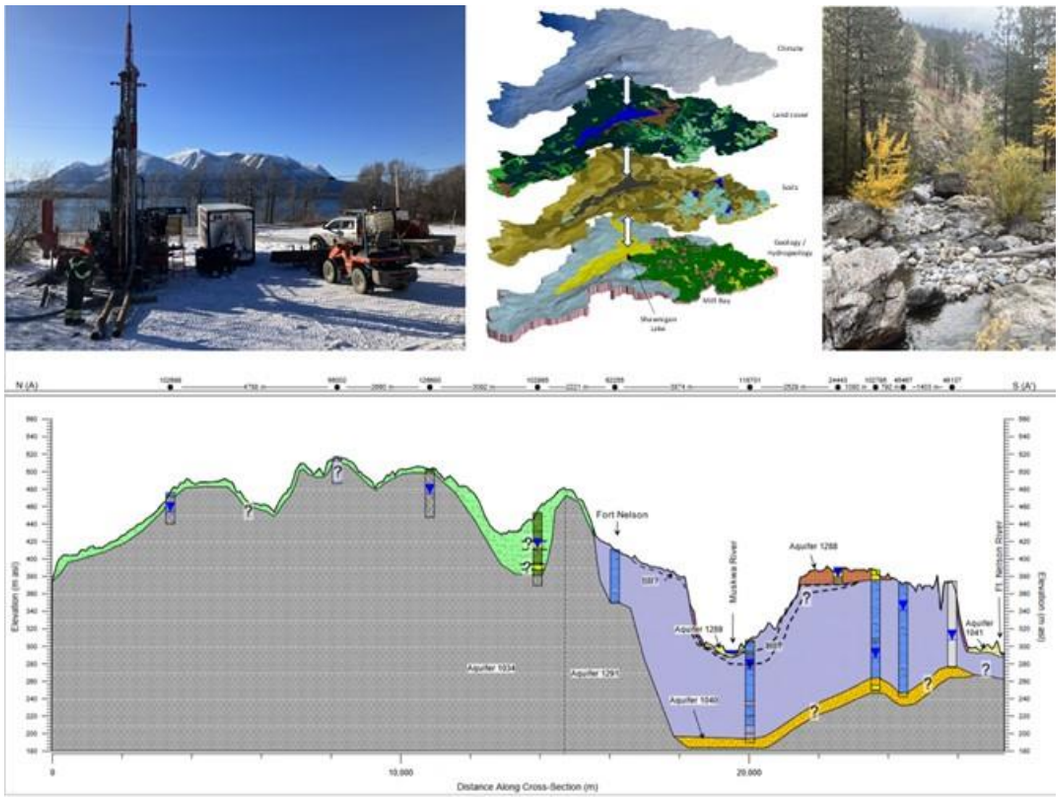
WATER SCIENCE SERIES

Compendium of Provincial Groundwater Science and Monitoring Projects: 2023-24



August 2024

BRITISH COLUMBIA

No. 2024-08

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.

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Cover Photographs:
Clockwise from top left:
Drilling of dry borehole at Atlin Lake. Photo: J. Yin
3D conceptual model of the Shawnigan Creek Watershed. Image: C. Donnelly
sn̓aaẋə lqaxʷiyaʔ (Vaseux Creek). Photo: J. Pogson
Conceptual model of geology and hydrogeology for Fort Nelson area aquifer mapping. Source: Lengyel et al. 2024

Acknowledgements

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PREFACE

The B.C. Provincial Groundwater Program originated in 1961 when the *Water Act* was revised to enable the licensing of groundwater. The primary goals of the Groundwater Program are to increase the understanding of groundwater resources in British Columbia and to promote the sustainable management and protection of groundwater resources. To advance these goals, there is an ongoing need to improve scientific knowledge and monitoring of aquifer characteristics, groundwater availability, and groundwater interactions with surface water. This knowledge is central to the review of groundwater licence applications in accordance with the 2016 *Water Sustainability Act* (*WSA*) and supports the goals of sustainable allocation and use of groundwater resources and science-based policy development.

The Groundwater Program is jointly administered by the Ministry of Water, Land and Resource Stewardship (WLRS), the Ministry of Environment and Climate Change Strategy (ENV) and the Ministry of Forests (FOR). Currently, groundwater science and monitoring projects are primarily supported through three main funding envelopes:

- the Groundwater Science Program, administered by the Watershed and Security Branch (WSS) in WLRS;
- dedicated funding in ENV to support the expansion, management and maintenance of the Provincial Groundwater Observation Well Network (PGOWN); and,
- the Water Research Portfolio, administered by FOR.

The Groundwater Program also partners with other ministries and agencies in support of groundwater related studies, including: the Ministry of Agriculture and Food (AF), the Ministry of Energy, Mines and Low Carbon Innovation (EMLI), the BC Energy Regulator (BCER), universities, local governments, and First Nations.

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 2023-24 fiscal year. The intent is to communicate to a wide audience about the nature of the projects undertaken and to provide an overview of the project results. Linkages to key institutions, personnel and supporting references are provided within each summary.

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 a primary source of groundwater information and data across the province, including mapped aquifers. The GWELLS database is used to: i) support and inform groundwater allocation and water rights; ii) prioritize groundwater management initiatives; iii) support the protection of groundwater quality and groundwater remediation efforts; and, iv) serve as a public resource for groundwater data, information and education.

As of July 29, 2024, the GWELLS database contained over 1,291 aquifers. The Province continues to conduct new aquifer mapping projects to expand and refine the database. The demand for mapping aquifers is ongoing as communities expand and 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 several factors including: i) local knowledge of emerging issues identified through regional work with communities, Indigenous Nations and transboundary jurisdictions; ii) the location of water wells in the provincial GWELLS database that are not yet associated with a mapped aquifer; and, iii) the location of major resource development projects (e.g., mines, oil and gas).

In 2023/24, aquifer mapping was completed in northeast B.C. within the Fort Nelson area and in the Kootenay-Boundary Region in the vicinity of the communities of Creston, Rossland, Castlegar and Salmo. Aquifer mapping was also initiated in the Lower Mainland Abbotsford area, with phase2 continuing in 2024/25.

Aquifer mapping information is used in groundwater allocation and licensing decisions under the *Water Sustainability Act* and is available to the public to inform groundwater well protection and land use planning. Spatial information about mapped aquifers can be accessed using the following tools:

- GWELLS – The Provincial database for storing, visualizing and retrieving water well records and aquifer information; and,
- iMapBC – allows users to view, visualize and analyze mapped aquifers along with hundreds of other data layers compiled from across the B.C. Government and other agencies. The provincial aquifer layer (Search "Aquifers" is named "Aquifers - All" and is found under the heading "Fresh Water and Marine."

Aquifer Mapping Studies, Northeast Region

Project Description

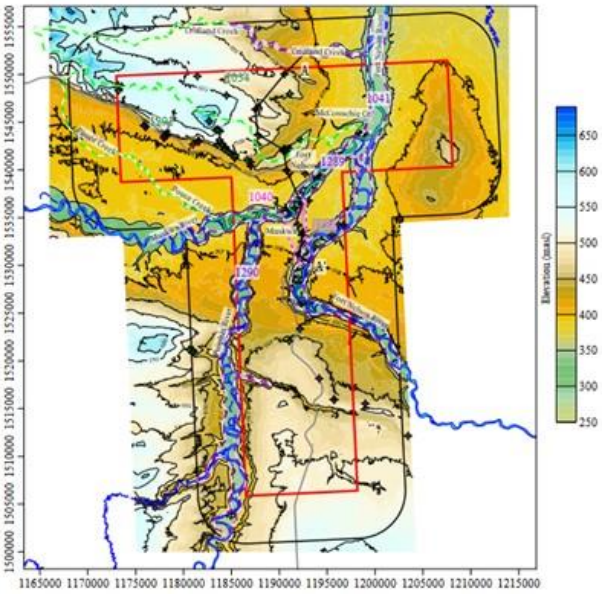
Phase 3 of the Northeast region aquifer mapping project focused on aquifers in proximity to Fort Nelson, B.C. Through identification and mapping of freshwater aquifers, this study provides a foundation for sustainable management of groundwater resources. This project integrated water well records from the GWELLS database with information from previous hydrogeologic studies and mapping of geology, topography, streams and springs to map new, and update existing, aquifers.

Project Outcomes

Three existing aquifers were updated, and four additional aquifers were mapped as an outcome of this study.

Relevance

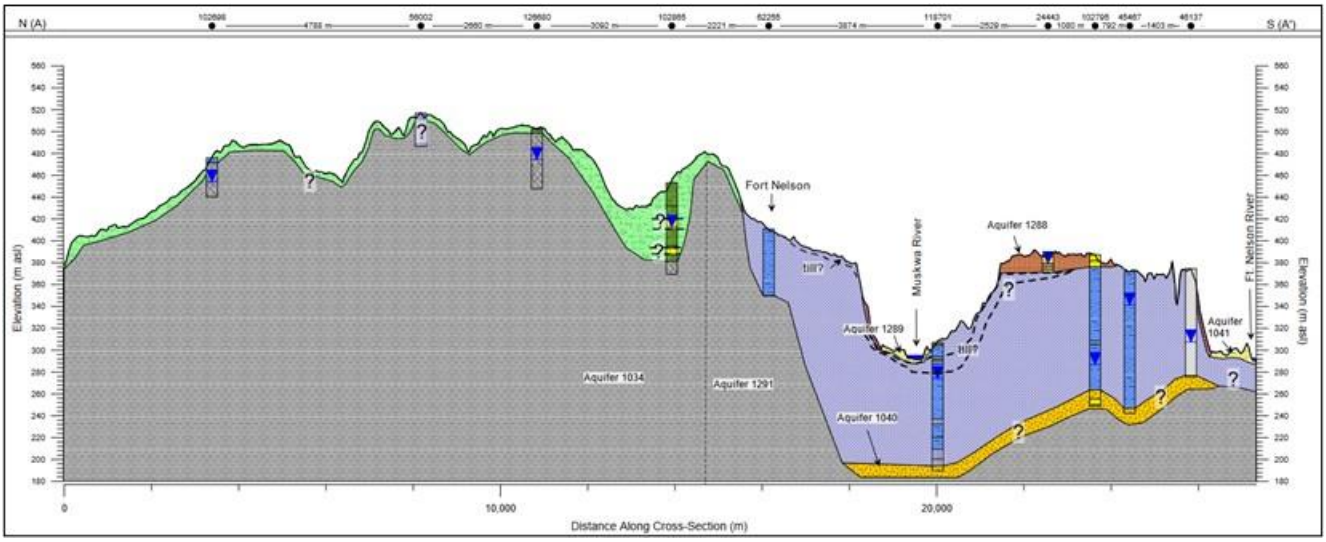
Results will inform groundwater licensing under the *Water Sustainability Act*. Results may also be used to inform priorities for groundwater protection, studies of hydraulic connections with surface waters, and groundwater availability analyses.



Study area with mapped aquifers (Source: Lengyel et al. 2024).

Learnings and Recommendations

Further studies could be conducted to improve understanding of surficial and geology, aquifer extents beyond the study area, or in the expansion of the Provincial Groundwater Monitoring Well Network.



Conceptual model of the geology and hydrogeology of the study area (Source: Lengyel et al. 2024).

References

Lengyel, T., J. Deri-Takacs, and A.C. Hinnell, 2024. Fort Nelson Aquifer Mapping and Hydrostratigraphic Characterization. Water Science Series: WSS2024-02. Province of British Columbia, Victoria.

Project Contacts

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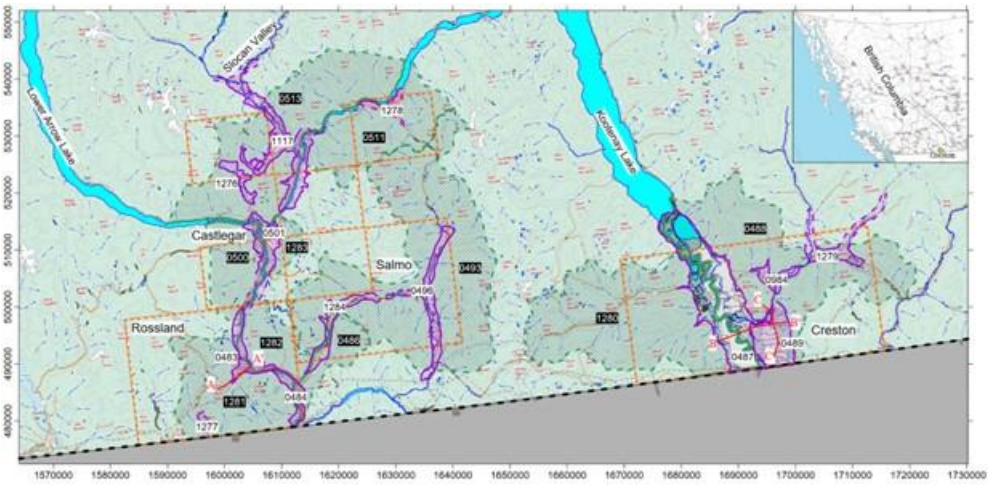
Funding Acknowledgements:
WLRS Groundwater Science Fund

Aquifer Mapping Studies, South Region

Project Description

Phase 2 of the South region aquifer mapping project focused on aquifers in proximity to Castlegar, Rossland, Creston and Salmo, BC. Updated aquifer mapping in Southern BC will support water management and groundwater licensing associated with future population growth in the area. The project integrated the GWELLS database with previous hydrogeologic studies, geology, topography, streams and springs.



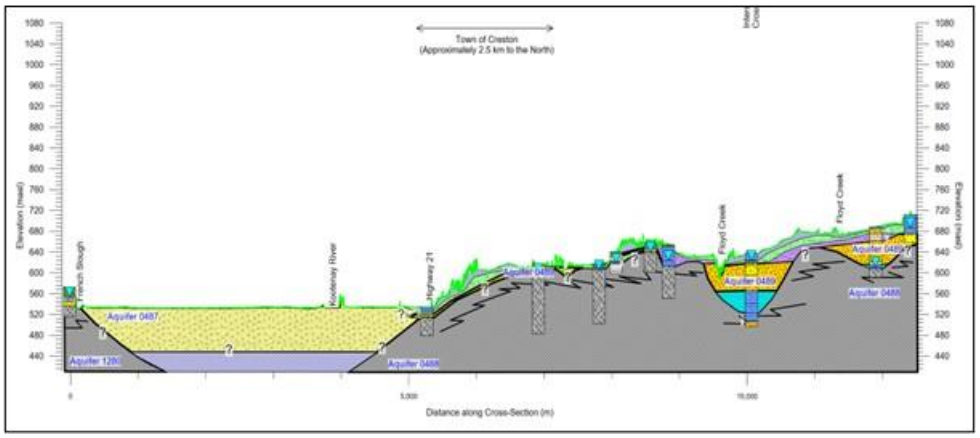
Study area with mapped aquifer (Source: Lengyel et al. 2024).

Project Outcomes

Fourteen existing aquifers were updated, and nine additional aquifers were mapped as an outcome of this study.

Relevance

Results will inform groundwater licensing under the *Water Sustainability Act*. Results may also be used to inform priorities for groundwater protection, studies of hydraulic connections with surface waters, and groundwater availability analyses.



Cross section of the hydrogeology of the Study Area (Source: Lengyel et al. 2024).

Learnings and Recommendations

Additional surficial geological/terrain mapping is recommended to assist with refining the overburden aquifers in the area. Additionally, little is known regarding how faults impact groundwater flow. Field investigations could better understand the impact. Future aquifer mapping studies are recommended north and east of the study area.

References

Lengyel, T., S. Verma, J. Deri-Takacs, and A.C. Hinnell, 2024. Aquifer Mapping in the Kootenay/Boundary Region of British Columbia: Creston, Rossland, Castlegar, and Salmo. Water Science Series: WSS2024-05. Province of British Columbia, Victoria.

Project Contacts

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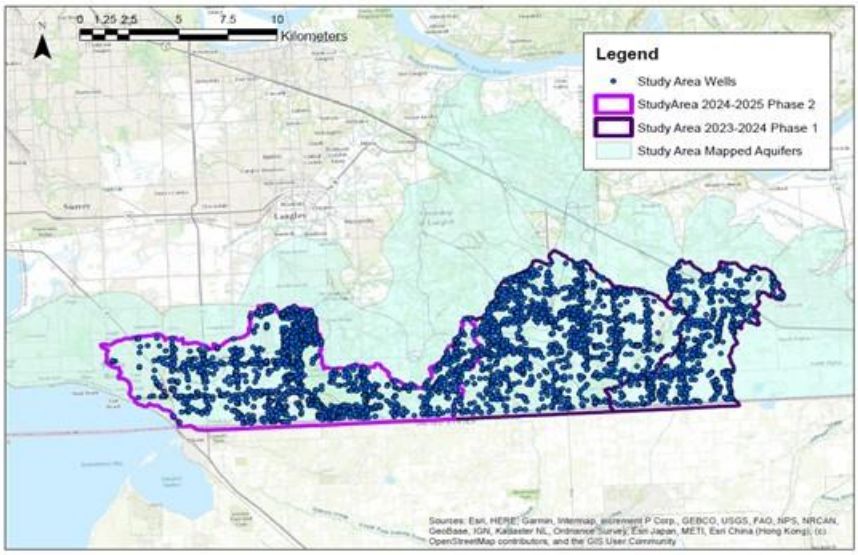
Funding Acknowledgements:
WLRS Groundwater Science Fund

Southern Langley and Surrey Aquifer Mapping, Lower Mainland

Project Description

Southern Langley and Surrey have experienced substantial groundwater development, population growth and contain complex hydrogeology. The Province initiated the Little Campbell River, Bertrand and Pepin aquifer mapping project to update and refine the hydrogeologic understanding of this area to support planning and decision-making related to the *Water Sustainability Act*. Phase 1 initiated in 2023 focused on the Bertrand and Pepin watersheds whereas future Phase 2 will focus on the Little Campbell River watershed. The study is in an area of the Lower Mainland with thick unconsolidated deposits. The distribution of these deposits – including the coarse-grained, permeable deposits that form the aquifers – reflects a particularly dynamic and complex geological history.



Study Area: Southern Langley and Surrey Aquifer.

Project Outcomes

Seven existing aquifers were updated, and four additional aquifers were mapped as an outcome of this study. Three of the mapped aquifers, described as the Abbotsford Shallow, Abbotsford Shallow West and Aldergrove Shallow are primarily unconfined and have the highest potential for hydraulic connection with surface waters. In addition to the delineation of mapped extents of aquifers and description of aquifer properties, the work involves the production of eight regional hydrostratigraphic cross sections to delineate the vertical relationships between aquifers and vertical extents.

Relevance

Results will inform groundwater licensing under the *Water Sustainability Act*. Results may also be used to inform priorities for groundwater protection, studies of hydraulic connections with surface waters, and groundwater availability analyses.

Learnings and Recommendations

Interpretation of hydrostratigraphy within the Phase 1 portion of the study area revealed the need for an additional study of deeper aquifers which extend into the Phase 2 study area. This additional study will be completed in Phase 2 (2024-2025). To improve the understanding of groundwater–surface water interactions and to identify critical aquifer management areas for baseflow and environmental flow maintenance, a high-resolution thermal imaging survey has been recommended to identify areas of groundwater seepage and upwelling.

References

Qin, K., J. Perreault, N. Gorski and J.P. Sacré. (in press, 2024). Hydrogeological Mapping and Analysis, Bertrand Creek and Fishtrap Creek Watersheds. Water Science Series. Expected Publication in 2024. Prov. B.C., Victoria B.C.

Project Contacts

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Funding Acknowledgements:
WLRS Groundwater Science Fund

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 groundwater level measurements collected through the network help inform water stewardship decisions across the province. Two main objectives of the network are:

1. Understanding local and regional hydrogeological processes; and,
2. Supporting the sustainable use of groundwater.

Information collected through the PGOWN is publicly available through several Provincial portals:

- Groundwater Level Data Interactive Map – includes all PGOWN-related information, such as the location of active and inactive monitoring wells; links to monitoring well construction reports; and groundwater level data and charts for real-time data and historical data.
- The Real-time Water Data Tool – is a browser-based information and data presentation system for access to continuous (time-series) surface, groundwater, and snow monitoring data.
- Drought Information Portal (Groundwater Conditions Map) – is a single source to access drought information and data across British Columbia, including groundwater percentiles and regional drought reports.
- The Environmental Monitoring System (EMS) Web Reporting Menu – is an on-line search tool for surface and groundwater quality information stored in the EMS database.

The PGOWN was formally established in 1961 and the network has evolved with new observation wells added over time while others have been discontinued as priorities, staffing levels and funding levels have fluctuated. As of July 2024, there were 240 active observation wells in the PGOWN. During the 2023-24 fiscal year, one existing observation well from a third party was adopted into the network. The new observation well is described in the following project summaries.

In addition to the PGOWN network, monitoring wells exist across the province to support a variety of initiatives and special research projects. These include wells operated in collaboration with neighbouring governments and First Nations. In some cases, these wells may eventually be integrated into the PGOWN network.

Surface Water Monitoring

The Province co-manages the Federal-Provincial Hydrometric Network with the Water Survey of Canada, which includes greater than 460 hydrometric stations across the province. Network operation costs are shared between the provincial and federal governments and 3rd parties. The majority of hydrometric stations are operated on larger river systems for a variety of objectives such as public safety, trans-boundary water management, and utility, 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 government of Canada, *Water Office* website (https://wateroffice.ec.gc.ca/).

Some provincial regions conduct additional local hydrometric measurements to fill data gaps on smaller systems to support licensing decisions. Monitoring of surface waters helps 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 for assessing water resources.

Adoption of OW513 in Terrace, B.C. – PGOWN Expansion in the North Natural Resource Area

Project Description

This project is a collaboration with the City of Terrace ("the City") to incorporate a previously drilled monitoring well into the *Provincial Groundwater Observation Well Network (*PGOWN). There are currently six observation wells in the Skeena Region. Observation Well 513 (OW513) is the most recent addition.

OW513 is located within city limits and was drilled in 1992 to assess groundwater availability for the municipal water supply. The well has been inconsistently monitored since 2018 and incorporating the well into the network will improve data quality by ensuring standard operating procedures are followed.

View of OW513 after bike path construction & view within enclosure. Photo: A. Morgan, WLRS.

Project Outcomes

OW513 monitors Aquifer 575, which is the City's primary water source. The City operates three production wells near this observation well. Although OW513 exhibits pumping interference (0.5 m), recovery is observed to be quick, the interference is less than seasonal changes in groundwater levels (2.5 m).

The data from the well will be used to support implementation of the *Water Sustainability Act,* including evaluating water licence applications and helping to prevent over-extraction in the aquifer. Data will also be used by the City of Terrace to inform maintenance, planning, and management of their infrastructure and supply.

Initially groundwater level data will be collected biannually, however, dependant on city approval, telemetry equipment for real–time data transfer may be installed in the future. Groundwater level data will be publicly available through the provincial Aquarius time-series database and the provincial Groundwater Level Data Interactive Map. Water samples will be collected and submitted for baseline water quality laboratory analysis, and the results will be made publicly available online.

Relevance

The aquifer associated with OW513 is hydraulicly connected to the Skeena River. The data collected from this well will provide a better understanding of the state of the aquifer, inform decision makers in the water authorizations group, and allow municipal staff to accurately monitor their groundwater resources.

Learnings and Recommendations

Groundwater water levels have fluctuated between 8.6 and 14.3 metres below ground surface since 2018 and change seasonally by approximately 2.5 metres per year. During the 5+ years of data collected before formal adoption into the network, water levels experienced multi-year increases, followed by multi-year decreases; however, long–term trends cannot yet be discerned. Regular and standardized monitoring of this station will provide more accurate data and a more robust understanding of the aquifer in the years ahead.

Partners

The City of Terrace

Project Contacts

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Funding Acknowledgements:
WLRS North Area Regional Operations
ENV Groundwater Monitoring Program

Atlin Monitoring Well Drilling, Atlin, B.C.

Project Description

This is a collaborative project between the Province of British Columbia and the Yukon to investigate and monitor groundwater levels within the transboundary Atlin Lake watershed. The project was initially suggested by the Yukon groundwater monitoring program, which performs ongoing monitoring and maintenance on the monitoring well in Atlin. The Province of B.C. maintains the data and provides funding for sampling and equipment. The cost to drill the two wells was shared between the B.C. Ministry of Forests; B.C. Ministry of Water, Land and Resource Stewardship; and the Yukon Department of Environment.

Drilling of dry borehole at Atlin Lake. Photo: J. Yin

Project Outcomes

Two test wells were drilled within the community of Atlin. The first test well was drilled less than 50 m from Atlin Lake to a depth of 37 m (120 feet). Sediments overlying the bedrock consisted of 5 m of sand and 20 m of compacted dry silts. Despite the proximity to Atlin Lake, and the borehole reaching at least 30 m below the lake surface, only an insignificant volume of groundwater was encountered at a depth of 14 m. Due to the lack of a water bearing aquifer to monitor, the well was closed. The second test well was drilled at the Atlin Airport into fluvial materials from Pine Creek, with groundwater reached at 9.5m (31 feet), on top of the underlying bedrock. This well installation was completed and is being actively monitored.

Completed monitoring well at Atlin Airport. Photo: J. Yin

Relevance

Historically there has been little groundwater level monitoring in the Northern third of B.C. In 2020, existing monitoring wells in this area were limited to one well in Dease Lake and three new wells in Fort Nelson. As Atlin Lake forms part of a transboundary watershed, groundwater behaviour in this area is of interest to both British Columbia and Yukon.

Learnings and Recommendations

The lack of wellbore logs in the area made it difficult to ascertain where aquifers are likely to exist. In these situations, visiting the site and speaking to the local community (as Yukon Department of Environment staff practiced) is recommended.

Partners and Linkages

Yukon Department of Environment

Project Contacts

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Funding Acknowledgements:
WLRS North Area Regional Operations
ENV Groundwater Monitoring Program
Government of Yukon

Pilot Collaborative Water Monitoring Program, Northeast B.C.

Project Description

The Northeast BC Pilot Collaborative Water Monitoring Program is a partnership with communities from Blueberry River First Nations, Doig River First Nation, McLeod Lake Indian Band, Saulteau First Nations, West Moberly First Nations and Halfway River First Nation. The program installed co-located: i) hydrometric water stations; ii) groundwater monitoring wells; ands iii) climate stations north and west of Dawson Creek. Surface water, groundwater, climate and benthic invertebrate data were collected and/or assessed at five sites. Researchers also engaged with McLeod Lake Indian Band and Halfway River First Nation representatives to collect cultural indicators associated with water quantity at monitoring sites. This is a first step toward a *two-eyed seeing* research approach that compares and combines settler and Indigenous science.

High flow water level survey, Doig River. Photo: R. Rolick.

Project Outcomes

The completion of the Program provides a unique dataset and assessment of both water quantity/quality and climate monitoring from five sites on the territories of Treaty 8 First Nations in Northeast BC. This information can support foundational research to inform evidence-based decisions by industry, governments, Indigenous groups and communities.

Relevance

The Ministry of Energy, Mines and Low Carbon Innovation's, 2019 Scientific Review of Hydraulic Fracturing in British Columbia report included a recommendation to increase water quantity and quality monitoring in NEBC. Concerns of Treaty 8 First Nations regarding water quality and quantity were also highlighted in the report, along with a need to incorporate Traditional Knowledge into research. The Pilot Collaborative Water Monitoring Program, Northeast BC aimed to collect water quantity and quality data to address recommendations in the report, as well as provide data for further uses such as groundwater–surface water interaction studies and watershed / water balance studies. The Program worked with First Nations within the study area to collect Traditional Knowledge data, as well as to provide data collection training for First Nation representatives.

Learnings and Recommendations

The baseline data resulting from the monitoring of groundwater, surface water and climate, and recording of cultural indicators, can be beneficial to future research. It is recommended that ongoing collection of the full data suite continue so that it can be leveraged to support decision-making and two-eyed seeing.

Partners and Linkages

Partners included: BC Energy Regulator, Ministry of Energy, Mines and Low Carbon Innovation, Shell Canada Ltd., Ministry of Environment and Climate Change Strategy, Ministry of Water, Land and Resource Stewardship, Matrix Solutions Inc., Geoscience BC, Staff and Knowledge Holders from participating First Nation communities.

References

Rolick, R.L., S.L. Lapp, W.T. Van Dijk and B.P. Shepherd. (2024): Pilot Collaborative Water Monitoring Program, Northeastern British Columbia: Final Program Report; Report 2024-06. Geoscience BC. 35pp.

Project Contacts

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Funding Acknowledgements:
Geoscience BC

3. GROUNDWATER CHARACTERIZATION AND RESEARCH

The Provincial Groundwater Program supports ongoing groundwater science and research projects to promote effective groundwater resource stewardship and to provide a technical basis for groundwater policy development. A number of these projects directly involve working closely with Indigenous Nations in the area of study.

In 2023-24, groundwater–surface water interaction studies were the primary area of focus. Research projects included both field-based studies and desktop studies, which encompassed a variety of objectives and focus areas. Advanced modelling assessments are becoming more common as water managers look to understand the cumulative effects of surface and groundwater withdrawals on the landscape. Assessments may also support the effective management of water resources during drought conditions.

Research into drought and extreme events also continued in 2023/24, with the River Forecast Centre and the Pacific Institute for Climate Solutions both funding projects to better understand and predict these events. In addition, work continues to improve access to groundwater information and data in B.C. through the compilation of various datasets into the aquifer dashboard and GWELLS.

Studies to characterize the location and dynamics of Groundwater – Surface Water interactions included:

- Assessment of Groundwater – Surface Water interactions on the Vaseux Creek Alluvial Fan, Oliver, B.C.
- Groundwater- surface water exchange dynamics in low gradient and tidally influenced streams in the Lower Fraser Valley.
- Upper Bulkley Groundwater – Surface Water Interaction Project, Houston, B.C.
- Preliminary Assessment of Hydraulic Connection, Chilliwack, B.C.
- Impact of Cumulative Groundwater Withdrawal on Surface Water and Groundwater Interaction in Stoney Creek Watershed, Vanderhoof, B.C.
- Rithet's Bog Groundwater Study, Saanich, B.C.
- Watershed Modelling to Support Water Allocation and Planning in the Shawnigan Creek Watershed, Vancouver Island, B.C.
- Prediction of Fresh Water Spring Location Using Random Forest Machine Learning, Doig River, B.C.

Studies that focus on the role of groundwater and drought:

- Drought and deluge: Informed water allocation decision making in a world of intensifying hydrologic extremes, South Alouette Watershed.
- Groundwater and drought - Implementation of groundwater level percentiles to support British Columbia's drought response.

Improving access to groundwater data in B.C.:

- Updates and enhancements to the GWELLS application and associated databases.

Assessment of Groundwater/Surface Water Interactions on the Vaseux Creek Alluvial Fan, Oliver, B.C.

Project Description

The Vaseux Creek Groundwater/Surface Water Interactions Study is a three-year project jointly managed by the Ministry of Water, Land and Resource Stewardship and the Okanagan Nation Alliance (ONA) on the traditional lands of the Osoyoos Indian Band (OIB). snʕaxəlqaxʷiyaʔ (Vaseux Creek) is a site of regular water scarcity-based conflict related to flow requirements for culturally significant fish species, anthropogenic water use demands, and the current hydrological regime. Analysis will inform our understanding of the dynamics between groundwater and surface waters to support effective water management on this site.

snʕaaxə lqaxʷiyaʔ (Vaseux Creek)
Photo: J. Pogson

Project Outcomes

Year 3 of 3 included refinement of the site conceptual model, on-going maintenance of six hydrometric stations, eight groundwater level monitoring locations, one Okanagan River level monitoring location, aquifer hydraulic conductivity testing at wells, collection of water level and quality data throughout the hydrologic year and summarizing the guidance from syilx Traditional Ecological Knowledge Keepers (TEKK).

Relevance

Pressures on water availability is increasing in many locations across the province due to expanding development, land use changes, and climate change effects. This study advances a deeper understanding of the relationship between snʕaxəlqaxʷiyaʔ (Vaseux Creek) and the underlying aquifer. By assessing the impact of water use on the system, it informs aquatic ecosystem recovery efforts and water management activities such as water licensing and drought response.

Learnings and Recommendations

Groundwater/surface water interactions on the Vaseux Creek alluvial fan are spatially and temporally complex. Environmental tracer analysis indicated three distinct sources of groundwater: mountain block recharge, the Okanagan River mainstem, and Vaseux Creek. Generally, Vaseux Creek loses water between the apex and the mouth with loss concentrated in the central braided and lower channelized sections of the fan. The naturalised rate of stream loss is a function of creek stage, wetted area, time since freshet, continuity of creek flow (antecedent moisture conditions when events occur), and groundwater level due to river stage rise. The actual loss of water from the creek is greater due to surface water diversions. This study concluded that the frequency and duration of dry periods would have been reduced without this additional loss from surface diversions. Groundwater use may affect streamflow on the lower fan though further investigation is required to assess the timing and magnitude of these potential impacts.

Partners and Linkages

Okanagan Nation Alliance, Osoyoos Indian Band, The Nature Trust of British Columbia, University of British Columbia (Okanagan), Okanagan Basin Water Board, Department of Fisheries and Oceans- Habitat Stewardship Program, Okanagan College.

Project Contacts

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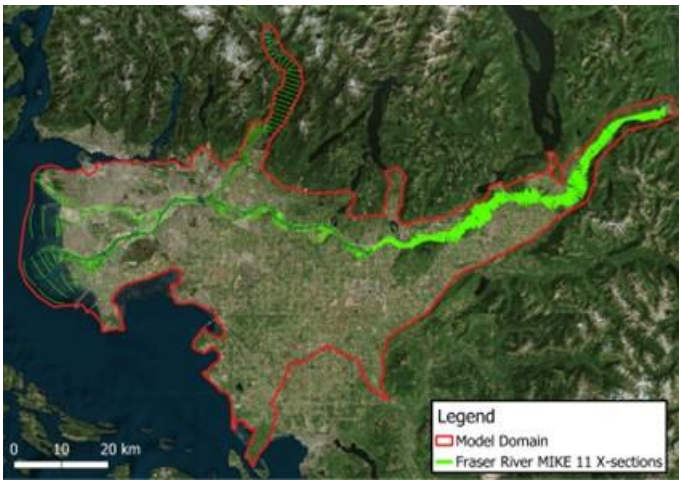
WLRS Groundwater Science Fund
WLRS South Area Regional Operations
ENV Groundwater Monitoring Program

BRITISH COLUMBIA

Groundwater - Surface Water Exchange Dynamics in Low-Gradient and Tidally Influenced Streams in the Lower Fraser Valley

Project Description

This study is focused on groundwater–surface water exchanges in tidally-influenced and low-gradient streams in the Lower Fraser Valley of the South Coast Natural Resource Region (South Coast Region). An empirical analysis of hydrometric data can aid in classifying stream types and identifying suitable flow indices that describe the variablity between stream types. A three-dimensional integrated hydrological model of the Fraser Valley will be used to characterize both the stream and groundwater flow regimes, as well as groundwater-surface water exchanges. Paired analysis of model output and empirical hydrometric data will be used to relate stream-type hydrological regimes to patterns of habitat availability and connectivity, which will help inform evaluations of ecological impacts of water withdrawals.



MIKE model domain and MIKE 11 River cross-sections.

Summary of Project Outcome

The goal of this project is to evaluate how aquifer-stream exchange and habitat dynamics vary among stream types. Over the past year, the focus has been on developing R scripts to characterize coastal lowland stream types. The hydrological model is being developed using MIKE software (DHI, 2023), which couples a MIKE SHE model with the B.C. River Forecast Centre's MIKE 11 River model. The geological model, developed by Simpson (2012), is being expanded to include the area east of Surrey, west to Chilliwack and North of the Fraser River. The MIKE 11 River model is being expanded to include all streams.

Relevance

Tidally-influenced and low gradient streams have unique flow patterns (e.g., tidal oscillations, flow cessation, and flow reversals), which preclude the use of standard methods used to assess Environmental Flow Needs (EFN). Currently there are no established methodologies in B.C. that support implementation of the *Water Sustainability Act* (WSA) for these stream types. Results of this study will inform water licensing under the *WSA* and contribute significantly toward the completion of actions outlined in the South Coast Region's 5-year water management plan.

Partners and Linkages

Simon Fraser University - Department of Earth Sciences, B.C. Ministry of Water, Land and Resource Stewardship - South Coast Region, B.C. Ministry of Water, Land and Resource Stewardship - B.C. River Forecast Centre.

References

DHI. (2023). MIKE SHE User Guide and Reference Manual. MIKE SHE (mikepoweredbydhi.help)

Simpson, M. 2012. Assessing Risk to Groundwater Quality Using an Integrated Framework. M.Sc. thesis, SFU.

Project Contacts

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Funding Acknowledgements:
WLRS Groundwater Science Fund

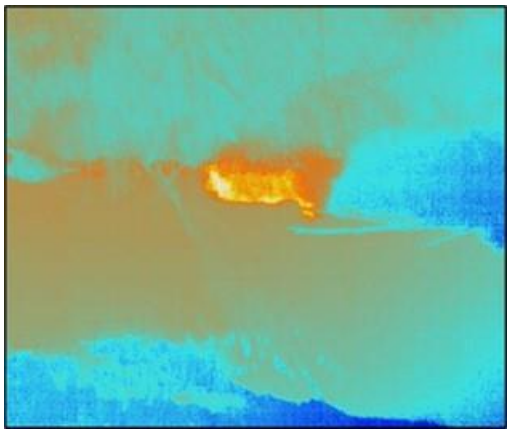
Upper Bulkley Groundwater – Surface Water Interaction Project, Houston, B.C.

Project Description

There is considerable interest around hydraulic connectivity and Environmental Flow Needs (EFN) in the Upper Bulkley River watershed. This is due to the watershed's natural propensity for drought and low flow conditions, high water temperatures, importance as a critical spawning area, and as a source of water.

Located east of Houston B.C., the watershed system has both a shallow valley fill aquifer with strong connections to surface water, and a separate deeper aquifer for which surface water connectivity is less well understood.

Initiated in 2018, the project used thermal drone imagery to guide groundwater level and seepage monitoring. At potential seepage locations, seepage meters and piezometers were placed in cross sections to monitor the flux of groundwater into the stream. Additionally, privately owned domestic wells were monitored to understand seasonal variability in the shallow and deep aquifers.



Thermal imagery of groundwater seepage into the Upper Bulkley River. Photo: S. Pittman

In-stream piezometer and seepage meter Photo: J. Wick

Project Outcomes

The project has entered the interpretation stage. Data collected includes drone imagery, aquifer water levels, and groundwater seepage discharge rates.

Relevance

The watershed's natural propensity for low water conditions and high-water temperatures raises considerations for water management in the area. This project supports not only water management decisions in the Upper Bulkley River watershed but is intended to provide critical water information to a multi-year, multi-stakeholder fisheries research project.

Learnings and Recommendations

Drone imagery was useful and should be considered for future projects. During equipment removal from the privately owned wells, it was found that one well was modified without notice. Use of that site and any data following the most recent visit was lost. Equipment at another volunteer site proved difficult to remove. Project leads should carefully consider these potential issues and risks before using private wells for aquifer monitoring.

Partners and Linkages

Project development and data sharing partners 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 use of private wells; and the B.C. Ministry of Forests.

Project Contacts

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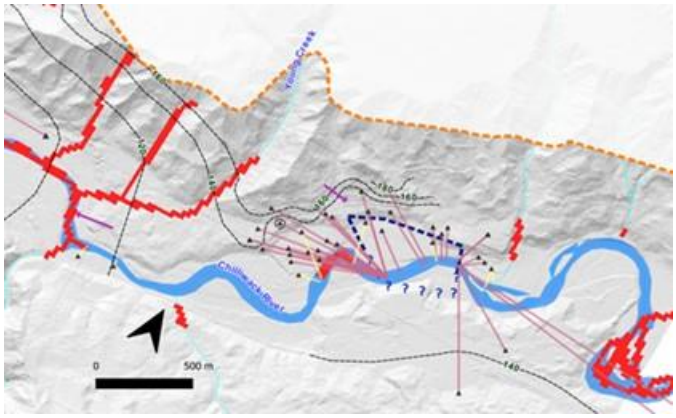
Funding Acknowledgements:
WLRS Groundwater Science Fund

Preliminary Assessment of Hydraulic Connection, Chilliwack, B.C.

Project Description

In this GIS-based desktop study, a conceptual model of how and where hydraulic connection between groundwater and surface water likely occurs was developed for 30 mapped aquifers in the City of Chilliwack. This assessment was then applied to estimate Streamflow Depletion Factors (SDF) for wells determined to be hydraulically connected.



Fraser Sumas Floodplain Points of Hydraulic Connection. Image: Wester Water Associates.

Project Outcomes

The study area was sub-divided into four distinct physiographic sub-areas: 1) the Fraser-Sumas Floodplain; 2) Columbia Valley-Cultus Lake; 3) Chilliwack River Valley; and, 4) Ryder Uplands. In each sub-area, the likelihood of hydraulic connection was inferred by mapping the groundwater flow directions, the presence/absence of a vadose zone, and the presence of a low permeability confining layer directly beneath the streams and then connecting wells to open stream reaches. Understanding of the aquifers and likelihood of hydraulic connection enabled conceptual models to be formulated regarding the sources of inflow, outflow and capture for the aquifers and to provide insight into the potential major allocation considerations.

Relevance

There is high reliance on groundwater in the City of Chilliwack, both for municipal drinking water supply and the large agricultural sector. Understanding the connection between groundwater and surface water is needed for water managers to assess licensing applications, to undertake curtailment during times of scarcity, and to assess total demand on streams when considering Environmental Flow Needs.

Learnings and Recommendations

Much of the Fraser River floodplain and Sumas Prairie area are underlain by lacustrine sediments with subtle but significant variability in lithology and permeability (e.g., silty sand versus clay). The data quality of well logs was found to be insufficient to interpolate the extent of potential confinement for the shallow unconfined aquifers. Instead, information from the B.C. Soil Survey Map was used to infer the presence of confining sediments. Soil mapping was compared to hydrogeological cross-sections, well logs, a Leapfrog model, and observations from a site visit (e.g., test pits, and areas of ponded water). It was found that soil polygons with >30% poorly or very poorly draining silt-clay loam or silt loam had the most representative distribution. It was recommended to seek opportunities to update the surficial geology and soils mapping in the area.

Calculated SDFs for most of the wells assessed in the study area range from less than a day to thirty days indicative of quick, responsive flow systems. This suggests taking action to curtail both surface water and groundwater uses to protect streamflow during drought is feasible.

References

Sivak, T. and M. Wei. 2024. Preliminary Assessment of Hydraulic Connection for the Chilliwack Area. Water Science Series, 2024-09, Province of B.C., Victoria.

Project Contacts

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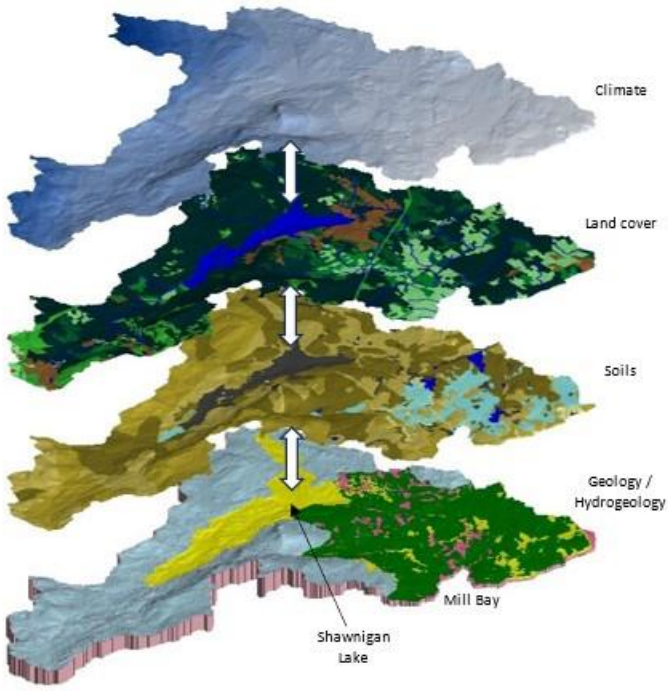
Funding Acknowledgements:
WLRS Groundwater Science Fund

Watershed Modelling to Support Water Allocation and Planning in the Shawnigan Creek Watershed, Vancouver Island, B.C.

Project Description

An integrated, physically based, three-dimensional numerical model of surface water and groundwater flow has been developed for the Shawnigan Creek watershed on Vancouver Island, B.C. This watershed has been subject to heightened stress in recent years due to increased water use and many groundwater wells that are likely hydraulically connected to fully recorded streams. The numerical model supports water allocation and planning efforts by serving as a decision support tool to assist West Coast Region staff in the conjunctive management surface water and groundwater resources.



3D conceptual model of the Shawnigan Creek watershed.

Project Outcomes

Key objectives and outcomes of the project include:

- Quantifying a monthly water balance that describes the primary inputs and outputs from the watershed – including precipitation, evapotranspiration, streamflow, overland flow, and groundwater flow. Results highlight periods of the year where there is a surplus or deficit of water and how the relative importance of each component of the water balance changes through the year.
- Quantifying hydraulic connection between aquifers and streams. Results suggest that the magnitude of hydraulic connection between aquifers and streams can not only vary spatially and temporally but also change direction in specific locations at certain times of the year.
- Quantifying cumulative effects of combined surface water and groundwater use on the water balance and hydraulic connection between aquifers and streams. Results suggest that water use has a small influence on the water balance but, depending on the direction of hydraulic connection, can lead to increased water losses from streams or reduced water gains to streams.
- Quantifying potential impacts of a future (conservative) climate projection on the water balance and hydraulic connection between aquifers and streams. Results suggest that future changes to precipitation and evapotranspiration can have an influence on the water balance and lead to increased water losses from streams in the summer months and increased water gains to streams in the winter months.

Relevance

This project illustrates an approach to support the Province's efforts to conjunctively manage surface water and groundwater and provides site-specific information that can be used by statutory decision makers when considering water licence applications. Future opportunities could include developing and applying similar numerical models to support water allocation and planning in other water-stressed areas of the province.

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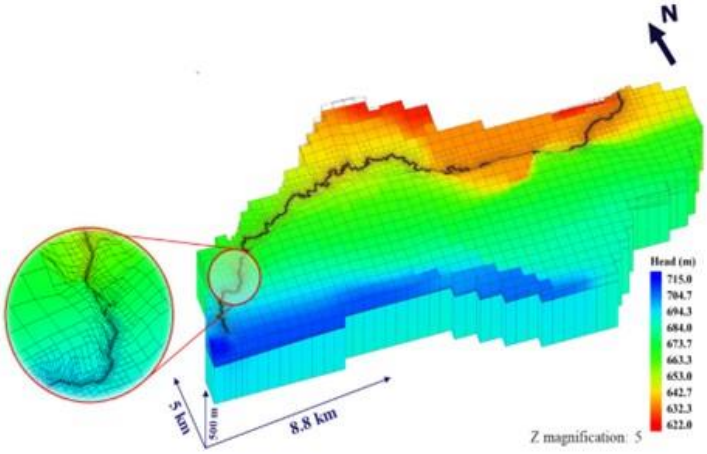
Funding Acknowledgements:
WLRS Groundwater Science Fund

Impact of Cumulative Groundwater Withdrawal on Surface Water and Groundwater Interaction in Stoney Creek Watershed, Vanderhoof, B.C.

Project Description

Groundwater and surface water form two interconnected components of the water cycle. Interactions between the two are a critical factor to consider when making groundwater management decisions. Often, hydraulic connectivity between surface water and groundwater is assessed by pumping one or several wells for a short period of time. However, this does not fully assess the impact of cumulative groundwater withdrawal, especially over longer time frames. This project attempts to address these unknowns by creating a three-dimensional model of these interactions in the Stoney Creek Watershed.



Three-dimensional numerical model of the interaction between aquifers and Stoney Creek within the Stoney Creek

Project Outcomes

In this project a numerical groundwater and surface water interaction model using a high-resolution digital elevation model (DEM) was employed to understand how groundwater withdrawal effects can change the behavior of groundwater and river interactions in a heterogeneous groundwater system in the Stoney Creek Watershed. The interaction between groundwater and Stoney Creek was modelled using the three-dimensional MODFLOW-USG code. The model parameters were calibrated using PEST, a parameter estimation code. Moreover, the risk analysis comprises two main components, hazard and vulnerability were utilized to classify production wells and determine the risk zones based on modeled water level changes due to groundwater withdrawal along with well location, type, and depth.

Relevance

Compared to the previous model developed for the project area (Aghbelagh et al., 2018), the current domain has been refined based on the newly available lithology data and recent aquifer mapping (Hinnell et al., 2020). The calibrated model will help water resources management to assess different water use and climate change scenarios.

Learnings and Recommendations

Stoney Creek is well connected to unconfined aquifers and is a primary source of shallow groundwater flow. However, there is uncertainty in the locations and degree of hydraulic connectivity between the surface water and the deeper confined aquifers, which posed a challenge for model calibration. A rigorous monitoring network is recommended to provide necessary data to further model validation.

Partners and Linkages

University of Northern British Columbia

References

Aghbelagh Y.B., J. Li, and J. Yin. 2018. Surface water and groundwater interactions in the Stoney Creek watershed: Insights from numerical groundwater flow modeling, EcoCat Report ID: 58104

Hinnell, A.C., T. Lengyel, S. Funk, J.J. Clague and Z.M. Hammond. 2020. Vanderhoof and Houston Aquifer Mapping and Hydrostratigraphic Characterization, Water Science Series, WSS2020-07. Province of British Columbia.

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Funding Acknowledgements:
WLRS Groundwater Science Fund

Rithet's Bog Groundwater Study, Saanich, B.C.

Project Description

Rithet's Bog, situated within the Colquitz watershed, is a 42-hectare nature sanctuary, and the last remaining bog ecosystem is the Greater Victoria area. The larger Colquitz watershed hosts a mix of predominantly agricultural and residential land and extends over the majority of the District of Saanich. The watershed has been extensively altered to reduce flooding and facilitate development resulting in highly variable streamflow and decreased groundwater discharge. Consequently, erosion of streambanks and water quality issues are concerns. Downstream of Rithet's Bog, the watershed hosts several fish species (cutthroat trout, stickleback, sculpin, salmon and bullhead); however, fish populations today are thought to be lower than historical levels. Rithet's Bog plays a key role within the watershed in buffering seasonal variation in downstream flow through water storage and nutrient uptake while providing important habitat for native plants and wildlife with limited local distribution. A weir was installed to improve water level stability and limit outflow from the bog in 2002. Today, over twenty years after this restoration action, volunteers with the Rithet's Bog Conservation Society have determined that although restoration actions have created some improvements, low summer water levels continue to be an issue, re-establishing native vegetation has been challenging, and further restoration actions are needed.

In Phase 1 of the study, precipitation, surface water and groundwater monitoring stations have been established to collect baseline data. Monitoring at these stations is ongoing. Quarterly water quality monitoring is being conducted to integrate water quantity information with water chemistry enriching the understanding of site conditions.

Groundwater monitoring within an area near the wetland inlet. Photo: Klaus Rathfelder

Labrador tea growing in the internal bog area. Photo: Klaus Rathfelder

Project Relevance

Previous research has demonstrated the significance of wetland interaction with groundwater regimes. Wetlands can serve as groundwater discharge or recharge zones depending on their climate, location, and seasonal effects. The connection between urban hydrogeology and ecosystem health has been understudied and more recently awareness of the potential impacts of land use development on ecosystems has developed.

Partners and Linkages

The Province is partnering with the Rithet's Bog Conservation Society and the District of Saanich to supply information and analysis that will support updates to Saanich's drainage planning or additional actions to support restoration.

Project Contacts

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Funding Acknowledgements:
WLRS Groundwater Science Fund

Prediction of Fresh Water Spring Location Using Random Forest Machine Learning, Doig River, B.C.

Project Description

The project leverages random forest machine learning to predict the locations of freshwater springs; a significant step forward from traditional regression analysis methods. Freshwater springs hold high environmental, cultural, and economic significance, hosting unique species and providing crucial microhabitats. However, their locations are influenced by various environmental and geological factors, making their prediction complex. While classic regression methods are invaluable in identifying linear relationships, they often struggle with complex patterns found in environmental and geological datasets. In contrast, random forests can effectively model these intricate relationships, constructing multiple decision trees to produce more accurate and robust predictions.

2023 results vs 2024 results.

Project Outcomes

The output from the random forest machine learning process offers an array of accuracy statistics, providing a detailed understanding of the model's predictive performance and the impact of each variable. Recent advancements have included the Normalized Difference Vegetation Index (NDVI) as an additional data layer, improving the model's accuracy, precision and recall. Additionally, research into alternative machine learning models, such as the Maximum Entropy (MaxEnt) model, is ongoing, furthering our goals to improve the model over the next year. We are actively preparing for field validation efforts, a crucial part of our project to both validate the model and identify additional spring locations. Furthermore, LiDAR imagery was processed and converted into a high-resolution digital elevation model (DEM) to compare with areas with the predicted presence of springs.

Relevance

Predicting the location of freshwater springs is of immense relevance due to their environmental, cultural, and economic importance. With changing climatic conditions and anthropogenic disturbances, springs are under increasing pressure. Understanding their potential locations will contribute to their conservation and sustainable use, benefiting ecosystems and human communities.

Learnings and Recommendations

This project has demonstrated the power and utility of machine learning in environmental science. Machine learning can capture complex relationships between multiple variables, making it an invaluable tool in predictive ecological studies. Moving forward, we will identify additional spring locations from field surveys and explore alternative machine-learning models to potentially increase overall accuracy and strengthen the application of the model to ongoing conservation and restoration efforts.

Partners and Linkages

Doig River First Nation, UNBC GIS lab.

References

Bystron, I. 2018. GIS-based analysis of spring occurrence and spring source areas in Peace River Regional District, British Columbia. [Date created: 2018-04-12]. Summit Research Repository (sfu.ca)

Project Contacts

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Funding Acknowledgements:
FOR Water Research Portfolio

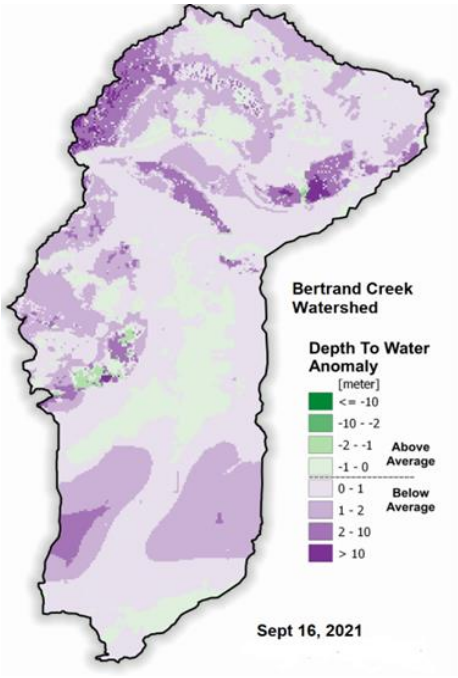
Drought and Deluge: Informed Water Allocation Decision Making in a World of Intensifying Hydrologic Extremes

Project Description

Climate change is resulting in shifts in hydrologic regimes that are increasingly accompanied by intensified extremes, including heavy rain events and prolonged drought periods. This Pacific Institute for Climate Solutions (PICS) Opportunity Project focuses on developing an adaptation solution to climate change, specifically, a strategy for building resilience to the impacts of climate extremes on water resources that can be implemented in water allocation decision making.

Summary of Project Outcome

Simon Fraser University hydrologists have partnered with Ministry of Water, Land and Resource Stewardship staff in the South Coast Region to 1) understand how coastal watersheds respond to extreme climate; and, 2) identify tools that can be used to aid in water allocation decision making.



Results of numerical groundwater model in Bertrand Creek watershed. Image: Simon Fraser University.

Relevance

Currently, water licences are issued in perpetuity; however, under s. 23 of the *WSA* a Water Manager may direct a licensee to submit to a review of the terms and conditions of their licence. There is currently no guidance on when, where (e.g., focus on selected areas) or how to do this review. The review offers a window of opportunity to introduce new terms and conditions for the water licence (e.g., monitoring, or a reduction in the water licence volume) to address climate extremes. In this regard, the Province is seeking input on what to consider when water licences are reviewed, and what new terms and conditions could be introduced.

Learnings and Recommendations

Year 2 of this project involved analyzing field data collected in the North Alouette Watershed during extreme weather conditions (e.g., the atmospheric rivers in 2021-22 and subsequent heavy rain events, and summer drought conditions in 2022 and 2023). Data include: stream temperatures (from in situ loggers, a drone mounted thermal infrared (TIR) sensor, and a LandSat TIR sensor); streambed temperatures; nitrate concentrations; stable isotopes of precipitation and waters. Integrated hydrological models of the North Alouette and Bertrand Creek watersheds were developed to quantify hydrological responses to extreme weather events. Observation well data throughout the Fraser Valley were analyzed to quantify the magnitude of groundwater level responses to extreme precipitation events and drought.

Partners and Linkages

Pacific Institute for Climate Solutions (PICS) – project funding
Diana Allen (Earth Sciences) and Jesse Hahm (Geography), Simon Fraser University
Jacquelyn Shrimer, Elyse Sandl and Michele Lepitre, B.C. Ministry of Water, Land and Resource Stewardship
Marc Porter, Pacific Salmon Foundation
Eric Saczuk, British Columbia Institute of Technology

Project Contacts

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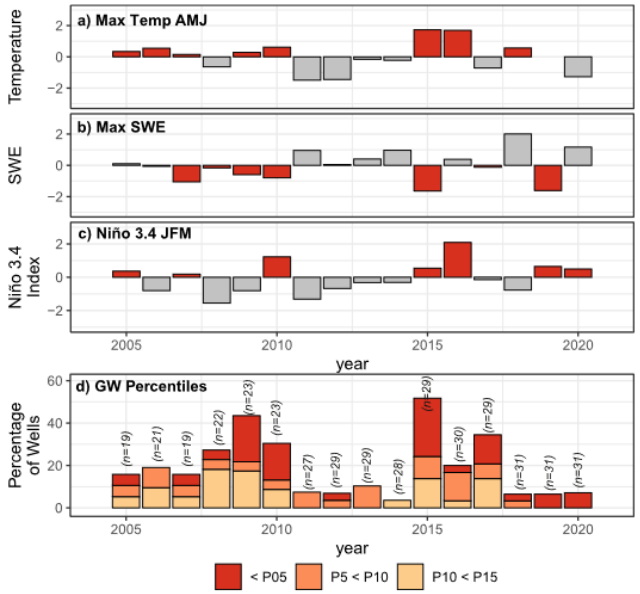
Funding Acknowledgements:
Pacific Institute for Climate Solutions
South Coast Regional Operations

Groundwater Drought Forecasting

Project Description

Groundwater drought can pose a major threat to the availability of groundwater for maintaining stream baseflows and water supply in B.C. The Province currently utilizes groundwater level percentiles from the Provincial Groundwater Observation Wells Network (PGOWN) to track groundwater conditions during drought seasons to inform their drought response. Having an early season indicator of groundwater drought could potentially provide advanced notice of groundwater conditions. Gullacher et al. (2023) identified hydroclimatic variables that could be used as early warning indicators for groundwater drought. This multi-year project aims to determine the feasibility of using hydroclimate variables to forecast groundwater conditions using statistically based models.



Hydroclimatic variables (spring temperature, maximum winter snow water equivalent, and the winter Niño 3.4 Index) that were determined to have relationships with low groundwater levels in South Central B.C. from Gullacher et al., 2023.

Project Outcomes

The overall objective of this project is to develop a model that can forecast the likelihood of groundwater levels in PGOWN wells being below normal (in possible drought conditions) in the weeks or months after the model is run. This feasibility study is using select wells across the province with sufficient data quality to determine if groundwater drought can be forecasted. If the model performs well, it could be expanded operationally. This model could then potentially provide a critical early heads-up for water managers to prepare for drought conditions.

Partners and Linkages

This project expands and potentially operationalizes the work completed in previous years (see References below) in the groundwater and drought projects led by Diana Allen from Simon Fraser University (SFU). This project is led by the River Forecast Centre in collaboration with SFU and staff in the Ministry of Water, Land, and Resource Stewardship, and Ministry of Environment and Climate Change Strategy.

References

Gullacher, A., Allen, D. M., & Goetz, J. D. (2021). Classification of groundwater response mechanisms in provincial observation wells across British Columbia, and Appendix A (data file). British Columbia Water Science Series. WSS2021-03. Retrieved from https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=59107

Gullacher, A., Allen, D. M., & Goetz, J. D. (2023). Indicators of Groundwater Drought in British Columbia. British Columbia Water Science Series. WSS2023-01. Retrieved from https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=60200

Gullacher, A., Allen, D. M., & Goetz, J. D. (2023). Early Warning Indicators of Groundwater Drought in Mountainous Regions. Water Resources Research. https://doi.org/10.1029/2022WR033399

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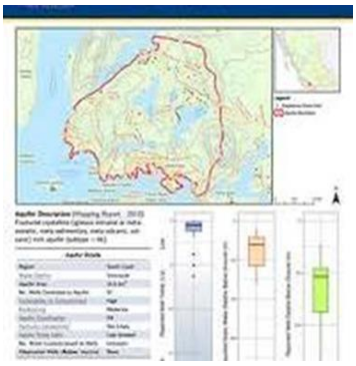
Funding Acknowledgements:
WLRS B.C. River Forecast Center

GWELLS Application and Aquifer Factsheet Updates

Project Description

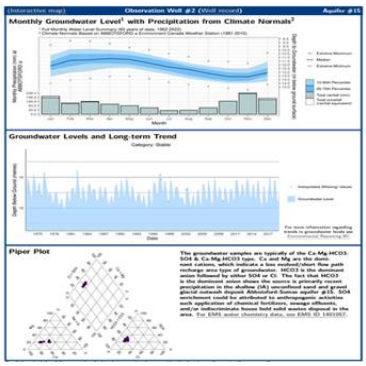
The Groundwater Wells and Aquifers (GWELLS) application is an interactive web-based platform for locating and accessing groundwater related information, including Provincial well records, aquifer and hydrogeologic information, and the registry of certified well drillers and pump installers. This project is a continuation of ongoing work to maintain, update, and enhance features and functionality of GWELLS. The main objective of the aquifer factsheets is to provide the most relevant aquifer information in a clear, concise, and easy-to-understand way.



Aquifer Factsheet Page 1

Summary of Project Outcomes

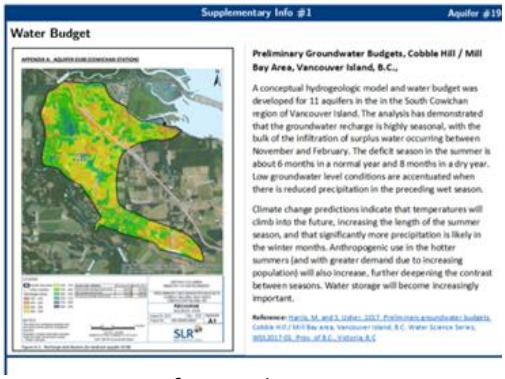
Work completed this year includes an update of the aquifer factsheets using the scripting languages R and R-markdown to retrieve, clean, analyze, summarize and display groundwater data in a concise manner. With support from the Groundwater Science Program, an R support contractor assisted with the scripting and designing of the various components of the factsheet into a concise format. Approximately 1238 auto-generated aquifer factsheets were produced during the 2023/24 fiscal year. Most of the aquifers (75%) have a one page aquifer factsheet with basic aquifer information. 12% of the aquifers have a two page aquifer factsheet with basic aquifer information, long-term groundwater level trends and water chemistry Piper plots. About 7 % of the aquifers have a 3 page aquifer factsheet with basic aquifer information, long-term groundwater level trends, water chemistry Piper plots and a cross section/ numerical model/ water budget and/or water quality information. About 6% of the aquifers have a two page aquifer factsheet with basic aquifer information and a cross section/ numerical model/ water budget and/or water quality information. All of the aquifers with a 2- and 3-page factsheet with long-term groundwater level trends and water chemistry Piper plots are associated with the Provincial Groundwater Observation Network (PGOWN) wells.



Aquifer Factsheet Page 2

Relevance

Providing aquifer information in a clear, concise, and easy-to-understand format assists statutory decision makers, academia, industry and the general public to make consistent, informed and efficient decisions related to sustainable water management.



Aquifer Factsheet Page 3.

Learnings and Recommendations

This project has demonstrated the power and utility of R scripts to work with large datasets in a manner that is reproducible, easily updateable and in an automated fashion.

Partners and Linkages

The aquifer fact sheet update was completed with an R support contract and oversight by staff in the Ministry of Water, Land, and Resource Stewardship.

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Funding Acknowledgements:
WLRS Groundwater Science Fund

4. ACKNOWLEDGEMENTS

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- B.C. River Forecast Centre
- B.C. Energy Regulator
- Blueberry River First Nations
- British Columbia Institute of Technology
- City of Terrace
- Department of Fisheries and Oceans Canada
- District of Houston
- District of Saanich
- Doig River First Nation
- Geoscience BC
- Halfway River First Nation
- Matrix Solutions Inc.
- McLeod Lake Indian Band
- Ministry of Agriculture and Food
- Ministry of Energy, Mines and Low Carbon Innovation
- Ministry of Environment and Climate Change Strategy
- Ministry of Forests
- Ministry of Water, Land and Resource Stewardship
- Nature Trust of British Columbia
- Office of the Wet'suwet'en
- Okanagan Basin Water Board
- Okanagan College
- Okanagan Nation Alliance
- Osoyoos Indian Band
- Pacific Institute for Climate Solutions
- Pacific Salmon Foundation
- Regional District of Bulkley-Nechako
- Rithet's Bog Conservation Society
- Saulteau First Nations
- Shell Canada Ltd
- Simon Fraser University – Department of Earth Sciences
- University of British Columbia (Okanagan)
- University of Northern British Columbia
- Upper Bulkley River Streamkeepers
- West Moberly First Nations
- Wet'suwet'en First Nation
- Yukon Department of Environment