophysics of the Quaternary aquifer systems indicate local recharge and relatively fresh groundwater of low mean residence time while the bedrock aquifer systems tended to be larger scale with lower quality water and longer residence times. Methane was found in many of the shallow groundwater samples with no evidence of deep thermogenic sources identified.



Water sampling and groundwater elevation locations.

Relevance

Understanding the connectivity and continuity within aquifer systems is fundamental to groundwater allocation and source water protection. The Quaternary geology in the Northeast is complex. Earlier aquifer mapping of this area was overly simplified and multiple distinct aquifer systems have been identified in areas previously mapped as a single aquifer. Detailed aquifer characterization provides insight into how groundwater quality and quantity might be affected by land use changes, resource extraction and climate change.

Learnings & Recommendations

1) Aquifer systems in the Peace region typically display a geochemical signature that is recognizable in the groundwater composition and which remains relatively consistent over time. Recharge of the groundwater aquifer systems tends to occur in the spring/fall when most of the precipitation occurs.
2) Methane concentrations in the groundwater range from 0 to near saturation (i.e., 10's of mg/L). The majority of methane found in groundwater is locally shallow sourced biogenic methane. There is no conclusive evidence of migrated thermogenic methane. The origin of these observations continues to be investigated.

Partners and Linkages

Partners on this project include; Simon Fraser University; the University of British Columbia; the University of Calgary; the Geological Survey of Canada; the BC Oil and Gas Commission; Geoscience BC and the Ministries of ENV, FLNRORD and EMPR

References

Morgan, S.E., D.M. Allen, D. Kirste, D. and C.J. Salas, 2017. Investigating the role of buried valley aquifer systems in the regional hydrogeology of the Peace River region, northeastern British Columbia (parts of NTS 094A, B); in Geoscience BC Summary of Activities 2016, Geoscience BC, Report 2017-1, p. 63–68.

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Acknowledgements:
FLNRORD Water Intended Outcome
Ministry of Environment

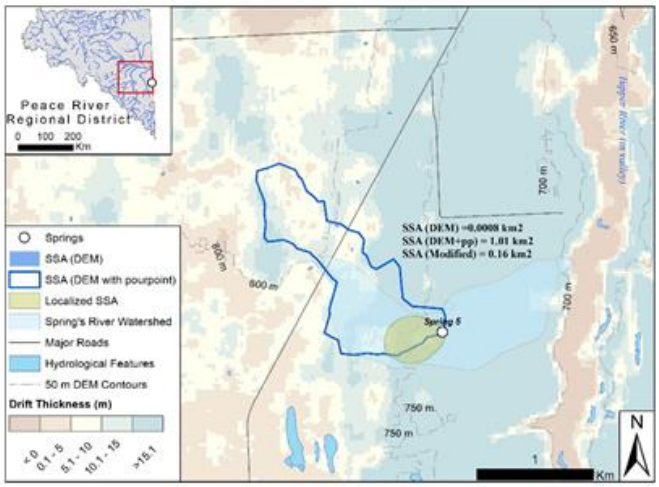
Spring Source Area Delineation and Monitoring, Chetwynd, B.C.

Project Description

Building on the master's thesis completed by Ismena Bystrom at Simon Fraser University, ongoing monitoring of springs in the Chetwynd area are being conducted to understand seasonal variation in spring flow using continuous discharge and specific conductance paired with water chemistry. The outcomes will further refine the estimation of spring source areas that were originally established using GIS and water chemistry analyses.

Summary of Project Outcomes

Springs in the Chetwynd area tend to be landscape controlled and are found to be expressions of both Quaternary and bedrock flow systems depending on the local geology. The location of springs can be predicted using GIS susceptibility maps based on physical and hydrologic attributes. Springs have a mixed mean residence time indicating that locally sourced recharge (within 400 m) can be important to spring occurrence regardless of the geochemical signature (source aquifer system).



Delineation of spring source area (SSA) for Spring 5 near Chetwynd, BC.

Relevance

Exploring and understanding the nature of springs and their sensitivity to land use is critical to preserving their integrity. Learnings about predictive mapping techniques to determine where springs are likely to occur and defining sensitive areas within the source areas of known springs is relevant to land use activities and the conservation of drinking water.

Learnings & Recommendations

1) Springs in NE BC are sourced from both Quaternary unconsolidated sediment aquifers and bedrock aquifers.
2) Measuring the discharge from a spring over the winter when the flows are less than 5 L/s has proven difficult. A novel approach using a trapezoidal flume and a non-contact water level sensor is being tested over the coming year

Partners and Linkages

Partners on this project include Simon Fraser University, and the BC Oil and Gas Commission.

References

Bystrom, I., D. Kirste, and D. Allen. (2017). GIS-based Approach to Spring Occurrence and Spring Source Areas in Northeast British Columbia. Report for the BC Oil and Gas Research and Innovation Society. pp. 68.

Bystron, I., D. Kirste, and D. Allen. 2016. Application of Multi-Criteria Analysis (MCA) for Potential Spring Occurrences: A case study for Northeastern British Columbia. The 69th National Conference of the Canadian Water Resources Association (CWRA). Montreal, Canada. May 25-27, 2016.

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Acknowledgements:
FLNRORD Water Intended Outcome

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 and First Nations, including:

- A Rocha Canada
- Fisheries and Oceans Canada
- Geological Survey of Canada
- Geoscience BC
- Mill Bay Waterworks
- Ministry of Agriculture
- Ministry of Energy, Mines and Petroleum Resources
- Ministry of Environment and Climate Change Strategy
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Ministry of Transportation and Infrastructure
- Salt Spring Island Water Protection Alliance
- Simon Fraser University
- The BC Oil and Gas Commission
- The City of Terrace
- The Convention of Baptist Churches of British Columbia
- The Cowichan Valley Regional District
- The District of Maple Ridge
- The District of Mission
- The District of Houston
- The District of Squamish
- The Fort Nelson First Nation
- The GWELLS development team
- The HUB at Cowichan Station
- The Islands Trust
- The Kitselas First Nation
- The Kitsumkalum First Nation
- The Office of the Wet'suwet'en
- The Regional District of Bulkley-Nechako
- The Regional District of Kitimat-Stikine
- The Resort Municipality of Whistler
- The Township of Langley
- The Upper Bulkley River Streamkeepers
- The Village of Pemberton
- The Wet'suwet'en First Nation
- University of British Columbia
- University of Calgary
- University of Northern British Columbia
- University of Victoria