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Ontario Geological Survey
Open File Report 6387

Regional-Scale Groundwater Geoscience in Southern Ontario: The 2023 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House

2023

ONTARIO GEOLOGICAL SURVEY

Open File Report 6387

Regional-Scale Groundwater Geoscience in Southern Ontario: The 2023 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House

Compiled by

A.K. Burt, D. Ford, S. Holysh, K.J.J. Kalmo and H.A.J. Russell

2023

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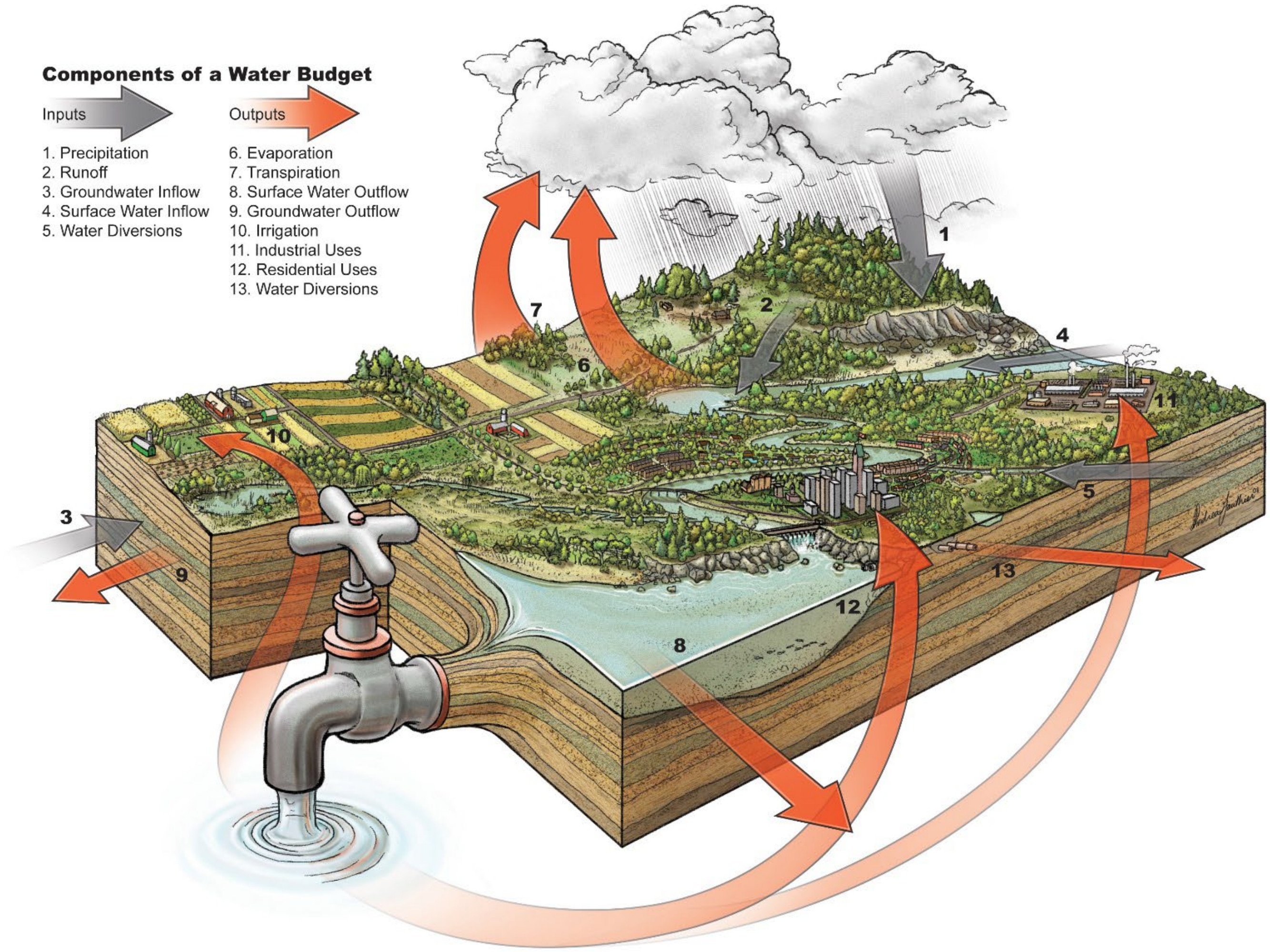
Regional-Scale Groundwater Geoscience in Southern Ontario: The 2023 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House

February 21, 2023 | Virtual Meeting

February 23, 2023 | Waterloo, Ontario



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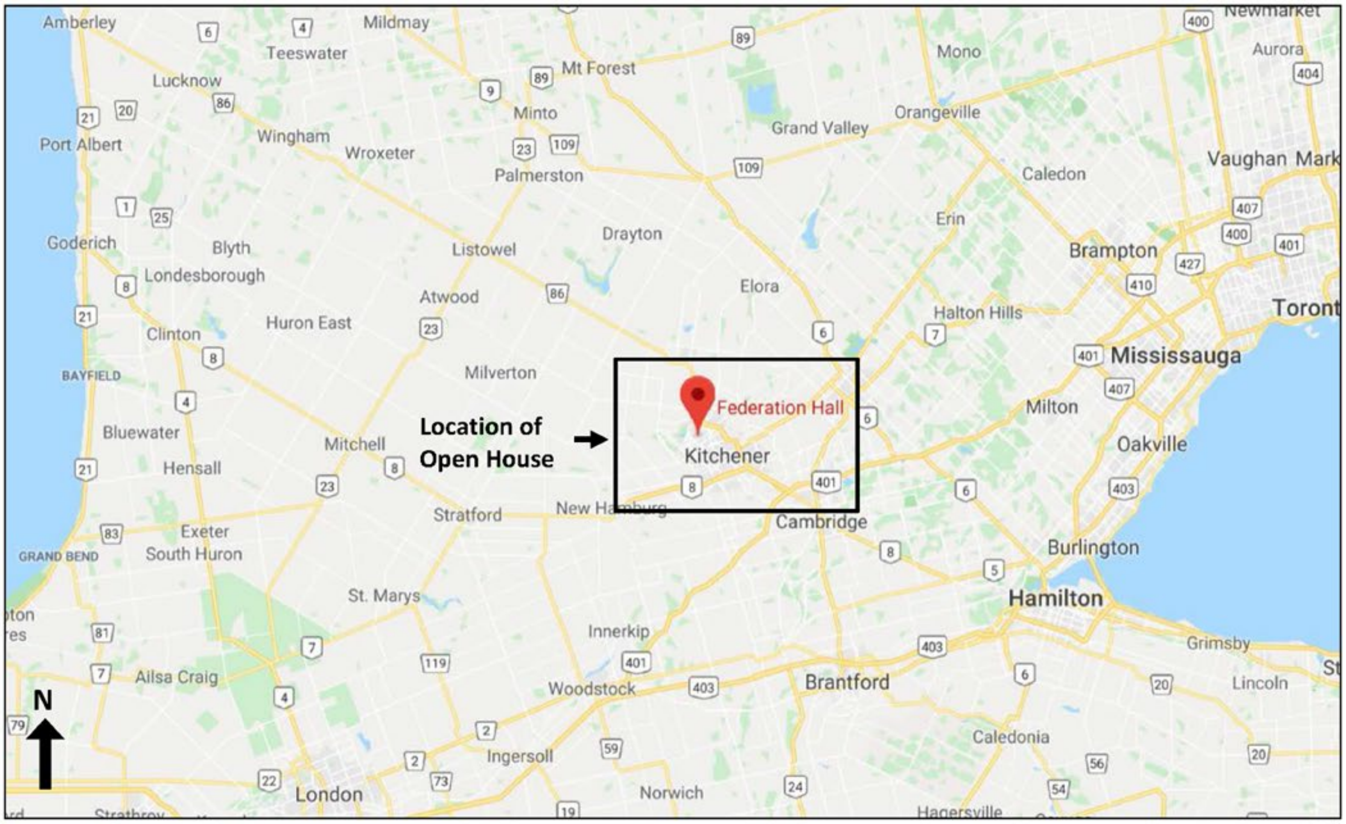
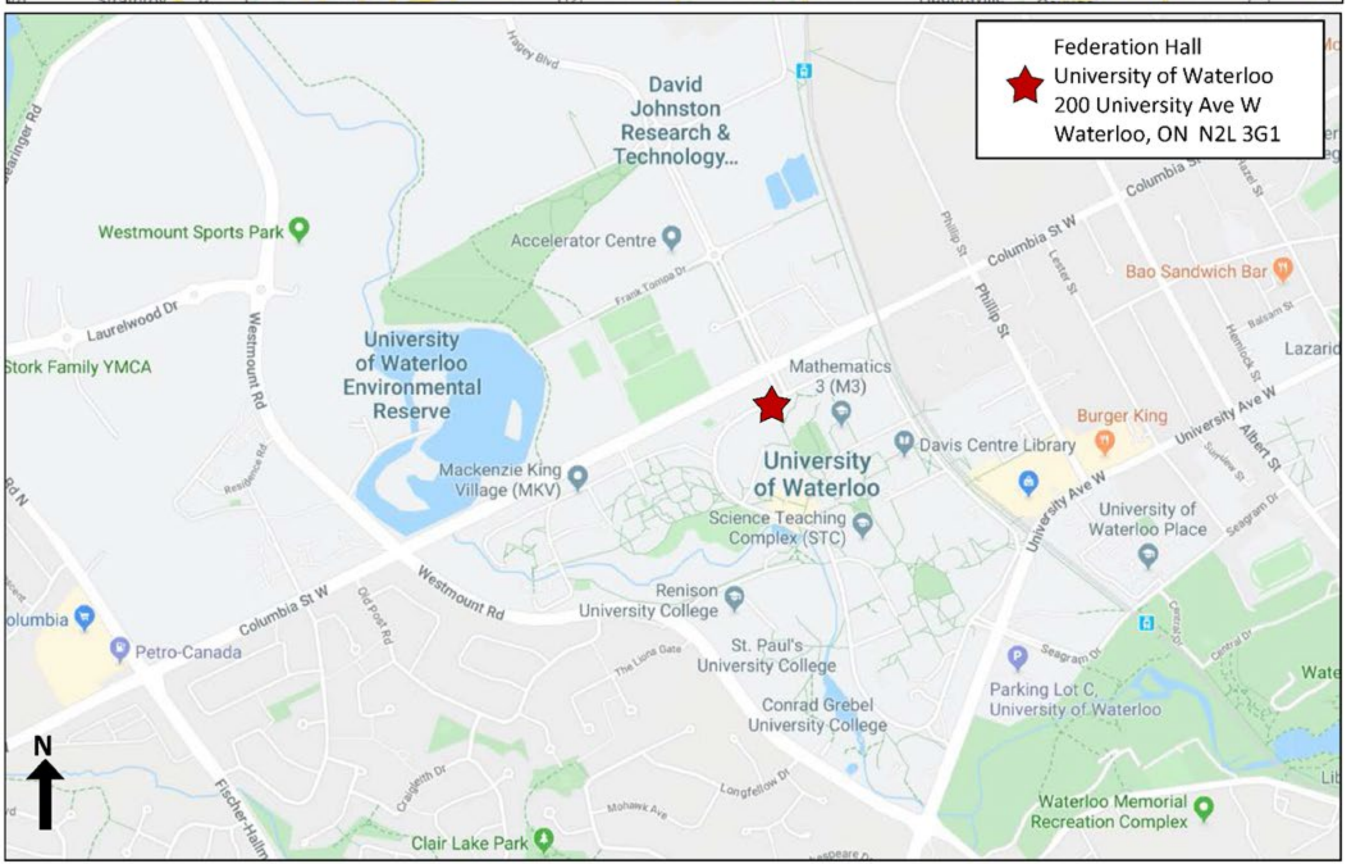
Location Map





Program

February 21 Virtual Oral Presentations

START	END	TITLE	PRESENTER	AFFILIATION	SESSION THEME
12:30	12:50	Opening Remarks and Land Acknowledgements	Beneteau / Boisvert / Bennett	OGS / GSC / OGS	
12:50	13:10	Science, Policy, and Community Connections: How the Past 25 Years Strengthened Local Understanding and Consideration of Groundwater Resources in Ontario	Coleman	CO	**Groundwater Programs and Policies**
13:10	13:30	Ministry of Environment, Conservation and Parks - Groundwater Activities Update	Brodie-Brown	MECP	
13:30	13:35	Provincial Geotechnical Borehole Database Refinements	Burt	OGS	**Data, Methods and Techniques**
13:35	13:55	The Geoscience Information Platform Program – Filling the Geoscience Data Gap	Lee	City of Ottawa	
13:55	14:00	Lithological Lock-down – Standardizing Geological Descriptions in Well Records	Burt	OGS	
14:00	14:05	The New GeologyOntario	Dodge / Sullivan	OGS	
14:05	**14:25**	**Discussion, Questions and Break**			
14:25	14:45	Meadow Restoration Along a Hydro Corridor in Toronto: Enhanced Hydrological Regulating Services	Qin	WSP Golder	**Land Management Practices**
14:45	14:50	Geochemical Analysis of Sources of Chloride in Groundwater and Surface Water of Varying Land Uses in Southern Ontario, Canada	Lackey	University of Guelph	
14:50	15:10	The Western Champlain Sea Regional Aquitard: Emerging Insights from Multidisciplinary Geoscience	Hinton	GSC	**Paleozoic / Surficial Geology Modelling, Characterization and Applications**
15:10	15:30	Time-Series Analysis of Champlain Sea Sediments using CT Scans from the Bilberry and Voyageur Creek Boreholes, Ottawa, Ontario	Herath	University of Ottawa	
15:30	15:50	Microtextural Analysis of Champlain Sea Mud, Ottawa, Ontario: Meiofaunal Activities and Their Geochemical Implications	Al-Mufti	GSC	
15:50	16:10	A Retrospective of 3-D Modelling of the Bedrock Geology and Hydrostratigraphy of Southern Ontario	Carter	Carter Geologic	
16:10	16:15	Investigating the Reliability of Borehole Density, Neutron and Sonic Logs for Porosity Estimation in the Silurian Lockport Group, Ontario	Ningthoujam	University of Ottawa	
16:15	16:35	Canada1Water: Groundwater–Surface Water Modelling for Climate Change Adaptation	Russell	GSC	**National Perspectives**
16:35	**16:45**	**Discussion, Questions and Closing Remarks**			

Program (continued)

February 23 In-Person Oral Presentations

START	END	TITLE	PRESENTER	AFFILIATION	SESSION THEME
8:00	8:55	Registration, Networking and Poster Session			Paleozoic / Surficial Geology Modelling, Characterization and Applications
8:55	9:20	Opening Remarks and Land Acknowledgements	Beneteau / Ford / Bennett	OGS / TRCA / OGS	
9:20	9:40	Filling the Hole – Introducing the Guelph 3-D Sediment Mapping Project	Burt	OGS	
9:40	10:00	Towards a Hydrogeological Understanding of the Provincial Groundwater Monitoring Network	Mulligan	OGS	
10:00	10:20	How Critical Review of WWIS Data Renewed the Debate over the Continuity of a Buried Bedrock Valley in Halton Region	Meyer	Aqua Insight Inc.	
10:20	**10:50**	**Break, Networking, Poster Session**			
10:50	11:10	Monetizing the Comprehensive Role of Water in Sustaining Ecosystem Services with a Fully Integrated Subsurface–Surface Water Model	Aziz	Aquanty	Groundwater / Surface Water Modelling
11:10	11:30	Modelling Groundwater Discharge to Surface Water Receptors Across Southern Ontario	Frey	Aquanty	
11:30	11:35	Analyzing Pathways via Which Septic System Wastewater Effluent Reaches Tributaries	Jobity	University of Western Ontario	
11:35	11:40	Evaluating Source Water Contributions to Streamflow in a Mixed Land-Use Precambrian Shield Watershed in the Sudbury Region: The Whitson River Subwatershed	Montgomery	Nipissing University	
11:40	12:00	Watershed-Scale Groundwater Data Communication at the Grand River Conservation Authority	Strynatka	GRCA	Outreach and Communication
12:00	12:20	Adapting Community Education and Engagement in a Changing Environment to Complement Water Management	Gomez Canzio	WWCGF	
12:20	**13:20**	**Lunch, Networking, Poster Session**			
13:20	14:50	Do Hydrogeological Data and Analyses Matter? Can They Help us Build Homes Faster?: A Panel Discussion on the Evolving Role of Hydrogeologists in Ontario Society	Holysh, Gerber, Gautrey, Chevrier, Hodgins	ORMGP, WSP, TRCA, RMW	Panel Discussion
14:50	**15:20**	**Break, Networking, Poster Session**			
15:20	15:40	Aquatic Ecotoxicology Measures Applied to Contaminated Groundwater Discharge to Surface Waters	Roy	ECCC	Aqueous Geochemistry, Isotopes and Contaminants
15:40	15:45	Investigating Watershed Behaviour and Nutrient Transport in an Intensively Managed Agricultural Watershed	Rixon	University of Guelph	
15:45	16:05	Estimation of Direct Groundwater Discharge and Salt (NaCl) Loading to the North Shore of Lake Ontario	Marchildon	ORMGP	
16:05	16:25	The Gas Well–Hydrogen Sulphide Connection in Ontario’s Groundwater. What It Means, Where It Happens, and What We Could Do To Fix It	Hamilton	Matrix Solutions Inc.	
16:25	**16:35**	**Wrap-up**			

Program (continued)

February 23 Poster Presentations

	TITLE	AUTHOR / PRESENTER	AFFILIATION
1	Ontario Geological Survey Student Outreach	OGS	OGS
2	Tritium in Shallow Groundwater of Southern Ontario	Priebe	OGS
3	Mapping of Background Groundwater Quality in Southern Ontario	Colgrove	OGS
4	Ambient Groundwater Program	OGS	OGS
5	Stick in the Mud Science: Geological Investigations in the City of Ottawa and Surrounding Champlain Sea Plain	Mulligan	OGS
6	Provincial Geotechnical Borehole Database Refinements	Burt	OGS
7	Lithological Lock-down – Standardizing Geological Descriptions in Well Records	Burt	OGS
8	3-D Sediment Models: Key Outputs	OGS	OGS
9	OGS Seamless Map Products	OGS	OGS
10	Aggregate Resources of Ontario Compilation	Handley	OGS
11	Refining a Regional Lithostratigraphic Model of the Elora Buried Bedrock Valley Using Airborne Electromagnetic and Magnetic Measurements	Gorrie	University of Guelph
12	Sedimentological Underpinnings of an Ongoing Buried Bedrock Valley Investigation in Elora, Ontario	Brown	University of Guelph
13	Climate Change Effects on Agricultural Nutrient Transport in a Southern Ontario Sand Plain System	Zeuner	University of Guelph
14	Analyzing Pathways via Which Septic System Wastewater Effluent Reaches Tributaries	Jobity	University of Western Ontario
15	Evaluation of Factors Influencing the Amount of Septic System Effluent Delivered to Streams	Angus	University of Western Ontario
16	Geochemical Analysis of Sources of Chloride in Groundwater and Surface Water of Varying Land Uses in Southern Ontario, Canada	Lackey	University of Guelph
17	Less is More: Road Salt Threatens Urban Water Quality	Radosavljevic	University of Waterloo
18	The Effect of Soil Moisture Content on Naphthalene Biodegradation	Ye	University of Waterloo
19	Effects of Groundwater Fluctuations on Natural Source Zone Depletion of Petroleum-derived Hydrocarbons in Contaminated Soils	Ramezanzadeh	University of Waterloo
20	How will Decreasing Winter Snow Cover Affect Agricultural Soil Nitrogen Cycling and Leaching to Groundwater: Results from a Lysimeter Study	Green	University of Waterloo
21	Microplastics Pollution: What Can We Learn from Stormwater Pond Sediments?	Nguyen	University of Waterloo
22	Separating and Analyzing Microplastics in Environmental Water and Soil Samples	Li	University of Waterloo
23	Investigating Drivers of Microplastic Pollution in Urban Settings	Reshadi	University of Waterloo
24	Modelling Phosphorus Retention in a Bioretention Cell: Implication for Groundwater Pollution	Zhou	University of Waterloo

	TITLE	AUTHOR / PRESENTER	AFFILIATION
25	Land Cover and Use as Drivers of Stream Chemistry and Dissolved Organic Matter Quality	Sethumadhavan	Brock University
26	Climate Change Impacts on Groundwater Contribution to the Streamflow Across a Mesoscale Precambrian Shield Watershed in Northeastern Ontario	Tafvizi	Laurentian University
27	Application of Text Mining and Machine Learning Algorithms in Describing Nutrient Transport in Surface Water–Groundwater Interactions	Elsayed	University of Guelph
28	Evaluating the Role of Groundwater–Surface Water Interactions in the Salinization of an Urban Stream at Watershed and Reach Scales	Hodgins	University of Western Ontario
29	Demonstration: Printed 3-D Hydrostratigraphic Model of Southern Ontario	Clark	OGSRL
30	Demonstration: Oak Ridges Moraine Groundwater Program	Holysh	ORMGP

Context

The 2023 Ontario Geological Survey (OGS), Geological Survey of Canada (GSC) and Conservation Ontario (CO) groundwater open house represents the 8th annual event. Previous open houses focussed on sharing the results of a collaborative OGS and GSC groundwater mapping and research program that ended in 2019. The annual open house was a key deliverable of this collaboration, and an important opportunity to keep the groundwater community apprised of new mapping, research and publications.

The annual groundwater geoscience open house has been extremely well received by clients, with attendee numbers increasing annually, from 95 in 2016 to 289 in 2020. Because of the COVID-19 pandemic, the 2021 and 2022 events were delivered virtually as 2 half-day sessions via the Zoom Video Webinars platform (Zoom Video Communications Inc.; Zoom). The virtual format allowed a wider audience to access the event. In 2022, a total of 675 people registered for the event, and we saw 469 attendees in sessions on Tuesday, February 15, and 348 attendees in sessions on Thursday, February 17, with an average viewing time of 110 minutes. Registrants from the United States equalled approximately 4% and another 1% from across the globe. Attendance comprised stakeholders and clients from the consulting industry (27%), provincial and federal government (27%), academic institutions (18%), municipalities (6%), Conservation Authorities (8%), non-governmental organizations (1%), and a remaining 13% who remained anonymous. Survey results indicate that attendees missed the opportunity for networking, discussion and collaboration that an in-person event offers; however, the overall satisfaction rate was still high.

The enduring popularity of the geoscience open house has prompted the move to a hybrid model. The 2023 event will see both a virtual day on February 21 and an in-person day on February 23 with the option to attend virtually via Microsoft® Teams® live platform.

The program offers presentations on a wide variety of topics grouped into themes. Our speakers represent the OGS, GSC, Environment Canada, Ontario Ministry of the Environment, Conservation and Parks, Conservation Authorities, the Ontario Oil, Gas and Salt Resources Library, consultants and academia. New for 2022 were a series of shorter "lightning" talks designed to allow students from Ontario universities and colleges to present their exciting research projects. These shorter talks proved popular and so, this year, the format will be extended to quick project updates. The in-person poster session will highlight the work of the hosting agencies as well as students from universities who are conducting groundwater research in southern Ontario. We encourage you to contact the authors directly for more information or to obtain copies of their posters. Hands-on demonstrations by the Ontario Oil, Gas and Salt Resources Library and Oak Ridges Moraine Groundwater Program will round out the program.

We trust that the 2023 open house will remain a valuable forum for sharing groundwater information and networking with peers in southern Ontario and beyond. Contact information for speakers is provided in this compilation to support future connections.

Associated publications of previous gap analysis, workshop(s) and open houses between 2015 and 2022.

2015

Russell, H.A.J., Priebe, E.H. and Parker, J.R. 2015. Workshop summary and gap analysis report: Unifying groundwater science in southern Ontario; Ontario Geological Survey, Open File Report 6310, 64p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6310

Russell, H.A.J. compiler. 2015. Workshop on Groundwater Data Framework and Hydrogeology Model, Southern Ontario; Geological Survey of Canada. (no formal publication, *see* **Groundwater Information Network**)

2016

Russell, H.A.J. and Priebe, E.H. compilers. 2016. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey and Geological Survey of Canada Groundwater Geoscience Open House; Geological Survey of Canada, Open File 8022, 34p. doi.org/10.4095/297722

2017

Russell, H.A.J., Ford, D. and Priebe, E.H. compilers. 2017. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Geological Survey of Canada, Open File 8212, 56p. doi.org/10.4095/299750

2018

Russell, H.A.J., Ford, D., Priebe, E.H. and Holysh, S. compilers. 2018. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Geological Survey of Canada, Open File 8363, 62p. doi.org/10.4095/306472

2019

Russell, H.A.J., Ford, D., Holysh, S. and Priebe, E.H. compilers. 2019. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6349 / Geological Survey of Canada, Open File 8528 (doi.org/10.4095/313529), 32p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6349

2020

Priebe, E.H., Ford, D., Holysh, S., Russell, H.A.J. and Nadeau, J.E. compilers. 2020. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6361, 46p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6361

2021

Priebe, E.H., Ford, D., Holysh, S., Nadeau, J.E. and Russell, H.A.J. compilers. 2022. Regional-scale groundwater geoscience in southern Ontario: The 2021 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6378, 24p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6378

2022

Burt, A.K., Ford, D., Holysh, S., Kalmo, K.J.J. and Russell, H.A.J. compilers. 2022. Regional-scale groundwater geoscience in southern Ontario: The 2022 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6379, 38p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6379

2023

Burt, A.K., Ford, D., Holysh, S., Kalmo, K.J.J. and Russell, H.A.J. compilers. 2023. Regional-scale groundwater geoscience in southern Ontario: The 2023 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6387, 61p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6387

Presentations from previous years can be found on the Groundwater Information Network (GIN) (http://gin.gw-info.net/service/api_ngwds:gin2/en/gin.html, under "News"). Presentations from 2021 are available on the GSC Groundwater Geoscience Program YouTube channel under Playlists (www.youtube.com/channel/UCHIc7ff3vEdII708VhgsLsg/playlists). Some presentations may be missing and, in those cases, permission was not granted by the respective organization of the author(s).

Contents

Contents (continued)

Contents (continued)

Microtextural Analysis of Champlain Sea Mud, Ottawa, Ontario: Meiofaunal Activities and their Geochemical Implications

Al-Mufti, Omar N.[1]; R. William C. Arnott[1], Marc J. Hinton[2], Sam Alpay[2], and Hazen A.J. Russell[2]

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[2] *Geological Survey of Canada, Natural Resources Canada, Ottawa, ON K1A 0E8*

Historically, most ichnological studies have focussed on the feeding and burrowing traces produced by macrobenthos. This may be because of the relative ease of recognizing macroscopically visible macrofaunal (>1 mm in diameter) trace fossils in core and outcrop. Meiofauna (<1 to ~0.045 mm in diameter), on the other hand, are abundant in modern marine sediments, but compared with macrofaunal traces, are uncommonly documented in the sedimentary record. This may be partly because of their small size, but possibly also the negligible textural and, therefore, optical contrast between burrow fills and the host (surrounding) sediment. In this study, glaciomarine strata of the Champlain Sea basin provide a nearly modern (late Pleistocene–Holocene) analogue to examine the occurrence and distribution of meiofaunal traces in subaqueous mud and to determine the spatial and temporal relationships between biologic activity and geochemical processes. Here, based on samples from 2 continuous cores, biogenic structures and associated diagenetic minerals are documented using optical and scanning electron microscopy. Near the base of the sedimentary succession, a few-metres-thick unit of laminated mud rhythmites transitions abruptly upward into bioturbated mud, representing the abrupt change from glaciolacustrine to glaciomarine conditions. Microscopic analysis of glaciomarine mud shows that burrow fills are several tens to a few hundreds of micrometres in diameter and are either silt rich with a clay-rich wall or are clay rich with a silt-rich wall. The size of the burrows and their architecture, which in bedding-plane views exhibit a distinctively sinuous shape, resemble those produced by modern marine nematodes. Notably, some burrows have been filled completely with diagenetic framboidal pyrite, indicating anoxic microbial activity that most probably was controlled by the bioavailability of reductants contained in the burrows, which most probably consisted of meiofaunal mucous secretions and fecal matter. Moreover, within these cement-filled burrows, pyrite framboids show partial replacement and overgrowth by clusters of diagenetic marcasite, a polymorph of pyrite. Marcasite requires acidic conditions, and its spatial association with framboidal pyrite, in addition to diagenetic kaolinite, suggests an influx of oxygen-bearing fluids that reduced the pH of previously sulfidic and ferrous sediments. This was probably facilitated by the abundance of tunnels made by shallow infaunal nematodes that enhanced pore-water advection and diffusion of dissolved oxygen and directed the downward migration of oxidation fronts in a redox depth-zoned sediment column.

Evaluation of Factors Influencing the Amount of Septic System Effluent Delivered to Streams

Angus, Evan A.[1]; James W. Roy[1,2], Thomas A. Edge[3], Christopher J. Jobity[1], and Clare E. Robinson[1]

[1] *Department of Civil and Environmental Engineering – University of Western Ontario, London, ON N6A 5B9*

[2] *Water Science and Technology Directorate, Environment and Climate Change Canada, Burlington, ON L7S 1A1*

[3] *Department of Biology, McMaster University, Hamilton, ON L8S 4K1*

Septic systems are widely used for domestic wastewater treatment in areas not serviced by a centralized wastewater treatment plant. As a result, septic systems may provide increased inputs of nutrients (phosphorus (P) and nitrogen (N)) to tributaries. However, quantifying their contribution to tributary nutrient loads is challenging because of the distributed location of septic systems across watersheds and untangling their contribution from other nutrient sources in a watershed. To improve large-scale estimates of the contribution of septic systems to nutrient tributary loads, there is a need to determine the fraction of septic system wastewater effluent that reaches tributaries and evaluate whether this fraction varies based on physical (e.g., surficial geology, agricultural tile drainage, setback distance) and demographic (e.g., median income, household age) characteristics of the subwatershed. This study addresses this knowledge gap through broad-scale water quality stream sampling and flow gauging conducted at 53 stream sites across the Lake Erie and Lake Simcoe watersheds, Ontario, Canada. The sites were selected to include subwatersheds with different physical and demographic characteristics combinations. Sampling was conducted at least four times at each site with sampling conducted under high- and low-flow conditions. Stream water samples were analyzed for concentrations of human wastewater tracers (artificial sweeteners, microbial HF183 marker) in order to determine the amount of septic effluent reaching the tributary, as well as nutrients (TP, SRP, NO_3-N and NH_4). Bivariate statistical methods were used to examine relationships between the fraction of septic effluent reaching the tributary and the physical and demographic characteristics. Preliminary data analysis indicates that the fraction of septic effluent reaching the stream may be greater during high flow compared to low flow conditions and greater in watersheds with older households, more built-up area, lower overburden drift thickness and more tile drained land. The findings of this study are needed to improve estimates of the contribution of septic systems to nutrient tributary loads as required to inform water quality and septic system management programs.

Monetizing the Comprehensive Role of Water in Sustaining Ecosystem Services with a Fully Integrated Subsurface–Surface Water Model

Aziz, Tariq[1,2]; Steven K. Frey[1,3], David R. Lapen[4], Susan Preston[5], Hazen A.J. Russell[6], Omar Khader[1,7], Andre R. Erler[1], and Edward A. Sudicky[1,3]

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Water is essential for all ecosystem services; however, a comprehensive assessment of overall water contributions to ecosystem services production has not yet been carried out. The main obstacle has been the missing representation of the integrated hydrologic cycle in the production of ecosystem services. Understanding the relationships among subsurface water, surface water and ecosystem services requires an integrated and quantified understanding of the full terrestrial hydrologic cycle concomitant with an assessment of ecosystem services. Evapotranspiration (also called green water) represents a core connection in which terrestrial ecosystems use water and deliver a broader set of ecosystem services in a watershed. In this study, we use a fully integrated hydrological model—HydroGeoSphere (HGS)—to capture changes in subsurface water, surface water and evapotranspiration, in combination with an economic valuation approach to assess ecosystem services over an 18 year interval (2000–2017) in the South Nation watershed, Ontario, Canada. Using the green water volumes and ecosystem services values as inputs, we calculate the marginal productivity of water. The valuation results show maximum green water consumption during abnormally dry years; for example, a value of $1.16 billion is attributed to green water during the severe drought experienced in 2012. Because subsurface water is a major contributor to the green water supply, it plays a critical role in sustaining ecosystem services during drought conditions. Conversely, the surface water contributions in green water provision over the evaluation interval are comparatively small. This study will inform watershed management on sustainable use of subsurface water to support ecosystem services provision during droughts and provide an improved methodology for watershed-based integrated management of ecosystem services.

Ministry of Environment, Conservation and Parks – Groundwater Activities Update

Brodie-Brown, Heather[1]; and Helen Zhang[1]

[1] *Ministry of Environment, Conservation and Parks, North Wing, 2nd Floor, 125 Resources Road, Toronto, ON M9P 3V6*

The Ontario government is committed to protecting our lakes, waterways and groundwater supply, now and for future generations. Our lakes, waterways and groundwater are a vital resource and the foundation of Ontario's economic prosperity and well being – supplying water to our communities, sustaining traditional activities of Indigenous peoples, supporting Ontario's economy, and providing healthy ecosystems for recreation and tourism.

The ministry continues to move forward with enhancements to the province's water taking program as part of its commitment to ensure our water resources are protected and used sustainably. Recent activities include the posting of permittee reported daily water taking data for 2019 and 2021 and work with the Ontario Geological Survey to develop updated lithological designations for use on water well records and to assign stratigraphic units and hydrostratigraphic data to Provincial Groundwater Monitoring Network well intake zones.

The ministry has continued to maintain the Provincial Groundwater Monitoring Network (PGMN) program and has made progress on several initiatives including improving timely data-sharing techniques.

In support of the commitments of the renewed Canada–Ontario Agreement on the Great Lakes Water Quality and Ecosystem health (2021 COA), the ministry has worked with partners to update groundwater indicators for the State of the Great Lakes 2022 Technical Report, supported the drafting of updates to the Canada–Ontario 2016 "Groundwater Science Relevant to the Great Lakes Water Quality : A Status Report" and funded a number of groundwater quality and quantity studies related to groundwater–surface water interaction, climate change effects and groundwater contaminant or pollutant transport.

This talk will focus on providing updates on Ministry groundwater-related activities such as these described herein.

Sedimentological Underpinnings of an Ongoing Buried Bedrock Valley Investigation in Elora, Ontario

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Detailed analysis of bedrock facies and diagenesis provides essential context for hydrogeologic investigation. Additionally, studying high-resolution cyclicity of deposits and the secondary overprint of their diagenetic history enables more confident geologic correlation with regional stratigraphy. Sound geologic context enables more confident identification of variability caused by irregular local features and processes. Buried bedrock valleys (BBVs) are important local features, the fill and genetic history of which may exert a strong control on subregional hydrogeologic trends. A BBV in Elora, Ontario, is expected to influence the hydrogeology of the mid-Silurian carbonate Lockport Group that it incises. To study this BBV, 4 bedrock boreholes were cored along 2 transects using a PQ3 triple tube core barrel to the depth of the regional Cabot Head Formation shale aquitard (~150 mbgs). Core logs were used to construct a local facies model and to study cyclicity within the Lockport Group. Petrographic study of recovered samples supplemented this analysis and will enable the contribution of the BBV to the diagenetic history of the Silurian rocks in this area to be assessed.

Interpretations of the core and thin sections reveal a net shallowing succession that records a maturing carbonate accumulation adjacent to thick inter-reef deposits. At the northeast transect, there is an approximately 80 m composite structure comprising smaller scaled stacked cycles consisting of basal 1–2 m crinoid accumulations which underlie 1–2 m *favosites* accumulations, which, in turn, underlie 1–10 m stromatoporoid accumulations. Upward, stromatoporoids change morphology from laminar to domal. This composite structure is succeeded by intermixed thinly bedded stromatoporoids and mixed skeletal deposits comprising a greater abundance of bivalves, gastropods, crinoids and nautiloids. At the southwest transect, basal thin-bedded crinoid accumulations are sharply overlain by 10 m of chert nodules that fine upward in size and are embedded in a dolomudstone matrix that becomes laminated upward. Overlying the chert is approximately 60 m of dolomudstone with rare tabulate coral and stromatoporoid floatstones. Capping the southwest transect is a mixed stromatoporoid-skeletal succession similar to the northeast transect. Zones of interest for future diagenetic study include dissolution-enhanced intervals underneath the valley floor and in the basal crinoid accumulations, cavernous porosity interrupting the dolomudstone, and discrete 1–2 m bands of fabric-destructive diagenesis in otherwise well-preserved successions.

This analysis will inform future investigation of mechanical strength, dissolution porosity and fracture intensity and how these vary within geologic formations and with proximity to BBVs. Future hydraulic data will confirm the importance of these features in altering flow pathways in the local hydrogeologic system. Process-based analysis of the hydrogeologic context of this BBV will provide the context needed to understand how hydrogeologic properties and flow pathways have evolved in this system.

Provincial Geotechnical Borehole Database Refinements

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In 2006–2007, a collaborative project was undertaken to assemble and standardize a province-wide database of shallow subsurface records drawing on several sources. Geological and, where available, pumping test information was captured from over 575 000 water well records obtained from the Ministry of Environment, Conservation and Parks (MECP) water well information system (WWIS). Since then, the WWIS has grown to over 900 000 records. Other data sets, termed legacy data sets, have not changed since inception. This includes the 1970s era Waterloo and Urban Geology Automated Information Systems. In contrast, geotechnical records have been added to the City of Ottawa database and new subsurface information is published by the Ontario Geological Survey (OGS) every year. Client access was provided through Land Information Ontario (LIO) until 2015 and then through OGSEarth. The database has proven to be a useful source of subsurface geologic information despite having numerous errors and inconsistencies. In response to client demand, the OGS has undertaken a multiphase improvement project designed to correct, convert and expand the database.

Phase 1 – Correction (nearing completion): Up-to-date water well records are accessible to the public (MECP WWIS) and will no longer be included in the geotechnical database. Instead, the geotechnical database structure has been improved to better reflect the WWIS, allowing a more seamless client-driven integration. Data import errors, spelling mistakes, inconsistent usage of terminology, and incomplete location data (NAD83, latitude–longitude) have also been addressed. The most exciting refinements are development of a map tool to check or confirm borehole locations and a search-and-export tool. A beta version of the corrected database will be released in the coming months.

Phase 2 – Conversion: The OGS is working collaboratively with MECP and a stakeholder advisory panel to improve the geological information recorded on water well records (*see* Burt, Grant et al. this volume, for details). The geotechnical database will be converted to the new nomenclature recommended for water well records.

Phase 3 – Expansion (ongoing): OGS subsurface sediment and bedrock information will be assembled (i.e., from Open File reports, Miscellaneous Releases—Data and Groundwater Resources Studies), digitized and converted to the new geotechnical database standards presenting a simplified stratigraphy as required.

Client access to the improved database will be provided through GeologyOntario and OGSEarth.

Lithological Lock-down – Standardizing Geological Descriptions in Well Records

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The Ontario Geological Survey is collaborating with a team of well technicians, geotechnical drillers and the Ministry of Environment, Conservation and Parks (MECP) on a multiphase project that will improve the quality and consistency of geological information recorded in water well records. Phase 1 of the project is focussed on improving new well records by developing a simpler and more meaningful set of terms and system for describing geological materials. A guidance document for using the new terminology will be prepared and will include photographs, simple descriptions and tips for identifying materials. The document will be formatted to be suitable for printed reference cards and easily viewed on mobile devices. If successful, Phase 2 will address existing records by converting the geological information contained in all of Ontario’s 910 000+ wells to the new nomenclature system.

Systems used in other jurisdictions range from free-form descriptions on paper forms that must be manually entered into a database to direct entry using digital picklists. Comparing these with the resulting databases has informed the current project and a 2-step digital entry form using picklists is being considered. Rock, sediment or “other” would be selected in step 1 and, if accurate, would be an improvement over many historical records. Based on the user’s selection in step 1, a series of optional picklists for lithology, descriptors, hardness, moisture and colour would activate for step 2. For example, selecting “rock” in step 1 would open a lithology picklist with terms including limestone, dolostone, shale, basalt and granite. A descriptor picklist with the terms layered, fractured, porous and weathered would allow additional information to be added. Many of the terms currently used will be retained, but usage will be restricted by the picklists. This will eliminate records with geological impossibilities, such as “limy granite”, or duplications, such as “granite and granite”. A few new terms, such as shaly limestone, will be added, whereas some existing terms, such as feldspar and greywacke, will be dropped.

In contrast, selecting “sediment” in step 1 would open a lithology picklist with terms including clay, silt, sand (fine, medium and coarse), gravel, boulders and peat. A second lithology picklist would contain modifiers such as clayey, silty, sandy and gravelly. The descriptor picklist would contain terms such as layered, till and wood fragments.

The next step for the project will be to test the proposed system using a province-wide subset of original descriptions obtained from PDF records in the MECP Water Well Information System.

Filling the Hole – Introducing the Guelph 3-D Sediment Mapping Project

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The Ontario Geological Survey initiated a new 1400 km^2 three-dimensional sediment mapping project in the Guelph area to fill a gap in coverage between Orangeville–Fergus (GRS 15) to the north, Waterloo Region (GRS 3) to the west, Brantford–Woodstock (GRS 10) to the southwest and the Niagara Peninsula (ongoing) to the south.

In general, the oldest and thickest sediment successions are in the west, whereas younger and thinner sediments are near the Niagara Escarpment in the east. Thicker sediments are found in buried bedrock valleys and along a series of moraines. The interlobate Waterloo Moraine, found in the far southwest of the area, is partially buried by streamlined Port Stanley Till. The centrally located Paris–Galt Moraine was deposited by a readvance of the Ontario lobe; smaller ridges of the Moffat Moraine were deposited as the ice retreated. A final late glacial advance deposited Halton till and the sandy fans of the Waterdown moraines along the top of the escarpment in the far southeast of the study area.

With the recent release of new light detection and ranging (lidar) data sets, 2022 field activities focussed on surficial mapping and stratigraphic data collection in the southeastern portion of the area where the typically thin sediments and extensive wetlands preclude drilling. Developing criteria for distinguishing between the multiple low-relief ridges of the Moffat moraines and the bedrock ridges characterizing the escarpment cuesta was a key activity. Low areas between both types of ridges typically contain extensive wetlands and accumulations of peat that often reached several metres in thickness. In places, only a thin bed of sand and/or gravel separated peat from bedrock, whereas, at other locations, potential confining units of glaciolacustrine clay and diamicton were observed. Rising above this landscape are drumlins ranging from less than 300 m in length and 10 m in height to greater than 1.5 km in length and 30 m in height. The bedforms record west to northwest ice-flow directions; some are composite forms and, in places, there are 2 orientations along a single feature suggesting overprinting.

New 1:20 000 scale surficial mapping, a ground gravity geophysical survey and drilling will support modelling in this geologically diverse area.

A Retrospective of 3-D Modelling of the Bedrock Geology and Hydrostratigraphy of Southern Ontario

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In 2015, the Geological Survey of Canada initiated a series of projects to construct three-dimensional (3-D) models of the bedrock geology and hydrogeology of southern Ontario. Two 3-D models of the bedrock geology were completed: version 1 in 2019 and version 2 in 2021, published as GSC Open Files 8618 and 8795, respectively. These formed the basis for development of a 3-D hydrostratigraphic model that was released in 2022 as GSC Open File 8927. All models were constructed using Leapfrog® Works at 400 m grid scale.

The lithostratigraphic model (Version 2) encompasses the entire 1500 m of Paleozoic bedrock of southern Ontario over an area of 110 000 km^2. Fifty-three model Paleozoic bedrock layers representing 70 formations, as well as the Precambrian basement and overlying unconsolidated sediment, are modelled. Formation-top data from a total of 20 836 Ontario petroleum wells, 199 OGS stratigraphic tests, 15 measured sections, 3 Michigan petroleum wells and 30 control points were utilized. An extensive QA/QC review of geological formation-top data was completed. Model features include 3-D extent of salt mining leases at Ontario's 2 underground salt mines, 3-D solution-mined caverns in salt units utilized for hydrocarbon and petrochemical storage and for salt mining salt, three-dimensional representations of oil and natural gas reservoirs, regional faults, and lithotectonic boundaries in the Precambrian basement. An uncertainty analysis of individual model layers has recently been completed. Public outreach and geological education initiatives include 3-D printed products and virtual reality (VR) realizations.

The hydrostratigraphic model comprises 14 hydrostratigraphic layers expressed as either aquifer or aquitards based on hydrogeologic characteristics in the intermediate to deep groundwater regimes below the influence of modern meteoric water. Hydrostratigraphic aquifer units are subdivided into 3 hydrochemical regimes: brines (deep), brackish-saline sulphur water (intermediate), and fresh (shallow). Included in the model are 3-D representations of oil and natural gas reservoirs, 3-D water level surfaces (uncorrected for density) for deep Cambrian brines and the fresh to sulphurous groundwater of the Lucas–Dundee formations regional aquifer, inferred shallow karst, base of fresh water, and total dissolved solids in aquifers of the Lockport Group.

Development of a 3-D model of dolomitization patterns within model stratigraphic layers of the Salina Group A-1 Carbonate and Salina Group A-2 Carbonate is underway as the final stage of 3-D modelling. This model utilizes legacy data from 1991 as a test of protocols and issues associated with adding attributes within the 3-D volumes of the model lithostratigraphic units. Interim model results illustrate interpreted paleoflow patterns of dolomitizing fluids within these 2 bedrock formations with implications for porosity distribution.

Printed 3-D Hydrostratigraphic Model of Southern Ontario

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A three-dimensional (3-D) printed scale model was built using 15 hydrostratigraphic units from Carter et al. (2022), covering southern Ontario. Aquifer layers in the model were altered with alcohol-based inks after printing to highlight 3 distinct hydrostratigraphic regimes: brines (deep), brackish-saline sulphur water (intermediate), and fresh (shallow) as defined by Carter et al. The model was printed at the same scale as a previously printed four-layer lithostratigraphic model (Carter et al. 2021) so they may be used in conjunction to explore the subsurface bedrock layers of southern Ontario.

Three-dimensional objects were created using Leapfrog® Works and exported as Wavefront objects (OBJ). The modelling software Blender® was used to edit the OBJ files for printing. Preparation included combining very thin layers into single printable parts and adding map elements like titles, scales and location markers. From 15 virtual model layers 6 aquitards, 1 aquiclude and 4 aquifer layers were made into parts for physical printing. Parts were exported for printing in Standard Triangle Language (STL).

Physical parts were printed in cherry red (Precambrian), gray (aquitards), black (aquiclude) and clear resin (aquifers) at a resolution of 50 µm using a Formlabs Form 3 resin printer. Print slicing was done using PreForm™ software. Parts were printed with a 1:4 000 000 horizontal scale and 1:40 000 vertical scale. Aquifer layers at this scale are physically very thin and were fixed to the underlying aquitard layer using a clear epoxy before curing. Fresh, sulphur and brine hydrochemical zones were stained blue, yellow and orange, respectively, using alcohol-based inks on the bottom side that permeate the uncured clear resin. Total printing time is approximately 55 hours with 18 hours of post-processing tasks for 1 complete model.

Final models measuring 14.5 cm × 10 cm × 6 cm are available through the Oil, Gas and Salt Resources Library in London, Ontario.

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Science, Policy, and Community Connections: How the Past 25 Years Strengthened Local Understanding and Consideration of Groundwater Resources in Ontario

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Over the past 25 years, Ontario invested significant resources improving hydrogeological studies, practice and professional capacity at the local level. This time of capacity building is essential to our understanding, protection and consideration of groundwater resources today. During the mid to late 1990s, funding was provided to regional and municipal governments to study and map groundwater resources (many worked with Conservation Authorities and other partners to complete this work). Studies were important for Municipalities across the Province, specifically, those relying mainly on groundwater to supply local populations with drinking water (and other water uses). Many early groundwater studies were adopted in regional and local planning frameworks initiating a process to plan for their consideration and protection in the development review process.

During the mid 2000s, in the wake of the Walkerton Tragedy (and resulting Judicial Inquiry and Recommendations), Ontario adopted a framework that recognized and amplified significant hydrogeological expertise at Municipal and Conservation Authority offices, *working together*, at the local level. Initial work focussed on watershed characterizations, water budgets, mapping of significant groundwater recharge areas and highly vulnerable aquifers and delineating drinking water protection zones: Intake Protection Zones (surface water) and Wellhead Protection Areas (groundwater). From the late 2000s onward, much of the technical work was well underway and advancing along with technology and technical capacity across Ontario. Innovative studies, partnerships and collaborations allowed greater results than any single group could have achieved. Further, Source Protection Plans and Policies gained a clear role in the planning process that is formalized and understood, if only related to Municipal Drinking Water Sources.

The innovative Drinking Water Source Protection framework and Source Protection Committees resulted in technical experts (including many contributing hydrogeologists and engineers) working directly with drinking water operators, drinking water source protection program managers, policy drafters, municipal politicians, provincial representatives, and networks of community partners, including business, agriculture, aggregates and environmental groups.

Currently, local level partnerships have strengthened and made the way for implementation that moves beyond data and technical studies to implementation and internalized ways of thinking and doing that protect our groundwater resources in a meaningful way. Simple examples are the Drinking Water Source Protection Zone signs that appear across the province and knowledge sharing opportunities, such as the Conservation Authorities' Geoscientists' Working Group. More complex examples are predictive models uses to assess water quality and quantity under a myriad of conditions including climate change considerations (often across Municipal boundaries to more meaningful scales).

These collaborations and partnerships, driven by significant investment, made way for a strong multi-disciplined drinking water source protection community. Hydrogeologists, especially where a Municipality relies principally on groundwater, are the glue that holds much of the science, innovation and advancement together. There are many successes and lessons learned from early work and there are opportunities for advancement and some challenges ahead of us with ongoing work to be done. Drinking Water Source Protection is an important reminder as to what can occur when we fail to plan or plan to fail.

It is important that we continue to advance the science and networks of professionals in the groundwater network to continue to plan for and protect both the groundwater resources of Ontario and the people using them.

We know that successful implementation takes ongoing commitment and investment; and multidisciplinary collaboration is key to operationalizing ways of thinking about our groundwater resources. Continuing communication, discussion and sharing knowledge will help propel us all forward in the further understanding and protection of our groundwater resources. May this conference continue to enhance this discussion and our shared goals and objectives.

Mapping of Background Groundwater Quality in Southern Ontario

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Recent regional mapping of the chemical composition of ambient groundwater in Ontario has led to the characterization of large-scale geological influences on groundwater quality and dissolved constituents. Data from the analyses of groundwater from more than 1700 drilled wells collected through the Ontario Geological Survey's Ambient Groundwater Geochemistry (AGG) Project (Hamilton 2015) have been used to spatially map discrete areas of southern Ontario where groundwater has a tendency toward elevated concentrations of specific groundwater-related constituents. Groundwater Resources Study 17 (Colgrove and Hamilton 2018) reports on the geological relationships and spatial extent of 13 chemical, bacteriological and gas constituents related to southern Ontario groundwater. Map sets are provided for arsenic (As), barium (Ba), boron (B), fluoride (F^-), iodide (I^-), nitrate (NO_3^-), chloride (Cl^-), selenium (Se), uranium (U), bacteria and groundwater-related gases (methane (CH_4), hydrogen sulphide (H_2S) and hypoxic gas). For each parameter, maps provided include 1) geological associations, 2) concentration distribution and 3) a simplified, geographical version. This study does not capture all aspects of groundwater composition and usability, but, rather, presents those of greater general interest and which have high potential to be characterized and mapped at a regional scale. This work was undertaken to put existing geological information with regard to groundwater into a more accessible format for technical and nontechnical users. The characterization of background concentrations of constituents that affect groundwater utility can aid in effective resource management in Ontario.

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The New GeologyOntario

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The Ontario Ministry of Mines has been working on an upgrade to the GeologyOntario Portal. We are pleased to announce that it will be launching on March 5, 2023.

The new GeologyOntario will include new features, such as a Hub Page, a newly created Spatial Search Tool, and major upgrades to the Text Search tool are all part of this GeologyOntario redesign. We are excited to share a preview of the new features.

Application of Text Mining and Machine Learning Algorithms in Describing Nutrient Transport in Surface Water–Groundwater Interactions

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Excessive release of nutrients (e.g., nitrogen and phosphorus) can cause eutrophication in lakes and rivers, deteriorating the quality of the available water resources, which has a negative influence on the environment and public health. In addition, nutrients can affect and quality of groundwater, threatening the security and health of drinking and irrigation water. Agricultural activities are one of the most prevalent non-point sources of pollution in surface water and groundwater when excess synthetic fertilizers and manure are applied, which can lead to critical environmental problems. Quantification of nutrient transport in groundwater and surface water is essential.

Data-driven models using machine learning (ML) and text mining (type of ML techniques) algorithms can be implemented as effective approaches for better understanding the nutrient transport processes in surface water–groundwater interactions. The application of data-driven models using ML algorithms can yield high performance for analyzing the complexity of transport processes because these models can deal with different scales of data sets and parameter variability. Also, ML models can diagnose the interdependence between the involved process variables because ML models deal with the input and output variables based on historical observations.

Two research directions were followed to apply ML and text mining algorithms on characterizing nutrient transport in surface water and groundwater. In the first direction, meta-research was implemented to extract meaningful information from previous nutrient transport studies and perform a systematic literature review through applying text mining on the abstracts of these studies. The main objective of this research was to review previous groundwater, surface water and groundwater–surface water nutrient transport studies using quantitative and qualitative analysis. The quantitative analysis was performed by a text mining algorithm to determine the most frequently examined topics. Then, these topics were investigated in a qualitative analysis to highlight the strengths and weaknesses in these studies. The insights of this work can be used to define the knowledge gaps that should be investigated in future studies and serve as a reference for the most frequent topics published in nutrient transport studies.

The second research direction addressed the application of classification ML algorithms on a data set of 5 observation sites in an agricultural watershed (Upper Parkhill watershed) in southwestern Ontario in Canada to categorize the nutrient concentrations in surface water using a group of input variables. The input variables included the weather conditions (e.g., precipitation), water chemistry parameters (e.g., temperature and pH), hydrogeological (e.g., groundwater levels), hydrological (e.g., surface flow) and field (e.g., land use and nutrient application amounts) conditions, whereas the main output variables were the nutrient concentrations in surface water. In addition, the interdependence between the process variables involved in nutrient transport was determined where the governing factors of nutrient concentrations were identified. The ML model simulation results can be used by decision makers to help improve groundwater and surface water quality in agricultural watersheds.

Modelling Groundwater Discharge to Surface Water Receptors Across Southern Ontario

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The objective of this project is to characterize groundwater (GW) discharge to surface water (SW) receptors across southern Ontario and to assess the influence of model spatial resolution when simulating GW–SW interactions.

Using the latest hydrostratigraphic model, a regional scale (109 565 km^2) fully integrated groundwater–surface water model was constructed in 2019. From the regional model, 13 watershed-scale models were derived that cover the full southern Ontario land-area domain. Subsequently, 11 site-scale models, ranging in size from 12.9 to 71.6 km^2, were constructed for the MECP Multi Watershed Nutrient Study (MWNS) locations. The site-scale models cover a range of physiographic settings and can be considered representative of GW–SW interaction characteristics across southern Ontario. The surface water network in the respective regional-, watershed-, and site-scale models resolves Strahler order 3, 2, and 1 stream/river segments. The 3 sets of models were all used to simulate GW–SW interactions and overall hydrologic conditions at the MWNS sites for the January 2017 to September 2020 interval, and model outputs were used to calculate groundwater contribution to surface water flow via the baseflow index (BFI).

Results from the site-scale simulations indicate an average BFI ranging from 0 to 0.8 across the 11 MWNS locations over the 32-month simulation interval, with an average of 0.22 across all locations. Seasonality was also observed in the BFI, with the highest average value (0.24) observed for summer, and the lowest average value (0.20) observed for winter when melt events dominate hydrologic conditions. In general, the largest intra-annual BFI variability aligned with the sites with the highest overall BFI. In contrast, the sites with the lowest average BFI exhibited the lowest intra-annual BFI variability. Preliminary analysis indicates that the linear correlation (r^2) between BFI values derived from the watershed and site-scale models is 0.3; similarly, the BFI correlation between the regional- and watershed-scale models is also 0.3. In contrast, when BFI values derived from the regional- and site-scale models are compared, the r^2 is 0.12. However, for 3 MWNS locations with low BFI results from the site-scale models (averages of 0.00 to 0.11), the regional-scale model also produced low BFI values (0.00 to 0.05). Using the site-scale models as a benchmark, the regional-scale modelling predicts the general BFI patterns, but not with the same level of precision as the watershed-scale modelling.

Adapting Community Education and Engagement in a Changing Environment to Complement Water Management

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The inclusion of community participation and engagement is key to the success of the management of ongoing water issues. Since 1996, the Waterloo Wellington Children's Groundwater Festival has actively worked to educate members of our community—starting at a young age—to spread awareness about water issues and the direct benefits of individual and collective water-based actions. The last 3 years brought new challenges that forced us to change our engagement approach. Complex problems require different methodologies and approaches: we adapted our programming to offer a hybrid model that aims to inspire a behavioral response that leads to grassroots changes to complement policy-driven conservation.

Refining a Regional Lithostratigraphic Model of the Elora Buried Bedrock Valley Using Airborne Electromagnetic and Magnetic Measurements

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Buried bedrock valleys infilled with Quaternary sediments can be productive aquifers when infilled with sand and gravel deposits. These sediments may enhance recharge and form preferential pathways for contaminants to reach regional bedrock aquifers. Understanding the distribution and nature of the Quaternary infill sediments within these geologically complex features is an important aspect of groundwater resource management.
An airborne electromagnetic (AEM) and magnetic survey using the Resolve™ frequency-domain system was completed over a 50 km^2 bedrock-groundwater-dependent region near Elora, Ontario, Canada. The effectiveness of this geophysical method to delineate the valley morphology and characterize variations in Quaternary and bedrock physical properties, such as clay content, was assessed using high-resolution continuous core, downhole geophysical logs, and surface electrical resistivity measurements along 2 transects. High-resolution logs were collected within and adjacent to the buried bedrock valley to characterize Quaternary and bedrock deposits.
A statistical bootstrapping approach was used to establish the range in electrical resistivity most likely associated with clay, diamict, and sand and/or gravel units based on inverted AEM resistivity models. The resulting statistical output was used to generate a 3-D lithostratigraphic model of the Quaternary deposits within and outside the buried bedrock valley region. This study demonstrates the utility of combining geophysical and geological datasets through statistical analysis to map bedrock morphology and Quaternary infill architecture at scales relevant to municipal groundwater flow systems.

How Will Decreasing Winter Snow Cover Affect Agricultural Soil Nitrogen Cycling and Leaching to Groundwater: Results from a Lysimeter Study

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In cold regions, climate change is expected to result in warmer winter temperatures and increased temperature variability. Coupled with changing precipitation regimes, these changes can decrease soil insulation by reducing snow cover, exposing soils to colder temperatures and more frequent and extensive soil freezing and thawing. Freeze–thaw events can exert an important control over winter soil processes and the cycling of nitrogen (N), with consequences for soil health, nitrous oxide (N_2O) emissions, and nearby water quality. These impacts are especially important for agricultural soils and practices in cold-temperate regions, such as in southern Ontario. We conducted a lysimeter experiment to assess the effects of winter pulsed warming, soil texture, and snow cover on nitrogen cycling in agricultural soils. We monitored the subsurface soil temperature, moisture, and porewater geochemistry together with air temperature, precipitation, and N_2O fluxes in 4 agricultural field-controlled lysimeter systems (surface area of 1 m^2 and depth of 1.5 m) at the University of Guelph's Elora Research Station over 1 winter (December 2020 to April 2021). The lysimeters featured 2 soil types (loamy sand and silt loam) which were managed under a corn-soybean-winter wheat rotation with cover crops. Additionally, ceramic infrared heaters located above 2 of the lysimeters were turned on after each snowfall event to melt the snow and then turned off to mimic snow-free winter conditions with increased soil freezing. Porewater samples collected from different depths in the lysimeters were analyzed for total dissolved nitrogen (TDN), nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+). N_2O fluxes were measured using automated soil gas chambers installed on each lysimeter. The results from the snow removed lysimeters were compared to those of lysimeters without heaters (i.e., with snow). As expected, the removal of the insulating snow cover resulted in more intense soil freeze–thaw events, which, in turn, enhanced dissolved N export from the lysimeters *via* 2 potential routes: leaching to groundwater and N_2O emissions. Both loss routes have important implications for water quality and greenhouse gas budgets; N loss to groundwater can negatively impact downstream streams and lakes that receive groundwater discharge, whereas N loss as N_2O increases radiative climate forcing. Overall, our study illustrates the important role of winter snow cover dynamics and soil freezing in modulating the coupled responses of soil moisture, temperature, and N loss from soils by enhanced NO_3^- leaching to groundwater and N_2O emissions.

The Gas Well–Hydrogen Sulphide Connection in Ontario's Groundwater. What It Means, Where It Happens, and What We Could Do To Fix It

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Recent high-profile problems with legacy oil and gas wells in Ontario include explosions and leaks of toxic hydrogen sulphide. These result from the confluence of natural geological factors and poor well construction and abandonment practices, the latter of which are a consequence of the province's oil and gas industry being one of the oldest in the world. The problems with natural gas (methane) leakage are self evident, but hydrogen sulphide (H_2S) is complicated. Small amounts of H_2S occur in 50% of Ontario's water wells at levels that are noticeable by smell, but are generally harmless. However, gas wells can yield H_2S at much higher, potentially dangerous concentrations. In Ontario, gas wells can produce H_2S in 3 ways. The first is as a primary component of sour gas, which is rare in Ontario and occurs predominantly in southwesternmost Ontario and off-shore in Lake Erie at concentrations rarely exceeding 2% by volume. This is low for sour gas, but is still far above the potentially lethal threshold of 100 ppm (0.01%). The other ways H_2S can be produced are by modern biogenic production as gas boreholes facilitate the mixing of 2 bioreactants: methane and dissolved sulphate. Mixing can occur by buoyant, upward gas leakage from deep reservoirs at depth, or alternatively by upward hydraulic gradients pushing deep, sulphate-rich fluids into shallow aquifers that naturally contain methane. Based on hydrochemical mapping by the Ontario Geological Survey, 3 relatively discrete areas in southwestern Ontario exhibit widespread H_2S and gas well problems and these will be discussed further in the presentation.

With over 27 000 wells in the Oil, Gas and Salt Resources Library database and other wells that are not recorded, notably those drilled early in the 20th century, the task of identifying and resolving the problematic wells may seem daunting. However, focussing on the most problematic areas with respect to geology and empirically observed hydrochemistry could greatly narrow the search for high-risk wells.

The scale of Ontario's industry is small compared with other jurisdictions, some of which have been very effective in mitigating the legacy of old gas wells. Thousands of wells, drilled primarily within the past 70 years, are abandoned in western Canada every year and Matrix Solutions alone has contributed to the remediation of tens of thousands of these. With adequate focus and prioritization, there is every possibility that Ontario could control and mitigate these problems in the not-too-distant future.

Aggregate Resources of Ontario Compilation

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In response to the demand for easily accessible and up-to-date information on aggregate resources of Ontario, the Ontario Geological Survey (OGS) released a geographic information systems (GIS)–based aggregate compilation: the *Aggregate Resources of Ontario* (ARO). This compilation is based on data compiled from aggregate resources inventory mapping conducted by the OGS from 1980 to 2022. Most, but not all, data are gathered from Aggregate Resource Inventory Papers (ARIPs) and Open File Reports (OFRs), which were originally published in hard copy and/or various digital formats and datums. This compilation includes edits made to the original source data, such as 1) fixing obvious errors; 2) removing inconsistencies at common boundaries, some of which are related to the conversion between NAD27 and NAD83; and 3) updating data from the referenced original ARIP or OFR and/or associated map(s) to include newer geological data and/or mapping, where the latter are available. These changes were made only if there was sufficient evidence on hand to justify the edits without the need for field visits (i.e., "ground truthing"). This compilation provides a single source for sand and gravel, buried and drift thickness (or bedrock) provincial mapping data. It is important to note that this compilation is **not** intended to be used as a standalone product and the referenced original reports should always be consulted in conjunction with this compilation. Although aggregate mapping and assessment are targeted mainly for land-use planning purposes, it is also a useful source of information for geotechnical or groundwater work.

Time-Series Analysis of Champlain Sea Sediments Using CT Scans from the Bilberry and Voyageur Creek Boreholes, Ottawa, Ontario

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Computed Tomography (CT) scans of sediment cores from 2 boreholes (BC16 and VC2) in east Ottawa produced CT-scan images and Hounsfield Unit (HU) profiles. Distinctively, all strata are characterized by a repeating pattern of upward increase followed by decrease in HU, which is interpreted to reflect the annual waxing (increasing) followed by waning (decreasing) of glaciogenic meltwater discharge. Five lithologically distinct, mud-dominated stratal units have been identified qualitatively using CT-scan images and HU profiles from the 2 boreholes. A time-series analysis of the HU values was conducted to substantiate these apparent trends and ultimately provide an unbiased quantitative evaluation of patterns in glaciogenic discharge. Periodograms computed for resampled HU values at regular depth intervals show comparable average bed thicknesses within each unit in the 2 boreholes. The estimated average bed thicknesses for units 1, 2, 3, 4a and 4b in the 2 boreholes are each approximately 2 cm, 4 cm, 13 cm, 25 cm and 25 cm, respectively, and are consistent with previous visual estimates. Periodograms of manually selected bed thickness data indicate periodic signals that are statistically significant. At 95% confidence interval (CI), units 2 and 3 show a periodic (repeating) bed thickness at ~2.2–2.4 years. In addition, units 2 and 4a show periodic bed thicknesses at ~14 and ~6.4 years, respectively. At a lower confidence level (90% CI), all units show the periodic bed thickness at ~2.2–2.4 years, unit 3 shows periodic bed thicknesses at ~2.8 and ~14 years, and units 1 and 4a show a periodic bed thickness at ~3.4–3.6 years. These preliminary results indicate that the quantitative assessment of CT-scan data from sediment cores may be used to search for periodic signals in sedimentary deposits and to potentially link those signals to paleoclimate and its control on glaciogenic discharge and, in turn, the character of sediment deposition in a glaciogenic basin.

The Western Champlain Sea Regional Aquitard: Emerging Insights from Multidisciplinary Geoscience

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The Rideau Valley Conservation Authority (RVCA), in collaboration with the City of Ottawa, is conducting the Bilberry Creek Hazard Mapping Project to identify and map flood risk and slope stability hazards along Bilberry Creek in Orleans, a suburb of Ottawa, Ontario. For a parallel study, the RVCA and the City of Ottawa drilled boreholes at 2 sites (to a depth of 48.8 m at BC16, and 65.9 m at VC2) to provide the Geological Survey of Canada (GSC) with near-continuous core samples for multidisciplinary investigations of Champlain Sea sediments and pore water. The GSC and partners are optimizing the availability of the cores and boreholes to 1) investigate the geological, hydrogeological and geochemical factors influencing geotechnical properties; 2) interpret geochemical changes arising from groundwater flow and diffusion; and 3) establish 2 new reference sites in Champlain Sea sediments.

Analytical measurements include hydraulic conductivity, diffusion, hydraulic head, pore water geochemistry and isotopes, exchangeable cation chemistry, bulk sediment geochemistry, physical and geotechnical properties, borehole geophysics, mineral magnetism, CT (computed tomography) scans, optical microscopy, SEM (scanning electron microscopy), EDS (energy dispersive X-ray spectroscopy), XRD (X-ray diffraction), pollen counts, and microfossil enumerations and their isotopic compositions. Results reveal 6 stratigraphic sediment units, including 3 deposited during the Champlain Sea period, with 1 exhibiting episodic *in-situ* deformation. Sediment grain sizes are dominated by mud with variable proportions of silt (48–68%) and clay (32–52%), typically with less than 0.3% sand. Borehole geophysical measurements and CT scans indicate correlation of silty beds at the 2 sites, which are approximately 3 km apart. The maximum pore water concentrations of major ions in the lower part of the sediment approach approximately 15% seawater composition. Indications from pore water concentration profiles suggest that both advection and diffusion are active in solute transport with downward groundwater flow indicated by hydraulic head profiles. Fall cone testing shows a wide range of sensitivities, with approximately 45% of samples exhibiting high sediment sensitivities (sensitivity >16). To our knowledge, these and emerging results of this investigation represent the most comprehensive suite of geoscientific analyses in thick sequences of Champlain Sea sediments.

Evaluating the Role of Groundwater-Surface Water Interactions in the Salinization of an Urban Stream at Watershed and Reach Scales

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Increasing salinization of fresh surface waters as a result of elevated chloride (Cl) is threatening aquatic ecosystems. An important source of Cl in temperate climates is road de-icing salt (commonly NaCl). Increasing summer Cl concentrations in urban streams indicate that groundwater transport could be an increasingly important transport pathway delivering Cl to streams during the non-salting seasons. The objective of this study was to evaluate the role of groundwater in delivering Cl to a small urban stream including understanding the spatial and temporal variability of these inputs. This was addressed through longitudinal stream surveys during summer baseflow conditions combined with high-resolution investigations along a highly Cl impacted 100 m reach. Longitudinal stream sampling showed areas of high groundwater discharge, inferred from radon-222 measurements, correlated with areas of elevated stream Cl concentrations in built-up areas, but with decreasing stream Cl concentrations in a forested setting downstream. The data illustrate the role of discharging groundwater in modifying summer stream Cl concentrations. The groundwater flux to the stream, as well as stream Cl concentrations, were highest at base flow and during a first flush at the start of the rain event; both then decreased through the event as overland flow and storm sewer contributions flushed the salt down the stream. At base flow, the stream Cl concentrations were consistently higher than acute toxicity limits during both salting and non-salting seasons. Higher resolution streambed porewater sampling, completed along a 100 m reach for 18 months, revealed Cl concentrations to range spatially from 300 to 5000 mg/L, with changes of 1000 mg/L over a 5 m distance. Electrical resistivity geophysical imaging traced a high electrical conductivity (representing Cl) groundwater plume connecting the highest streambed porewater Cl concentrations to a nearby parking lot and road, which persisted year-round. Interestingly, the streambed areas with groundwater upwelling had the highest porewater Cl concentrations in the summer–fall. In contrast, areas of surface water downwelling had the highest porewater Cl concentrations during winter, coincident with the highest stream Cl concentrations. Overall, the study highlights the importance of groundwater pathways in contributing to salinization of urban streams and the year-round persistence of this delivery pathway.

Do Hydrogeological Data and Analyses Matter? Can They Help Us Build Homes Faster? A Panel Discussion on the Evolving Role of Hydrogeologists in Ontario Society

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Planning, urbanization and environmental protection all continue to be areas of dramatic change in today's Ontario. The panel discussion will be wide ranging focussing on the role of hydrogeologists in today's Ontario.

- What aspects of current hydrogeological practice are in need of review and/or change?
- How might the role of hydrogeologists change as new policies and other initiatives take effect?
- What tools do we need to facilitate such role changes?

Taking the time to reflect on our role in society, and how it might evolve going forward, is an essential role of learned associations and practitioners, and this Open House provides a unique opportunity to explore this area.

- Does hydrogeology only matter when an ill-advised borehole or subsurface infrastructure elements winds up costing many tens of thousands of dollars?
- Can we leverage years or decades of hydrogeologic data and analyses to reduce uncertainty and be more efficient in determining the extent of subsurface data requirements?

As one of several documents that are submitted in support of new development, hydrogeology reports, given the need for drilling and associated field work, are generally prominent in terms of the time and costs involved to investigate a site. Responsibility for reviewing these reports now largely lies with municipalities, having been transferred from the Province. Consultants spend time and money to support their client's development plans, and where municipal or conservation authority staff are available, there is also considerable time spent in reviewing these reports.

- Is the amount of work on both sides warranted?
- Does it hinder the government's current push to build more homes faster?

There appears to be a trend in some municipalities, with no hydrogeologists on staff, for consultants to provide, in addition to their supporting report, a simple self-assessment checklist of how their studies meet municipal requirements. Does the report have a site plan? Have the correct number of boreholes been drilled for the size of the site? Has water quality sampling been done and presented? Have water levels been measured over a sufficiently long period of time? On what page is a cross section available? So without reading the report itself, review staff can approve a report with little time or technical knowledge involved. The onus is on the consultant to flag any groundwater-related issues that might need to be addressed as the development progresses.

- Is this "hands off" approach a satisfactory methodology for moving forward?
- Are technical staff satisfied that their work is effective in contributing to Ontario's growth?
- Can this approach help the Province in its push for building more housing faster?

Turning to future societal roles for hydrogeologists, there is a movement in some European countries to the concept of subsurface planning (von der Tann et al. 2018). For example, rather than approving large condominium development applications on a case-by-case basis, as is currently done in Ontario, municipalities are setting certain subsurface areas aside for specific infrastructure (subway tunnels, parking garages, large sewer and water mains, etc.) well in advance of when they will be required. Development applications would have to fit within the constraints of this subsurface planning policy regime. Or consider our climate crisis and the dramatic need for a reduction in greenhouse gas emissions.

- Might geothermal energy be a significant part of the solution in urban areas going forward?
- Are hydrogeologists currently getting prepared and trained to lead such changes for society?
- Do such paths constitute a road forward for how hydrogeologists might continue to effectively contribute to society?
- Should we be more active in promoting such endeavours to society?

Central to all of the above, and to the role of hydrogeologists in Ontario society going forward, is the need for increased efficiency in how we undertake our jobs. Certainly, ready access to data, and analysis of that data, should play a more prominent role in moving forward.

Building upon the 2019 Panel discussion, the 2023 Panel will continue to explore the contributions that hydrogeologists are making, and will continue to make, to Ontario society. Join us for what is anticipated to be a lively discussion.

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Analyzing Pathways via Which Septic System Wastewater Effluent Reaches Tributaries

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Septic systems are widely used across North America for domestic wastewater treatment in areas not serviced by a centralized wastewater treatment plant. Septic systems may deliver various contaminants of concern to surface waters, but quantifying their contribution to stream loads is challenging because of the distributed locations of septic systems across a watershed combined with uncertainties regarding the pathways delivering septic effluent to streams (e.g., groundwater transport, overland transport following failure, illegal direct connections). It is important to understand the pathways delivering septic effluent to streams as the specific pathways determine the fate of the contaminants and their ultimate delivery to a stream. The objective of this study was to distinguish the pathways delivering septic effluent to streams in multiple subwatersheds and explore how these pathways vary seasonally and between dry and wet weather conditions. To achieve this objective, artificial sweeteners (acesulfame, saccharin, cyclamate, sucralose), *Escherichia coli*, and microbial DNA markers (HF183 and human mitochondrial markers) were used as tracers for septic effluent in 4 streams within the Lake Erie watershed. The use of these human wastewater indicators concurrently gives an indication of the amount of septic effluent in a subwatershed that is entering the stream and its delivery pathways. High spatial-resolution longitudinal stream surveys were also conducted to identify contributing areas or even specific locations delivering septic effluent to the streams. Seasonal samples at 2 to 4 locations, along with high-frequency samples through rain events at the outlet, were assessed using concentration-discharge (C-Q) relationships to determine how septic effluent inputs and contributing pathways may vary over different climatic and flow conditions. Data indicate the utility of these combined approaches for analyzing the pathways via which septic effluent is reaching the stream, including identifying locations where septic effluent may be delivered to the stream through illegal connections. The findings from this study are needed to provide information on making science-informed decisions regarding septic system regulations, maintenance and inspections, as well as improving quantification of contaminant loads to tributaries from septic systems.

Geochemical Analysis of Sources of Chloride in Groundwater and Surface Water of Varying Land Uses in Southern Ontario, Canada

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Chloride concentrations in waters of the western Lake Ontario Basin have been increasing over the last century, corresponding with the heightened urbanization occurring in southern Ontario. A by-product of urbanization is the escalation of anthropogenic impacts on the natural environment. The primary driving factor of the increased chloride in groundwater and surface waters across the basin has been attributed to road salt (predominantly NaCl), commonly applied to impervious surfaces as a de-icer. Along with road salt, other possible anthropogenic chloride sources include landfill leachate, wastewater, agricultural products and water softeners. To better understand the main sources of chloride in the basin, both groundwater and surface water samples were collected at 4 sites having varying land uses across the Credit River watershed. The samples were analyzed for major ions and isotopic tracers. Results from the ion analyses were interpreted using chloride–bromide plots to determine contaminant end members. Additional examination of the major ion suite, targeted analysis of artificial sweeteners as wastewater tracers and select herbicides as urban runoff tracers, and analysis of isotopic tracers will guide the placement of each sample on binary mixing curves. Results from the geochemical analysis were furthered using geospatial evaluation of past and present land use for possible chloride contamination sources. Preliminary results from chloride–bromide plots suggest that there is a mix of road salt, landfill or wastewater, especially at the more urbanized site. Geochemical parameters will be examined on a seasonal basis to further distinguish the varying sources of anthropogenic chloride throughout the watershed. The results of this research aim to highlight the seriousness of the rising chloride concentrations and guide recommendations for management of anthropogenic chloride sources within the Great Lakes basin and beyond.

The Geoscience Information Platform Program – Filling the Geoscience Data Gap

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The City of Ottawa (City) annually invests approximately $3 million investigating the local subsurface geotechnical, hydrogeological and environmental conditions in support of municipal planning, development proposals, infrastructure designs, construction and environmental protection studies. Much of this valuable geoscience data remains with individual consulting firms and in City project files and is relatively inaccessible to internal and external stakeholders. Through the City's Geoscience Information Platform (GIP) program, knowledge of and access to readily available, consolidated, and high-quality geoscience information and data that are useable, will help to mitigate risks in the design and construction of infrastructure projects, to the public and to the natural environment.

In alignment with the City's strategic initiative to improve overall asset management, the GIP Program will provide 1) available, accessible and useable authoritative geoscience data and information to internal and external stakeholders from publicly released products from the Geological Survey of Canada (GSC) and the Ontario Geological Survey (OGS); and 2) access to a compiled, organized and actively managed geoscience database housing consolidated useable data from these authoritative sources, such as geoscience data collected from GSC and OGS staff or consultants for City projects. This will enable users to readily access and assess the most up-to-date, integrated geoscience information. Similar to physical infrastructure assets, such as roads and buildings, all of Ottawa will benefit when digital infrastructure assets—geoscience data and information, are soundly managed and maintained.

The City's one-stop subsurface shop for accessible, geographically referenced, useable geoscience data at your fingertips—the GIP, is already providing internal City stakeholders (external access is a future step) with an increased understanding of Ottawa's geotechnical, hydrogeological, and environmental surface and subsurface landscape. This allows for improved decision making, such as knowledge of potential costly subsurface conditions (e.g., unstable soils or flowing conditions) and reduced costs, such as reduced drilling and investigation costs. With minimal to no digital data handling, the GIP is anticipated to be a long-term, valuable resource for technical practitioners across the Ottawa region.

Separating and Analyzing Microplastics in Environmental Water and Soil Samples

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Quantifying the distribution of microplastics in environmental compartments, such as soils, sediments, groundwater and surface water, is crucial to understanding and predicting the fate and transport of microplastics in the environment. However, a major challenge when analyzing microplastics is that they are closely integrated within their environmental matrices (e.g., soil, sediment, suspended matter). Hence, microplastics require separation from these matrices using methods that 1) do not damage the surfaces of the particles and 2) extract all the particles that are present in the sample or, in other words, that have a high recovery efficiency. We have optimized an extraction procedure that combines density separation (using a zinc chloride brine solution) with wet peroxide oxidation to separate microplastic particles from the other inorganic and organic matter in their environmental matrices. Following separation of the microplastic particles, the particles are analyzed for size, shape and polymer type using laser direct infrared (LDIR) spectroscopy. LDIR images and maps a population of microplastic particles present in a sample to generate their size and polymer type distributions. Information about the polymer type, shapes and size distributions act as a fingerprint which can inform the interpretation of the potential source(s) and extent of degradation and/or weathering of the microplastic particles. We have evaluated the effect of particle size on the recovery efficiency of the extraction method using sample spikes and found, as expected, that the recovery efficiency decreases with decreasing particle size. This effect of particle size on recovery efficiency was corrected for by continuing to spike microplastics standards of different sizes to extractions of environmental samples and correcting the microplastics concentrations of different sizes quantified using LDIR. We also validated that the extraction method did not damage the surface chemistry and Raman or infrared spectra of representative polyethylene particles. Overall, the developed procedure is an effective method that separates particles with a high recovery efficiency without damaging the surface properties of the particles and with reproducible recovery efficiencies that can be corrected for. This technique will enable the accurate characterization and quantification of microplastics in environmental sediment, soil and water samples.

Estimation of Direct Groundwater Discharge and Salt (NaCl) Loading to the North Shore of Lake Ontario

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The role of regional groundwater systems on the Great Lakes is investigated along Lake Ontario's north shore. Streamflow captures most of the groundwater that contributes to Lake Ontario. Hydrograph separation performed on stream gauge data suggests that most of the measured stream flow (~2/3) in south-central Ontario streams originates from groundwater seepage, whereas overland runoff contributes the remaining discharge. From the lake's perspective, this is referred to as indirect groundwater discharge.

In contrast, direct groundwater discharge to Lake Ontario (i.e., along the shoreline) remains considerably uncertain, with some historical estimates provided by Haefeli (1970, 1972), Singer (1974), Ostry (1979a, 1979b), Ostry and Singer (1981), McCulloch (1973) and Hodge (1978). Here, 12 numerical groundwater and integrated flow models are used to determine direct groundwater discharge volumetrically, with the added advantage being that both the direct and indirect groundwater discharges can be isolated. Direct groundwater discharge to the north shore of Lake Ontario was estimated to amount to roughly less than 10% of groundwater discharge for the study area, consistent with historical estimates.

Combining the knowledge of long-term direct and indirect groundwater discharge to Lake Ontario's north shore along with groundwater chemistry, we are led to estimates of groundwater contributions to Great Lake water quality along the nearshore littoral areas. Here, we focus on chloride.

A thorough review of road salt issues along the north shore of Lake Ontario is provided by Mackie et al. (2022). A comprehensive presentation of chloride concentration and trends in surface and groundwater in Ontario is provided by Sorichetti et al. (2022). Here, we take this knowledge and provide estimates of current chloride loading from groundwater along the north shore by capitalizing on the existing groundwater data and knowledge assembled and managed by the Oak Ridges Moraine Groundwater Program.

Current evidence suggests long-term direct groundwater discharge loadings range from 2 to 14 kilotonnes/year of chloride to the north shore of Lake Ontario. Indirect groundwater discharge loadings to the lake from streams along the north shore are estimated to contribute an additional 10–50 kilotonnes/year of chloride. For context, chloride loadings from all sources to Lake Ontario (groundwater, surface water, contaminant point sources, etc.; not including inflow from Lake Erie) are estimated to range from 1700 to 2500 kilotonnes/year (Chapra et al. 2009).

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How Critical Review of WWIS Data Renewed the Debate over the Continuity of a Buried Bedrock Valley in Halton Region

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The Ministry of the Environment, Conservation and Parks (MECP) Water Well Information System (WWIS) data set contains data that is applied in hydrogeological studies across Ontario. Hydrogeological data contained in the data set are often the only source of hydrogeological data in rural areas of the province. However, it is generally agreed that WWIS data contain a mix of valuable and potentially misleading data.

A hydrogeological study was completed in 2011 that concluded that the 2 bedrock valleys that underlie the communities of Acton and Georgetown are not connected and are separated by a rise in the bedrock surface near Limehouse, Ontario. Halton Region commissioned a hydrogeological study in 2021 that included review of the interpreted continuity of the buried bedrock valley between the 2 communities. The project team in the 2021 study used the online mapping tools in the Oak Ridges Moraine Groundwater Program web site to scrutinize the WWIS well logs cited in the 2011 study, and other related data sets in the area. Careful review of the data within the ORMGP web site and additional data sources, determined 1 key domestic well noted to have bedrock observed near ground surface was incorrectly mapped by the driller and, subsequently, given incorrect well co-ordinates by the MECP in the WWIS. Relocating this domestic well, from the Limehouse area to its correct location, opened the door for re-interpretation of the continuity of the buried bedrock valley. Confirmatory drilling to determine the presence or absence of the buried bedrock valley near Limehouse is currently underway.

The findings from this study serve as a reminder of the value of critically reviewing all available hydrogeological source data, including original MECP well logs, particularly where such data deviate from expected interpretations.

Evaluating Source Water Contributions to Streamflow in a Mixed Land-use Precambrian Shield Watershed in the Sudbury Region: The Whitson River Subwatershed

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Synoptic surveys of stable isotopes of water ($\delta^{18}O$ and $\delta^{2}H$) are commonly used to assess source water contributions (e.g., groundwater, snowmelt, precipitation, surface water) to streamflow and are being increasingly integrated into government monitoring programs and hydrological modelling studies, supporting water management and conservation practices, and water quality assessments. The Whiton River project is focussed on improving understanding of hydrologic function and groundwater–surface water interactions in the Whitson River subwatershed, located withing the Greater Sudbury region. The objective of this study is to understand how different sources of water are contributing to streamflow over space and time using synoptic surveys of $\delta^{18}O$ and $\delta^{2}H$ and additional water chemistry parameters.

The Whitson River subwatershed is located in the Vermilion River watershed, a tertiary watershed that delivers water downstream to the Spanish River and onward to Georgian Bay and includes most of the Greater Sudbury municipal area. The Whitson River subwatershed (defined by the outflow to the Vermilion River) is approximately 328 km^2 and the main stem has a total length of 71 km. Landcover across the Whitson subwatershed is about half (49%) forested, with an additional third covered by agricultural (21%) and urban (13%) uses. Over the summer–fall period (June–November) of 2021, biweekly baseflow surveys of streamflow, surface waters (15 locations) and precipitation (2 rain gauges) were conducted within the watershed. Surveys were scheduled to coincide with discharge surveys conducted by Conservation Sudbury along the river's main stem with additional measurements made at headwater sites where and when conditions allowed. Working with Conservation Sudbury, groundwater was sampled from 2 Provincial Groundwater Monitoring Network wells and additional municipal wells within the watershed. Surface water and groundwater sampling included field measurement of temperature, specific conductance, pH and dissolved oxygen. Water samples were analyzed for stable isotope ratios of $\delta^{18}O$ and $\delta^{2}H$ using a Picarro liquid water isotope analyzer (L2120-i) in the Department of Geography at Nipissing University. Cation and anion concentrations were analyzed in the Biogeochemistry Lab at the University of Waterloo. Bivariate plots of $\delta^{18}O$ and $\delta^{2}H$, $\delta^{18}O$ and chloride, and $\delta^{2}H$ and chloride defined endmembers of ambient groundwater (depleted in heavy isotopes and low in chloride), urban groundwater (depleted in heavy isotopes and high in chloride), and surface water (enriched in heavy isotopes and low in chloride) that can contribute to streamflow. Based on these definitions, two-component and three-component mixing models were generated to estimate streamflow contributions in the main stem over the summer and fall seasons. Models show groundwater contributed approximately 50% or more of baseflow in the summer, dropping to around 15% in the fall along the main stem of the river. Three-component mixing models showed urban groundwater contributed approximately 30% or more to baseflow in the summer, dropping to around 4% in the fall. Baseflow estimates derived from graphical hydrograph separation were similar to mixing-model groundwater estimates in summer but suggest this approach would overestimate groundwater contributions during the fall season when surface water makes up a large percentage of stream baseflow. Assessment of source water contributions to streamflow across the Whitson River subwatershed has provided new insights into hydrologic function and groundwater surface–water interactions in this Precambrian Shield watershed.

Stick in the Mud Science: Geological Investigations in the City of Ottawa and Surrounding Champlain Sea Plain

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The Champlain Sea was an embayment of the Atlantic Ocean that covered much of the lowlands around the Ottawa and St. Lawrence rivers until approximately 10 000 to 13 000 years before present. Muds deposited in the Champlain Sea infill locally deep (>90 m) buried bedrock valleys and create unique geological conditions that have a profound impact on groundwater chemistry and flow paths, geotechnical properties of soils and, most famously, geohazards related to the possibility of large retrogressive landslides. An improved understanding of best practices when working with these challenges involves developing a thorough knowledge of the history of the Champlain Sea and the properties of associated sediment units deposited as the Laurentide Ice Sheet withdrew from the region. The Ontario Geological Survey has initiated a sediment mapping project in the City of Ottawa in order to improve understanding of the distribution and thickness of marine muds, to provide additional constraint on the spatial and vertical variations in mud geochemistry, to improve knowledge of bedrock topography in the vicinity of buried valleys, and to provide additional constraint on the properties and architecture of buried and surficial coarse-grained sediments that influence groundwater recharge, flow and storage in the region.

Towards a Hydrogeological Understanding of the Provincial Groundwater Monitoring Network

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The provincial government operates 2 important programs that are critical for understanding the groundwater resources of Ontario: the Provincial Groundwater Monitoring Network (PGMN) led by the Ontario Ministry of Environment, Conservation and Parks (MECP); and a geological mapping and modelling led by the Ontario Geological Survey (OGS). The PGMN is a broad groundwater monitoring network that consists of 521 wells in various aquifers across the province designed to monitor ambient groundwater levels and chemistry conditions and, at select sites, monitor barometric pressure, rainfall and soil moisture. Although the network contains some lithological information, the groundwater information has not been put into a geologic framework. The OGS-led and collaborative OGS–Geological Survey of Canada (GSC) geological mapping and three-dimensional (3-D) modelling focusses on characterizing the nature and geometry of the sediments and bedrock units that form aquifers and aquitards in southern Ontario. For PGMN wells within existing 3-D model areas, the stratigraphy for each well screen will be determined directly from the 3-D model, whereas PGMN records located outside existing model areas will be interpreted through analysis of geological maps, available geological data, nearby well records, existing 2-D geological mapping and consulting reports and/or data. Confidence levels will be assigned to reflect proximity to high-quality geological reference data for the well record.

The project objectives are to

- link the PGMN well screen and open borehole intervals with the best available stratigraphic information from detailed geological investigations and basic physical hydrogeological properties, providing a broader context in which to interpret the groundwater data;
- ensure consistency of nomenclature and approach by using standardized geological interpretations;
- create a database and digital map product that provides users with access to the linked stratigraphic (OGS) and hydrogeologic (MECP) data within a GIS (OGSEarth; MECP Well map portal).

The PGMN data are used by various groundwater managers including the government, municipalities, industry, academia and the well construction industry. Development of a robust geological framework around PGMN well sites and screened intervals will assist in future work in understanding regional or temporal variations in hydrogeological characteristics.

Microplastics Pollution: What Can We Learn from Stormwater Pond Sediments?

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Microplastics are an emerging pollutant. They are a threat to aquatic life because of their resistance to degradation. In urban watersheds, stormwater runoff is a major carrier of microplastics to downstream water bodies. Green infrastructure, in particular stormwater ponds (SWPs), provide both flow reduction and pollutant removal functions. As expected, recent studies have reported high microplastics retention efficiencies in SWPs. However, the variability in the retained microplastic types and sizes among, and within, SWPs remain understudied. Hence, the factors controlling microplastics accumulation in SWP sediments are still not fully understood. The aims of this study are to 1) assess the variability in microplastics types, sizes and abundances within SWP sediment samples; 2) determine the influence of sediment properties on microplastics accumulation in sediments within and between SWPs; and 3) relate microplastics loads in stormwater runoff to upstream land use. One hypothesis is that, within a stormwater pond, microplastic particles associated with fine-grained suspended matter and organic carbon will preferentially accumulate farther away from the inlet, whereas microplastics in coarser suspended matter are deposited near the inlet. Another hypothesis being tested is that catchment land use modulates the loading of microplastics in stormwater runoff and the microplastics accumulation rates in SWPs. Thus far, we have collected sediment samples from 5 SWPs with varying catchment land use types (commercial, industrial and residential) in the City of Kitchener in Ontario. The microplastics were extracted from the sediment using a combined density separation and wet oxidation method. Sediment characteristics, including grain size, mineralogy and organic carbon content, were also analyzed to evaluate their impacts on the within-pond spatial distribution of microplastics accumulated in the sediments. The preliminary results at one of the ponds receiving runoff from an industrial catchment show that microplastic fragment accumulation rates decreased from 9×10^7 particles $m^{-2}\cdot yr^{-1}$ in the inlet forebay to 2×10^7 particles $m^{-2}\cdot yr^{-1}$ in the main basin. Moreover, ponds in the industrial catchments exhibited the highest sediment burial and organic carbon accumulation rates, followed by ponds receiving stormwater from residential and commercial areas. Our ongoing research will shed light on the contribution of urban catchments to microplastic pollution and the factors controlling microplastics retention by SWPs.

Investigating the Reliability of Borehole Density, Neutron and Sonic Logs for Porosity Estimation in the Silurian Lockport Group, Ontario

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The Oil, Gas and Salt Resources Library is a data repository for petroleum well data in Ontario. It has approximately 50 000 porosity and permeability drill core analyses from 500 cores. It also has geophysical logs (e.g., gamma, density, neutron, sonic) from approximately 6000 wells. A significant challenge for geotechnical and hydrogeological studies of the region is the accessibility of digital data on porosity and permeability. Recent work completed on approximately 20 000 core analyses for the Silurian Lockport Group is geographically concentrated within productive oil and gas pools. An opportunity therefore exists to expand the porosity characterization for southern Ontario by using geophysical logs that are more geographically dispersed. As part of this study, scans of analogue geophysical logs are converted to digital data (LAS format) in a process that considers quality assessment and quality control (QA/QC) to obtain useable results.

From the digitized geophysical data, density, neutron and sonic logs are selected to mathematically derive porosity values that are then compared with the measured core porosity values in 42 select petroleum wells to determine the reliability of the respective log types. Preliminary results are focussed on bulk density and sonic logs rather than the many key neutron logs that exist in dated formats. In this study, a good positive correlation is observed between density log porosity and core porosity. Conversely, sonic log porosity shows no correlation with the core porosity data. This can be attributed to the difference in responses of density and sonic logs in the Lockport Group dolostones.

The formation density log measures the bulk density of the formation (solid and fluid parts) and, as such, the derived porosity values indicate total porosity (i.e., interparticle (primary) pore spaces, and vugs and fractures (secondary) pore spaces). The sonic log, on the other hand, measures interval transit time of a compressional soundwave travelling through the formation by recording the first arrival waveform that usually corresponds to a route in the borehole wall free of fractures and vugs, which ultimately results in the derived porosity reflecting primary porosity. As molds, vugs and fractures contribute significantly to the total porosity of the Lockport Group dolostones, density log porosity is postulated to be a more accurate representation of the true porosity. Nonetheless, sonic log remains a useful geophysical tool because the difference between density and sonic porosities can be used to determine the secondary porosity value of the formations.

Tritium in Shallow Groundwater of Southern Ontario

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Ontario Geological Survey (OGS) Groundwater Resources Study 20 presents a spatially detailed, tritium concentration interpolation that represents shallow, modern recharge conditions in groundwater across southern Ontario (Priebe and Hamilton 2022). Also included is a description of data sources, the data selection process, and the approach to interpolating tritium concentrations. The tritium and well data used here were taken from the OGS Ambient Groundwater Geochemistry Project (AGGP) database revision recently published by Hamilton (2021). The AGGP was conducted from 2007 to 2019 in southern Ontario with the aim of characterizing baseline groundwater geochemistry of major overburden and bedrock aquifers. The southern Ontario study area, for this project and the AGGP, covers approximately 95 000 km^2. It is anticipated that the shallow groundwater tritium interpolation offered here may be used as a proxy for the precipitation input function needed for estimating groundwater ages, to support baseflow separation, or simply to investigate relative age ranges and tritium trends in shallow groundwater systems. While no interpolation is perfectly reliable, the data and supporting information provided in this Groundwater Resources Study and its associated files offers users the opportunity to assess reliability as they interpret these result in their area(s) of interest.

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Meadow Restoration Along a Hydro Corridor in Toronto: Enhanced Hydrological Regulating Services

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The Meadoway project, led and implemented by the Toronto and Region Conservation Authority (TRCA), aims to restore 200 ha of underutilized green space to healthy native meadow habitats, and complete a 16 km linear multi-use trail along the Gatineau Hydro Corridor across Scarborough, Ontario. This large city-scale project is expected to restore urban ecosystems and is hypothesized to enhance hydrological regulating services (e.g., erosion and flood control) through the transition from turf grass to deep-rooted native meadow plants. This study aims to test this hypothesis.

In the first part of this study, a systematic literature review was conducted to reveal the hydrological regulating services provided by urban greenspace, as well as key performance indicators (KPIs) and monitoring methods used to evaluate them. It was discovered that urban greenspace can provide hydrological regulation functions, including runoff retention and reduction, through enhanced infiltration, soil moisture retention, evapotranspiration and runoff quality improvement through sediment filtration and nutrient absorption. Vegetation composition and structure, as well as soil characteristics, affect runoff retention and reduction capacity of urban greenspace by controlling the infiltration and percolation capacity.

In the second part of this study, *in-situ* infiltration tests, penetrometer tests and soil sampling were conducted in 2020 on 2 pre-restored turf lands and 2 restored meadows. Soil samples were analyzed for bulk density and porosity. Water balance analysis was conducted by simulating artificial rainfall events with different return periods upon undisturbed vegetated soil samples with accompanying saturated hydraulic conductivity measurements using a mini-disk infiltrometer. The restored meadows had a similar *in-situ* saturated hydraulic conductivity with turf lands, but had a lower cone index, and a higher bulk density and lower porosity than the turf lands. The rainfall simulation tests showed that the turf lands generated much more surface runoff than the restored meadows during rainfall events with return periods from 2 to 100 years. This study indicated that the restoration of native meadows can enhance the hydrological regulating functions of urban greenspace by flood control.

Less is More: Road Salt Threatens Urban Water Quality

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In cold and cold-temperate regions worldwide, the excessive use of de-icers for removing snow and ice from roads, sidewalks and parking lots is causing salinization of freshwater resources, with far-reaching implications for human and aquatic ecosystem health. We investigated 20 years (2001–2020) of lake water chemistry data, changes in watershed land cover and land use (LCLU), and changes in road salt management practices to assess the impact of road salts on Lake Wilcox (LW), a small kettle lake located in the Greater Toronto Area, Ontario, Canada. Since the late 1950s, the LW watershed has been undergoing a progressive conversion from agricultural to urban LCLU. The mean mass of road salt currently applied across the watershed is around 3720 $t{\cdot}yr^{-1}$ of which, according to our estimates, only 10 to 30% reaches the lake. In other words, 70 to 90% of the salt is being retained in the watershed, likely accumulating in, and hence contaminating, soil and groundwater. Despite the high salt retention in the watershed, time-series trend analyses show significant increases in sodium (Na^+), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}) and dissolved inorganic carbon (DIC) concentrations in LW over the past 20 years. In addition, the LW water chemistry has transitioned from a mixed SO_4^{2-}–Cl^-–Ca^{2+}–Mg^{2+} type to a Na^+–Cl^- type because of the divergent trajectories of the dissolved ion inputs from the watershed. Moreover, as a result of salinization, LW exhibits worsening symptoms usually associated with eutrophication, in particular, longer and more severe periods of hypoxia and anoxia of the hypolimnion that, in turn, promote an increasing contribution of internal phosphorus loading from the bottom sediments. In the case of LW, these eutrophication-like symptoms are driven by a strengthening of the water column stratification because of the rising salinity and, thus, the density of the lake water and not, as is usually assumed, increasing watershed nutrient loading. The theoretical chlorinity threshold at which the water column of LW would no longer be able to overturn is estimated at 1.63 $g{\cdot}kg^{-1}$ (45.9 $\mu mol{\cdot}L^{-1}$). A simple mass balance model for lake chloride predicts that, for the business-as-usual scenario, LW could reach this meromixis threshold by the year 2045, beyond which vertical mixing in the lake would be strongly impeded, hence, causing the further expansion of anoxia in the lake. Our results thus imply that stricter controls on road salt applications are needed to protect the water quality in the lake. They further highlight the need for additional research about the growing groundwater salt legacy in urban watersheds that could represent a long-term threat to freshwater resources.

Effects of Groundwater Fluctuations on Natural Source Zone Depletion of Petroleum-derived Hydrocarbons in Contaminated Soils

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Hydrocarbon-contaminated subsurface environments represent a serious pollution problem that poses hazards to water resources. Groundwater fluctuations affect the biogeochemical processes controlling petroleum hydrocarbon (PHC) biodegradation and the generation of methane (CH_4) and carbon dioxide (CO_2). Therefore, understanding the impacts of groundwater fluctuations on natural source zone depletion of PHCs is critical for environmental risk assessment and the design of remediation strategies for contaminated soils and groundwater.

This study comprised an eleven-month soil column experiment to simulate the effects of water table fluctuations on methanogenic PHC biodegradation rates and pathways. Eight columns were filled with 45 cm of undisturbed soil cores collected from a PHC contaminated site in London, Ontario. Four columns simulating fluctuating water table conditions were subjected to 3 successive 3-week cycles of drainage and imbibition. In the remaining 4 columns, the soils remained saturated over the period of the experiment, simulating a static water table. The responses to the imposed water table fluctuations and naphthalene injections were monitored by measuring soil surface CO_2 and CH_4 effluxes, dissolved CO_2, CH_4, and O_2 concentrations, depth-dependent redox potentials, moisture content, $\delta^{13}C$ composition of CO_2 and CH_4, porewater dissolved organic carbon (DOC), dissolved inorganic carbon (DIC) and major anions at the end of each drainage-imbibition cycle.

The results show that maximum CO_2 and CH_4 effluxes were up to 15 times higher during the drainage periods than during the imbibition periods as a result of the release of accumulated CO_2 and CH_4 and aerobic degradation. Also, the average dissolved CH_4 concentration decreased by 44% during the drainage periods because of the release of CO_2 and CH_4, aerobic CH_4 oxidation, and inhibition of methanogenesis in the presence of O_2, whereas the average dissolved CO_2 increased by 120% as a result of oxidation of DOC and CH_4. The results of $\delta^{13}C$ for CO_2 and CH_4 showed the prevailing methanogenic pathway shifted from hydrogen-based methanogenesis to acetate-based methanogenesis in the ethanol–naphthalene spiked soils because of the increase in acetate concentration. Then, CH_4 oxidation in the fluctuating columns became the prevailing pathway after the first drainage period. Moreover, the average naphthalene concentrations dropped by 80% and 49% in the fluctuating and static soil columns, respectively. The results of this study shed new light on understanding the soil drying and rewetting effects on methanogenic hydrocarbon degradation and mitigation of petroleum-derived contamination of soil and groundwater.

Investigating Drivers of Microplastic Pollution in Urban Settings

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As one of the emerging contaminants and the major by-products of plastic materials, microplastics (MPs) have recently been stated as being remarkable contaminants of different environmental matrices including soils, sediments, groundwater and surface water. Stormwater and flowing surface water are important carriers of MPs to downstream surface water bodies, such as ponds and lakes, yet little work has been done to develop models for predicting MP loads in these systems. One common approach in contaminant load modelling is to couple a hydrological model with relationships relating the contaminant concentration or load to explanatory variables, such as water discharge, typically the most important variable controlling concentrations and loads, and variables representing other drivers of contaminant loading, such as land use and climate. In this work, our goal is, therefore, to assemble a database of MP load and/or concentration and discharge measurements in different flowing surface water systems, as well as potential explanatory variables, such as catchment land use and climate conditions, to examine the dependencies of MP loading on these explanatory variables. We searched the Scopus® and Web of Science™ databases and found 64 articles focussing on quantifying MP loads or concentrations in different surface water systems and extracted or calculated the relevant data for the database. The main focus of this work is urban settings, or their sheer impact on microplastic production in larger areas of mixed land cover types. Despite inconsistencies in the definition of MPs, as well as in sampling, extraction and analytical methods, the results indicated a significant relationship between impervious land cover and MP loading within urban catchments (polynomial R^2 = 0.75), where each hectare of imperviousness corresponds up to 7% of increase in MP concentration. The MP loads were, unsurprisingly, highly positively correlated with flow (R^2 of up to 0.86), which is the basis for the relationship between MP concentration and climatic factors. We also found that there is a high positive correlation between total suspended solid (TSS) concentrations and MP concentrations and, therefore, also between their respective loads, which has been reported by others before and indicates that TSS loads can be used to estimate MP loads in the absence of sufficient data. The relative importance of discharge, land use and climate variables as drivers of MP loading has not yet been investigated, and our assembled database will enable the prediction of MP loads in stormwater, streams and rivers at the watershed scale using the explanatory relationships derived from our analysis.

Investigating Watershed Behaviour and Nutrient Transport in an Intensively Managed Agricultural Watershed

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Water quality and quantity issues in the Great Lakes basin are perpetual and increasingly complex as climate and land use continue to change. Inadequate land and stormwater management practices in rural Ontario have led to consequences to human and aquatic life, such as perpetual algal blooms and contaminated drinking water systems. There remains a gap in holistic rural water management studies to support practices that reduce such consequences. A deeper understanding of the water cycle in rural settings and the interconnections between different components of the water cycle (including artificial drainage) is essential to sustain growing rural communities.

Research is conducted in a small southwestern Ontario watershed within the jurisdiction of the Ausable Bayfield Conservation Authority. The land use in the watershed is primarily agricultural, underlain by low permeability soils. The Ontario Ministry of the Environment, Conservation and Parks (MECP) established an Integrated Climate and Water Monitoring Station at the outlet of the watershed along the main channel in 2012. Year-round watershed-scale groundwater and surface water quality and quantity monitoring began in 2017. Completed work includes integrated modelling of groundwater–surface water interactions (Persaud et al. 2020), a groundwater vulnerability assessment (Persaud and Levison 2021), identification of spatial and seasonal nutrient (N, P) dynamics in groundwater and surface water (Rixon et al. 2020; Mackie et al. 2021; May et al. 2023) and determination of the effect of land use changes on the morphology of the creek (Gardner et al. 2022).

The current monitoring network in the watershed includes 6 surface water sites that are monitored for water quality and discharge (including a tile drainage outlet); and 8 wells from which groundwater elevation and water quality are monitored. Discrete sampling methods are used to monitor surface water and groundwater concentrations of P, N, stable isotopes of water ($\delta^{18}O$ and $\delta^{2}H$), and ^{222}Rn. These data are being applied to support the investigation of hydrologic processes and nutrient transport using novel techniques, including isotopic analysis and machine learning applications. It has been found that routine incorporation of isotopic tracers in monthly sampling, as a complement to traditional monitoring variables, may provide an improved assessment of watershed monitoring objectives. Using isotopic tracers paired with nutrient concentrations from an edge-of-field site, and watershed wide, highlight spatial (local and regional) and temporal variations of hydrologic processes and nutrient transport. For greater understanding of the flow and nutrient transport processes, integrated mathematical models, including surface water–groundwater interactions, are used to describe the watershed response under various field (e.g., land use) and climate conditions. In addition, data-driven models using different machine learning algorithms are implemented to quantify nutrient transport in the surface water–groundwater interactions. Machine learning algorithms can effectively determine the interdependence between different transport process variables in a simple manner. An acoustic Doppler current profiler (ADCP) is being used to quantify sediment and nutrient transport in Parkhill Creek. Knowledge gained from this study and associated method development are relevant to policy makers, scientists and landowners to better understand watershed behaviour and climate impacts on watershed health.

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Aquatic Ecotoxicology Measures Applied to Contaminated Groundwater Discharge to Surface Waters

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In assessing groundwater contamination, hydrogeologists typically focus on identifying source areas, tracking contaminant transport and fate through groundwater systems, and determining its arrivals at receptors. One key receptor is aquatic ecosystems. For contaminated groundwater that reaches and discharges to surface water bodies, it is common to report on the concentrations of contaminants in shallow groundwater near the water body. In addition or alternately, concentrations in the receiving water may be determined, often at base flows for streams. These measured concentrations are then compared to water quality guidelines for the protection of aquatic life (if available for the contaminant). Additional information relevant to the health of the aquatic ecosystem—organism exposures, toxicological hazard, and actual impacts (at scales of organism health to community structure)—are less common. The scientific literature provides limited guidance on measurements to provide such information specific to groundwater-sourced contamination. This presentation will discuss a series of collaborative research projects recently performed within the Great Lakes basin with the objective to provide more ecologically relevant data and assessment to address groundwater contaminant risks to aquatic ecosystems. These include i) on-site exposure to a landfill contaminant plume across multiple zones of the aquatic ecosystem: within the sediments (endobenthic zone), on the sediment surface (epibenthic zone) and in the overlying water (pelagic zone); ii) watershed-scale exposure resulting from mass loading of widespread road salt groundwater contamination to streams; and iii) ecotoxicology testing to better measure (and quantify) the risk or impact under field conditions for discharging plumes versus reference conditions.

Canada1Water: Groundwater–Surface-Water Modelling for Climate Change Adaptation

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The impact from Climate Change on Canada's water resources requires an integrated national solution. Canada1Water (C1W) will help First Nations, rural Canadians, agriculture and natural resource extraction (forestry, mining) communities to adapt to climate change, particularly where such changes may be most extreme, for example in northern Canada. It is a 3-year collaborative research and development partnership between Aquanty Inc., Natural Resources Canada, and Agriculture and Agri-Food Canada. It will model the complete water cycle for continental Canada with a focus on groundwater–surface water. Results will be integrated from land surface modelling (to capture the land–atmosphere energy balance), and dynamically downscaled regional climate models, to support the physics-based groundwater–surface water (GW–SW) modelling.

For computation efficiency, and to accommodate distinct regional differences in physiography and hydrogeological processes and issues, Canada has been divided into 7 major catchment areas, with groundwater–surface water model domain areas ranging from 800 000 to 2.3 million km^2. Model spatial resolution varies from 1 to 5 km and resolves fourth-order streams and approximately 7500 lakes and will have 6 to 8 hydrostratigraphic layers. A range of temporal resolutions that extend from hourly to monthly is implemented for the historic and forward-looking GW–SW simulations. Model calibration and validation utilizes a wide array of terrestrial and remote sensing data, including provincial groundwater monitoring networks, national hydrological network stations, and the Gravity Recover and Climate Experiment (GRACE) data. The C1W data sets will facilitate future, regional- and local-scale analysis anywhere within Continental Canada using a nested modelling approach. Model data sets and outputs will be published under an Open Government Data licence.

Land Cover and Use as Drivers of Stream Chemistry and Dissolved Organic Matter Quality

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The molecular composition of dissolved organic matter (DOM) affects aquatic carbon cycling, metal transport and microbial productivity, but information linking land cover and disturbance to specific molecular properties of DOM remains lacking. In this study, we use Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR–MS) and absorbance spectroscopy to characterize the molecular and optical properties of DOM across 30 different lake and tributary sites in the Durham and Kawartha Lakes regions. Using the Ontario Watershed Information Tool (OWIT), watershed characteristics, and land cover and/or land use were quantified and linked to changes in specific DOM molecules. Preliminary findings reveal spatial differences in mass spectra, where DOM in tributary regions is low in mass to charge ratios with more positive spectral slope values, suggesting increased DOM reactivity in tributaries when compared to lakes. Using a combination of water chemistry data and land cover information our project will link important landscape characteristics that influence water and DOM quality; key information to help predict how aquatic ecosystems will change with increasing land disturbance

Watershed-Scale Groundwater Data Communication at the Grand River Conservation Authority

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The Grand River Conservation Authority (GRCA) has been monitoring continuous groundwater levels at over 50 sites in the watershed for the past 20 years. The monitoring program initially began with the installation of Provincial Groundwater Monitoring Network (PGMN) wells in 2002. Today, the PGMN network in the Grand River watershed consists of 40 monitoring wells.

In the mid-2000s, the Ontario Geological Survey (OGS) funded a study to investigate the Dundas buried bedrock valley, a significant buried bedrock valley that stretches across the central portion of the watershed. In the 2010s, and onward, the OGS continued their work in 3-D overburden mapping in the Region of Waterloo, the Orangeville Moraine area, and the southern Grand River watershed. Through partnerships with the OGS in these studies, the GRCA has retained an additional 21 long-term monitoring wells converted from boreholes drilled by the OGS.

Groundwater monitoring data provided through the PGMN and OGS–GRCA sites have been used in numerous projects across the watershed, such as subwatershed, source protection and climate change studies, planning applications, and university research.

The use of monitoring data by site-specific projects is an excellent use of the monitoring data, but does not provide an overall picture of groundwater conditions across the watershed to communicate with groups, such as the GRCA board of directors, the GRCA-led low water response team, and the general public.

In 2021, GRCA began 2 pilot projects to better communicate groundwater level data to the watershed community: groundwater conditions mapping and near real-time data streaming. The first project summarizes groundwater conditions on a watershed scale, and "rolls up" groundwater level data that is collected on an hourly basis, into a monthly median for each site. Monthly median groundwater levels for each site are compared to the site's long-term monthly percentile data, classified by percentile ranges as lowest (<10%), low (10–25%), normal (25–75%), higher (75–90%), and highest (>90%), and mapped on a watershed scale. While these ranges are designed as a qualitative indicator, and should be interpreted with a degree of caution, on the whole, they provide a snapshot of information about how drought affects groundwater levels, the complex relationship between recharge and aquifer levels, and the groundwater–surface water relationship on a watershed scale.

For the second project, 2 PGMN wells equipped with telemetry for near real-time data transmission through GOES (Geostationary Operational Environmental Satellite) funded by the Ministry of Environment, Conservation and Parks (MECP), were further equipped with barologgers by GRCA. Both data feeds transmit to GRCA's WISKI database along with manual measurements and downloaded logger data, to create a robust data build-up similar to how GRCA's surface water data is managed. This near real-time data is now streamed onto GRCA's web pages along with other near real-time surface water data collected by the GRCA.

The groundwater conditions maps are currently provided to the GRCA board quarterly as a part of an overall watershed conditions report, and provide a broad level overview of conditions to the low water response team. Meanwhile, the near real-time data provides quick and easily accessible hydrographs to monitor for groundwater conditions. The objective of both products has been to provide efficient and simple access to groundwater monitoring data to technical and non-technical audiences.

Climate Change Impacts on Groundwater Contribution to the Streamflow Across a Mesoscale Precambrian Shield Watershed in Northeastern Ontario

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The impacts of climate change on precipitation and temperature can alter the pattern, timing and rate of groundwater contribution to streamflow with implications for seasonal streamflow and river water quality. In northeastern Ontario, Precambrian Shield watersheds are characterized by their heterogeneity in land cover and geology which, along with regional differences in climate alteration, will contribute to differences in how changes in climate will impact water resources. However, regional studies of climate change impacts on groundwater and surface water contributions to streamflow in northeastern Ontario are currently limited.

The objective of this study is to evaluate the possible impacts of climate change on source water partitioning to streamflow across the 12 740 km^2 Sturgeon River–Lake Nipissing (SN) watershed, in the northeastern Ontario, by integrating climate predictions and distributed hydrological modelling. Application of isoWATFLOOD, an isotope-enabled semi-physically based distributed hydrologic model has been developed for the SN system using both discharge and stable isotope ($\delta^{18}O$ and $\delta^{2}H$) values in streamflow for calibration, supporting more accurate simulation of hydrological processes than with discharge alone. This effort has been supported by 6 years (2012–2018) of monthly streamflow isotope samples collected across 11 locations within the watershed and daily streamflow records sourced from 5 gauging stations. Simulated discharge was calibrated (2001–2019) and validated (1990–2000) temporally; simulated streamflow $\delta^{18}O$ was calibrated and validated spatially. Model calibration was performed using the Ostrich tool kit with the PA-DDS algorithm, considering 2 optimization objective functions: Kling-Gupta (KGE) for flow and $\delta^{18}O$.

Modelling of climate impacts on streamflow was conducted for 2020 to 2082, using a base period of 1990–2019 for which simulations were used to compare the impacts of future climate change projections. Using a base period ensures consistency in any bias resulting from climate projections for both past and future simulations. The k-mean approach was used to select the appropriate number of climate change models to cover more than 90% variability in projected precipitation and temperature. Eight different global circulation models (GCMs) from Coupled Model Intercomparison Projects (CMIP5) and 2 greenhouse gas emission scenarios (RCPs 4.5 and 8.5) were employed, resulting in 96 simulations (2 ×8 ×3). Impacts of climate change on groundwater contribution to the streamflow are reported for 3 time spans: 2020–2040, 2041–2061, and 2062–2082. Metrics of groundwater and direct runoff contributions to streamflow, freshet peak flow, monthly, seasonal and annual mean streamflow are targeted to assess predicted variation in hydrologic function because of climate change. Results highlight the importance of considering the heterogeneity of the landscape in estimating the impacts of climate change on groundwater–surface water interaction in the northeastern Ontario watersheds. Changes in groundwater contribution rates to the streamflow in the next 60 years should be considered in future water resources management and infrastructure plans.

The Effect of Soil Moisture Content on Naphthalene Biodegradation

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Petroleum hydrocarbon (PHC) contamination of drinking water resources and groundwater-dependent ecosystems is a major problem worldwide. Biodegradation is a key process contributing to the natural attenuation and remediation of PHCs in the subsurface, but the rates and pathways of PHC biodegradation depend on various environmental factors, including soil moisture. Soil moisture exerts an important control on porewater dissolved oxygen (O_2) availability and solute transport and, by extension, on microbial biodegradation activity. To investigate the effect of soil moisture on naphthalene biodegradation, we performed a microcosm incubation experiment under soil moisture conditions ranging from 60% to 100% water-filled pore space (WFPS), and 100% WFPS with ponded water, at a constant temperature of 25°C. Naphthalene-spiked soil microcosms were incubated for approximately 100 days and sampled weekly to biweekly. Time-series data were generated for headspace gas concentrations, porewater chemistry and total soil naphthalene concentrations. Analysis of total soil naphthalene over time revealed that net biodegradation rates were fastest under 60% WFPS conditions, and slowest under fully saturated conditions. Total soil naphthalene data were fit to a first-order kinetic rate equation. These data exhibited 2 distinct temporal phases: Phase 1, characterized by an apparent first-order rate constant of 0.4 day^{-1}, followed by Phase 2, characterized by an apparent first-order rate constant of 0.04 day^{-1}. For each of the 2 phases, the apparent first-order rate constant was similar across the different soil moisture treatments. Porewater chemistry data indicated that Phase 1 was dominated by microbial respiratory processes, whereas Phase 2 was dominated by fermentative processes. That is, the order-of-magnitude change in the apparent first-order degradation rate constant of naphthalene coincided with the onset of (slower) fermentative biodegradation. Overall, our results imply that spatial and temporal variations in soil moisture could bring about large variations in the effectiveness of PHC natural attenuation at contaminated field sites. Results such as those presented here can help inform how we represent PHC biodegradation in fate and transport models for the vadose zone and the underlying groundwater compartment.

Climate Change Effects on Agricultural Nutrient Transport in a Southern Ontario Sand Plain System

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Determining effective methods for quantifying the future impact of climate change is a field of research that has grown dramatically in the past decades and has spread across many disciplines. Climate change has the potential for significant socioeconomic impacts on critical industries and resources, such as agriculture, groundwater (GW) and surface water (SW) quality in southern Ontario. Shifting weather patterns, such as earlier snow melts, and increasing dry and wet extremes pose significant threats to food production sustainability. Additionally, source water is threatened by unknown impacts of these extremes in water quantity and quality. The main goal for this research is to understand nitrate transport with emphasis on extreme storm events and longer term climate changes in an agriculturally intensive sand plain aquifer. This is carried out using a research site in an agricultural subcatchment in southern Ontario. Whitemans Creek is a subwatershed of the Grand River watershed, which eventually discharges to Lake Erie. The land use in the Lower Whitemans Creek (LWC) subcatchment is mainly cash crops (corn, soybean and winter wheat) above a shallow, sandy aquifer. Fast infiltration, combined with increased extreme storm events, presents a potential economic threat to the agri-food industry and a health threat to humans and the environment through transport of nitrogen compounds originating from fertilizers. Monthly monitoring of 10 wells and 6 surface water locations combined with field-scale extreme storm event sampling using lysimeters, drive points and continual surface water sampling over 2 years are informing the development of a SWAT-MODFLOW-RT3D model of the subcatchment. The model will be calibrated and validated using historic and newly collected field data, and then used to assess the impact of extreme storm events and longer term climate changes on nitrate concentrations in the groundwater and creek. Through modifying land use practices over long-term periods using the model, best management practices can be recommended to provide a resiliency plan for the agri-food sector and for protection of source water. The preliminary results obtained from the monthly sampling show a tendency of higher nitrate concentrations (above drinking water limits, 10 mg/L NO_3–N) in the wells located at the northern and southern end of the basin catchment, whereas the surface water nitrate concentrations vary less throughout the main creek. Also, important concentrations of sulphate were reported only at the watershed's outlet. These preliminary results are being used to form a conceptual model of nutrient transport processes in the watershed, and to inform future storm-event monitoring approaches.

Modelling Phosphorus Retention in a Bioretention Cell: Implication for Groundwater Pollution

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Bioretention cells (BRCs) have emerged as one of the green infrastructure and low impact development (LID) practices to reduce peak discharge and nutrient export in urban areas. Despite growing implementation globally, understanding of phosphorus (P) cycling and retention mechanisms in BRC is limited. In this presentation, we present a novel numerical reactive transport model to simulate the fate and transport of P in a BRC system in the metropolitan Greater Toronto Area. Unlike existing BRC models, our model incorporates a detailed representation of the biogeochemical reaction network that control P cycling and retention within the BRC. We used this model as a diagnostic tool to determine the relative importance of different P removal processes and their contributions to the P accumulation trajectory within the BRC over 8 years of operation. Model results were validated against time-series flow data, plus water chemistry and soil filter media P concentration depth profiles measured between 2012 and 2019. A sequential extraction analysis was also applied to soil cores collected in 2019 to validate the model-derived P pools profiles. The model simulations reproduce the total P (TP) and soluble reactive P (SRP) outflow loads with the TP accumulation rate in the soil filter media and the partitioning of P between different soil chemical pools. The simulation results indicate that groundwater recharge is the dominant mechanism responsible for decreasing the surface water discharge from the BRC (63% runoff reduction), which implies potential impact of infiltrated stormwater on groundwater quality. But that bioretention cell is still efficient at reducing P concentration of infiltrated stormwater since accumulation in the soil filter media is the predominant P removal mechanism (57% of TP influx), and the filter media was not saturated after 8 years of operation. Of P retained within the soil filter media, 48% is highly stable, 41% potentially remobilizable and 11% easily remobilizable. In addition to elucidating P cycling, our model can help to assess the impact of BRC design choices on P retention efficiency and the stability of the retained P within the soil filter media and eventually to predict the P transport to groundwater aquifers.

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Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton(short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 9**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy) / ton (short)	1 ounce (troy) / ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights / ton (short)	1 pennyweight / ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

*Note: Conversion factors in **bold** type are exact. The conversion factors have been taken from or have been derived from factors given in the* Metric Practice Guide for the Canadian Mining and Metallurgical Industries, *published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

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