Natural Resources Canada | Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8528

ONTARIO GEOLOGICAL SURVEY
OPEN FILE REPORT 6349

Regional-scale groundwater geoscience in southern Ontario: an Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists open house

H.A.J. Russell, D. Ford, S. Holysh, and E.H. Priebe
(compilers)

2019

Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8528

ONTARIO GEOLOGICAL SURVEY
OPEN FILE REPORT 6349

Regional-scale groundwater geoscience in southern Ontario: an Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists open house

H.A.J. Russell[1], D. Ford[2], S. Holysh[3], and E.H. Priebe[4]
(compilers)

[1] Geological Survey of Canada, 601 Booth St. Ottawa, Ontario K1A 0E8
[2] Toronto and Region Conservation Authority, 5 Shoreham Drive, Downsview, Ontario M3N 1S4
[3] Oak Ridges Moraine Groundwater Program, 5 Shoreham Drive, Downsview, Ontario M3N 1S4
[4] Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, 933 Ramsey Lake Road, Sudbury, Ontario P3E 6B5

2019

Permanent link: https://doi.org/10.4095/313529

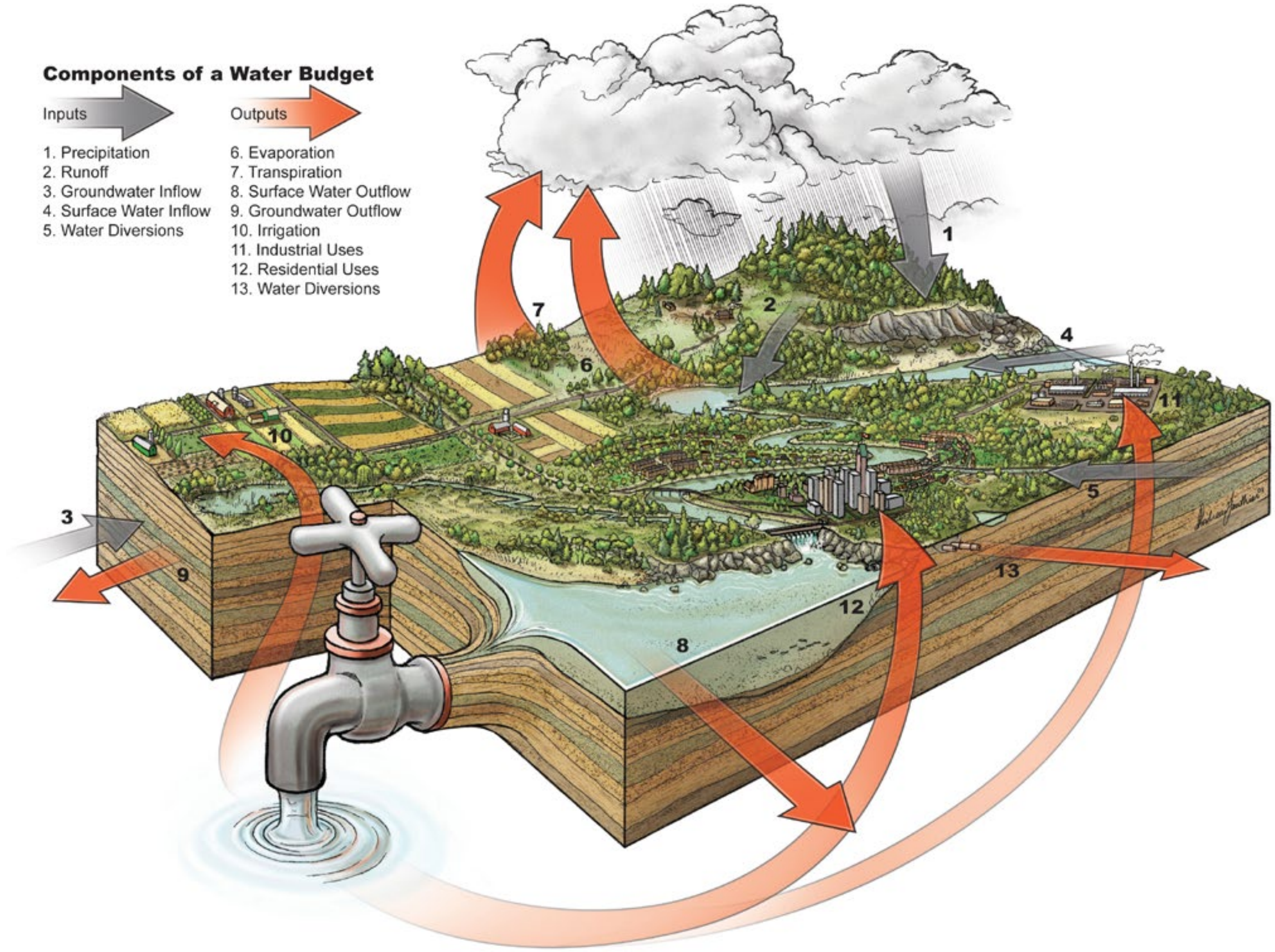
This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Recommended citation
Russell, H.A.J., Ford, D., Holysh, S., and Priebe, E.H., 2019. 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 8528 (*also* Ontario Geological Survey, Open File Report 6349) 46 p. https://doi.org/10.4095/313529

Publications in this series have not been edited; they are released as submitted by the author.

Regional-scale groundwater geoscience in southern Ontario: an Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists open house

February 27th and 28th, 2019 | Delta Hotel, Guelph



Scan me

Groundwater Information Network

Compiled by:

Hazen A.J. Russell, Geological Survey of Canada
Don Ford, Toronto and Region Conservation Authority
Steve Holysh, and Oak Ridges Moraine Groundwater Program
Elizabeth H. Priebe Ontario Geological Survey

Geological Survey of Canada, Open File 8528.
Ontario Geological Survey, Open File Report 6349.

Canada

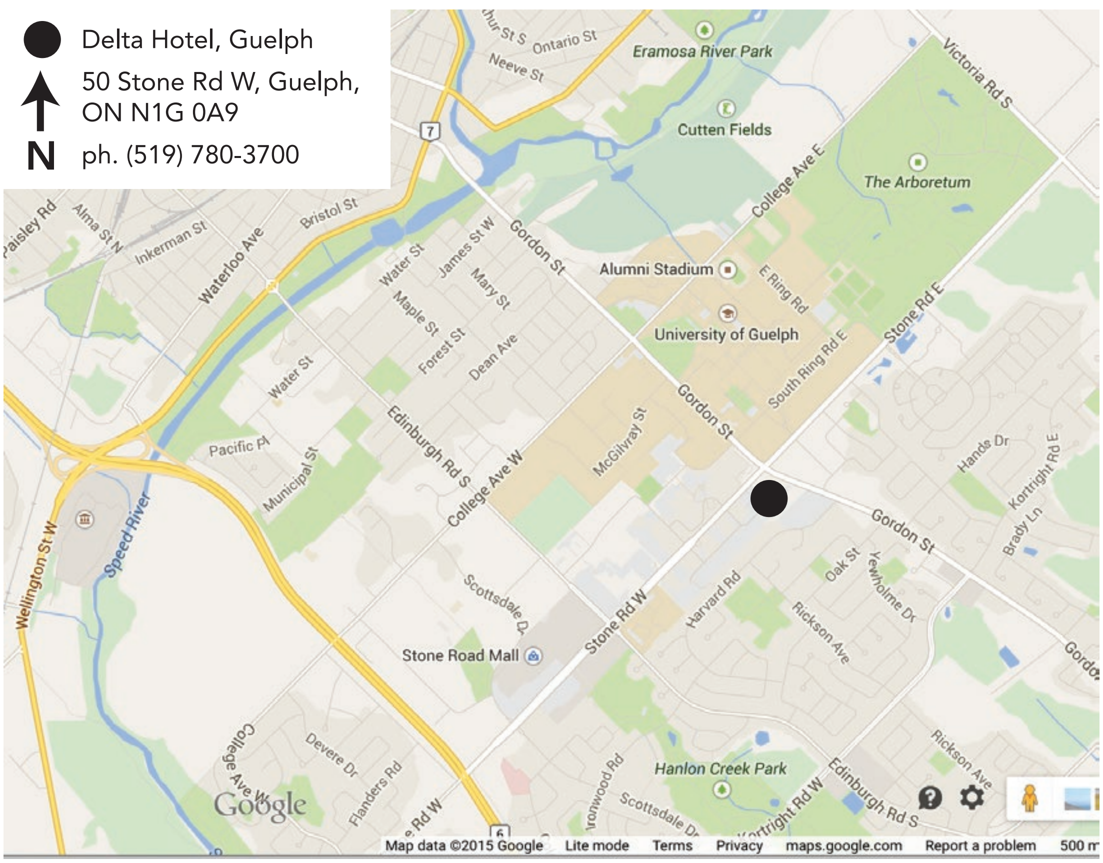
CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Ontario

Conservation ONTARIO Natural Champions

iah aih

Location Map



Program

OGS/GSC/CO Workshop 2019

February 27. Oral Presentations (Preliminary)

START	END	TITLE	PRESENTER	AFFILIATION
8:00	9:00	Registration and Networking		
8:50	9:00	Introduction: Logistical Details	Russell/Priebe	
9:00	9:10	Introduction	Yves Michaud	GSC
9:10	9:30	The Ontario Geological Survey's Groundwater Initiative: Highlights from the Past Two Decades	Elizabeth Priebe	OGS
9:30	9:50	OGS – GSC Collaboration on Regional Groundwater Studies 2015 – 2018: Conclusion	Hazen Russell	GSC
9:50	10:10	Update on Ontario's Water Quantity Management (Policy, Program and Science) Review	Heather Brodie Brown	MOECP
10:10	**10:40**	**Break**		
10:40	11:00	Hydrogeological Terrains and Typical Settings of Southern Ontario	David Sharpe	GSC
11:00	11:20	Multi-order Hydrologic Position: A High-Resolution Dataset for the Conterminous United States	Kenneth Belitz	USGS
11:20	11:40	Groundwater Research in Southern Ontario by Environment and Climate Change Canada	Jim Roy	ECCC
11:40	12:00	3-Dimensional Modelling of Quaternary Deposits in South Simcoe County for Groundwater Applications	Andy Bajc	OGS
12:00	**13:20**	**Lunch**		
13:30	13:50	Opportunities and Challenges Provided by Regional-scale LiDAR Data Sets	John Lindsay	University of Guelph
13:50	14:10	Geospatial Distribution of Chemical, Bacteriological and Gas Parameters in Southern Ontario Groundwater	Laura Colgrove	OGS
14:10	14:30	Geochemistry of Southern Ontario Quaternary Sediments	Ross Knight	GSC
14:30	14:50	Applications of Borehole Geophysical Logs in Groundwater Studies	Heather Crow	GSC
14:50	**15:10**	**Break**		
15:10	15:30	A 3-D Geologic Model of the Paleozoic Bedrock of Southern Ontario	Terry Carter	Carter Geoscience
15:30	15:50	A Development of a Fully Integrated Groundwater – Surface Water Modelling Platform for the Phanerozoic Basin Region of Southern Ontario	Steven Frey	Aquanty
15:50	16:10	Monitoring Groundwater Changes in Southern Ontario using GRACE Satellite Gravity Measurements	John Crowley	Canadian Geodetic Survey
16:10	**16:30**	**Wrap-up**		

Program (cont.)

OGS/GSC/CO Workshop 2019

February 28. Oral Presentations (Preliminary)

START	END	TITLE	PRESENTER	AFFILIATION
8:30	9:00	Registration/Networking		
9:00	9:10	Welcome to Day 2 Conservation Authorities Geoscience	Ford and Holysh	TRCA / Oak Ridges Water
9:10	10:20	**Are we on the Right Track?** A Panel Discussion on the Future Direction of Groundwater Management in Ontario **PANELISTS** Jennifer Stephens, Dave Belanger, Jim Buttle, Tessa Di'Iorio, Victor Doyle, David L. Rudolph	Steve Holysh	Oak Ridges Water
10:20	**10:35**	**Break**		
10:35	12:00	**Are we on the right track?** (Panel Discussion continued)		
12:00	**13:20**	**Lunch**		
13:30	13:50	Hydrogeology of the Deep Flow System within Quaternary Sediments, South-central Ontario	Richard Gerber	Oak Ridges Water
13:50	14:10	Hydraulic Tomography Analysis of Municipal Well Operation Data with Geology-Based Groundwater Models at the Mannheim Wellfield in Kitchener, Ontario, Canada	Xin Tong	University of Waterloo
14:10	14:30	Using 222-Radon Surveys and Regional Scale Groundwater Models to Evaluate Groundwater Discharge to Lake Simcoe	Clare Robinson	University of Western Ontario
14:30	14:50	Optimization of Low Impact Development Placement through Shallow Subsurface Characterization	Tara Harvey	LSRCA
14:50	15:10	Application of a Regional Scale Integrated Modelling Platform Towards Watershed Insights'	Steven Frey	Aquanty
15:10	**15:30**	**Break**		
15:30	15:50	Comprehensive Groundwater Data Management & Analyses – Raising the Bar	Steve Holysh	Oak Ridges Water
15:50	16:10	A Renaissance in Regional Hydrogeology	David Rudolph	University of Waterloo
16:10	**16:30**	**Wrap-up**	Russell / Priebe / Ford / Holysh	

OGS/GSC/CO Workshop 2019

February 27 and February 28. Poster Presentations (Preliminary)

	TITLE	AUTHOR	AFFILIATION
1	Insights from Combined Interpretation of Sediment Cores and Geophysical Logs in the Niagara Peninsula, ON	Abigail Burt	OGS
2	The Ambient Groundwater Geochemistry Program: Northeastern Ontario Pilot Project	Kayla Dell	OGS
3	Deconstructing the Newmarket Till in South-central Ontario	Riley Mulligan	OGS
4	3-Dimensional Modelling of Quaternary Deposits in South Simcoe County for Groundwater Applications	Andy Bajc	OGS
5	Interferometry A Case Study in Southern Ontario	Junhua Li	CCMEO
6	Intersections of Wildfire, Water and Land: Using Groundwater Science to Reduce Risks to Water Supplies	Shona de Jong	Queen's University
7	*Downscaling SMOS/SMAP Soil Moisture Product Using Radarsat Data: A Case Study in Southern Ontario*	Junhua Li	CCMEO
8	*The Bells Corner Borehole Geophysical Calibration Facility of the Geological Survey of Canada*	Heather Crow	GSC
9	*A Chemostratigraphic Framework for Southern Ontario: A Progress Report*	Ross Knight	GSC
10	Virtual Reality Visualization of Phanerozoic 3D Bedrock Model	Jordan Clark	OGSRL
11	*An Animation of the 3D Phanerozoic Geological Model of Southern Ontario*	Hazen Russell	GSC

* titles in italic have no abstract in current volume, see 2018.

Context

The 2019 Ontario Geological Survey (OGS)– Geological Survey of Canada (GSC) Open House is the fourth and concluding open house that marks the end of a five year collaborative project in Southern Ontario. The Open house continues previous years collaboration with Conservation Ontario for day 2.

The first day of the open house continues to profile OGS and GSC research with an attempt to integrate perspectives from the USGS and other Canadian federal departments and Ontario provincial ministries. Day two focuses on work completed by, and in collaboration with Conservation Authorities in Southern and Eastern Ontario. The morning is reserved for a panel discussion and Question period, the afternoon continues the format of talks related to Conservation Authority collaboration.

Talks on the two days continue to be 20 minutes in length; however, there is an expanded time frame during the health breaks and at the end of the day to network and also interact with authors who decided to have poster presentations. Poster presentations will be on display for the complete two days.

In 2016 four key issues were identified as being the focus of presentations. This year we continue to emphasize:

- Outcomes of the OGS-GSC 2012-2015 Groundwater Geoscience Knowledge Gap Analysis
- Canada – USA Great Lakes Water Quality Agreement /Canada – Ontario Great Lakes Agreement
- Provincial Groundwater Data Management and modelling.
- Conservation Authority Geoscience

As in previous years, the 2019 open house builds upon the issue of outreach and communications identified in the 2012-2015 OGS Gap analyses1. It is the fourth in a series of annual open houses planned for late winter to connect with groundwater practitioners and policy makers in southern Ontario, and share updates on OGS-GSC geoscience activities. The 2019 Open house marks the end of the federal – provincial collaboration for this open house. In 2020 a new format will emerge as Conservation Ontario and Provincial Ministries work together to maintain a strong communication framework for groundwater geoscience for Southern Ontario.

Acknowledgements

Day two has been sponsored by a contribution to Conservation Ontario Geoscientists Group by the International Association of Hydrogeologists Canadian National Chapter (IAH-CNC). The time and effort of the workshop presenters and their respective agencies is much appreciated. The TRCA handled conference administration for both days. M. Clement helped with administrative aspects for the OGS and GSC. The Conservation Authorities participation has been coordinated by Conservation Ontario's Geoscience Group (COGG). An internal review at the GSC by B. Kjarsgaard is much appreciated. Donna Ferguson and Glenn Ferguson completed graphic production of the workshop program. This is a contribution of the Groundwater Geoscience Program of the Geological Survey of Canada, Natural Resources Canada. This work is a contribution of the GSC-OGS Southern Ontario project on groundwater 2014 – 2019.

Associated publications of previous gap analysis, workshop(s), and open houses between 2015 and 2019.

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, 64 p.

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, 34 p. **https://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, 56 p. **https://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, 62 p. **https://doi.org/10.4095/306472**

Presentations from previous years can be found on the **Groundwater Information Network (GIN)** under news. Some presentations may be missing and in those cases permission was not granted by the respective organization of the author(s).

Table of Contents

Table of Contents (cont.)

Dimensional Modelling of Quaternary Deposits in South Simcoe County for Groundwater Applications

Bajc, Andy F. and Riley P.M. Mulligan
Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development and Mines, Sudbury, ON P3E 6B5 • andy.bajc@ontario.ca

As part of its Groundwater Initiative, the Ontario Geological Survey has constructed a 3-dimensional (3-D) model of Quaternary deposits in South Simcoe County for groundwater applications. A conceptual stratigraphic framework, informed by the recent acquisition of high-quality geological and geophysical data, consists of 15 hydrostratigraphic units overlying Ordovician bedrock. Although the project has resulted in an improved understanding of bedrock topography, details of the bedrock surface including the morphology and origin of the Laurentian valley, remains still debated.

The 15 hydrostratigraphic units comprise 3 main groups. These include: 1) an Illinois Episode (or older package), consisting primarily of diamicton, overlain by non-glacial sediments spanning the Sangamon interglacial and earliest part of the Wisconsin Episode; 2) a thick (up to 125 m), Early-Middle Wisconsin transgressive sequence of glaciolacustrine deposits (Scarborough and Thorncliffe Formation equivalents) laid down in a high-level lake bordered by the advancing Laurentide Ice Sheet (LIS). Subsequent overriding of the lake basin by the LIS initiated deposition of the Late Wisconsin Newmarket Till which continued during and after multiple phases of tunnel valley erosion; and 3) a mixed package of late glacial and post-glacial gravel, sand, silt and clay associated with the interlobate Oak Ridges Moraine along the southern margin of the study area, kame terrace deposits along the Niagara Escarpment and glaciolacustrine sediments in low-lying areas.

The soon to be released 3-D model, with a block size of 100 m, and accompanying Groundwater Resources Study report supplements previously released datasets, including results of geophysical surveys and continuously cored boreholes. These data provide an improved understanding of the distribution, architecture and facies variability of sediments comprising the Quaternary succession for future hydrogeologic modelling exercises. Outputs include an abbreviated version of the subsurface database (including stratigraphic picks) used for the creation of the model, a series of both continuous and discontinuous surfaces for hydrogeologic modelling (available as both ArcGIS and ASCII grids), structural contour and isopach plots with accompanying maps showing the distribution and quality of data used in their generation, and N-S and E-W cross-sections plotted at 2 km intervals using both a hydrostratigraphic legend and a simplified aquifer-aquitard-bedrock scheme. Derivative products include aquifer recharge and vulnerability maps. Much of this information will be viewable in a Google Earth® platform for enhanced interactive viewing and interpretation.

Multi-order Hydrologic Position: A High-Resolution Dataset for the Conterminous United States

Belitz[1], Kenneth; Richard Moore[2], Terri Arnold[3], Jennifer Sharp[3], and J. Jeffrey Starn[4]

[1] *U.S. Geological Survey, Carlisle, MA, 01741 • kbelitz@usgs.gov*

[2] *U.S. Geological Survey, Pembroke, NH, 03275*

[3] *U.S. Geological Survey, Urbana, IL, 61801*

[4] *U.S. Geological Survey, East Hartford, CT, 06108*

The location of a point within a stream network can be an important measure in hydrology. Hydrologic position (HP) is defined here by two metrics: lateral position (LP) and distance from stream to divide (DSD). LP is the relative position of a point between the stream and its watershed divide. DSD for a point is the sum of the shortest distance to the stream (DS) and the shortest distance to the divide. LP is the quotient of DS divided by DSD. In addition, HP is specified relative to a stream network of a given order, and hence each point is assigned multiple values of HP. The highest stream order in the conterminous U.S. is ten (Mississippi River below Missouri River).

Hydrologic order "n" is defined here as the network of streams of order n and higher. For example, hydrologic order 1 is the network of all streams, and hydrologic order 2 consists only of streams of order 2 and higher. For a given hydrologic order, watershed divides are defined by Thiessen polygons, rather than by topographic divides. A Thiessen watershed consists of all points that are closer to a given stream than to any other stream. Thiessen watershed divides can change from one hydrologic order to the next. The term multi-order hydrologic position (MOHP) is used to acknowledge that HP for a point is defined for each of the different hydrologic orders. MOHP was developed for nine hydrologic orders.

MOHP for the conterminous U.S. was developed using the National Hydrography Dataset Version 2 (NHDPlusV2). The NHDplusV2 represents streams and waterbodies as flowlines, and includes an attribute equivalent to stream order. In addition, it was necessary to identify streams in Canada and Mexico that are close enough to the U.S. to influence computations. Values of MOHP were identified using a raster approach with a 30-meter cell size. The file sizes for the resulting geodatabases – LP and DSD for 9 hydrologic orders for about 8.7 billion cells – were large. Consequently, an additional dataset was developed for 90-m cells by subsampling the 30-m datasets.

Two case studies, using random forest models, are presented that demonstrate the utility of MOHP as predictor variables: geomorphic province in California's Central Valley, and depth to the water table for the Fox-Wolf-Peshtigo drainages in Wisconsin.

Update on Ontario’s Water Quantity Management (Policy, Program and Science) Review

Brodie-Brown, Heather

Ministry of Environment and Climate Change, Foster Bldg., 9th Floor, 40 St Clair Ave W, Toronto, ON M4V 1M2 • heather.brodie-brown@ontario.ca

Ontario's Government for the People is committed to preserving water for families now and for future generations. To achieve this Ontario is undertaking a thorough review of the province’s water taking policies, programs and science tools to ensure that vital water resources are adequately protected and sustainably used in the face of a changing climate and continued population growth. Ontario has extended the moratorium on water taking permits by one year, now ending December 31, 2019, to allow time to complete this review and consult on any recommended enhancements.

At the 2018 OGS-GSC Workshop, the ministry presented, “The Science behind Ontario’s Water Quantity Management Review” and outlined key aspects of the water quantity science work being undertaken to ensure a robust and adaptive approach to water resources management into the future, and the water quantity scientific work being undertaken to improve our understanding of water resources knowledge on Ontario. The ministry's consultant, BluMetric Environmental Inc. (BMEI) presented an outline of water quantity science and jurisdictional reviews and water quantity assessments being undertaken.

The Ministry will provide an update on the moratorium extension and the water quantity management review, particularly the science components and some of the findings of the BMEI project. As identified in the draft "Preserving and Protecting our Environment for Future Generations: A Made-in-Ontario Environment Plan" the focus moving forward will include examining approaches to assess and manage multiple water takings, establish priorities for different water uses, prepare and respond to drought conditions and ensure the knowledge gained through the drinking water source protection program helps inform our water management programs.
(https://prod-environmental-registry.s3.amazonaws.com/2018-11/EnvironmentPlan_1.pdf)

Insights from Combined Interpretation of Sediment Cores and Geophysical Logs in the Niagara Peninsula, Southern Ontario

Burt[1], Abigail K. and Heather Crow[2]

[1] *Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development & Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5 • abigail.burt@ontario.ca*

[2] *Geological Survey of Canada, Natural Resources Canada, 601 Booth Street, Ottawa, ON K1A 0E8*

In 2013, the Ontario Geological Survey (OGS) initiated a three-dimensional (3-D) mapping project encompassing the Niagara Peninsula in support of source water protection and land use planning. Key project goals are to 1) build a regional scale 3-D framework model of Quaternary deposits that form both regional and local aquifers and aquitards, and 2) characterize the internal properties of the modeled units.

Between 2014 and 2017, 99 continuously cored boreholes were drilled, geologically logged, photographed and sampled in the field. Detailed sedimentological observations and field penetration test results on clay-rich intervals of core have now been augmented by pebble lithology counts and laboratory grain size and carbonate content analysis. Records were also kept regarding drilling methods, core recovery and intervals with drilling fluid losses.

The Geological Survey of Canada collaborated in the borehole study by acquiring a suite of geophysical logs in 14 boreholes which had been converted to PVC-cased monitoring wells. Natural gamma and induction (apparent conductivity and magnetic susceptibility) logs were acquired to investigate lithological variation within the sediments. Downhole seismic logs were acquired to measure material velocities. High-resolution fluid temperature logs identified regional groundwater temperature trends.

Significant changes in geophysical log responses were evident at major stratigraphic boundaries while subtle variations in responses provided insights into the geochemical and physical properties of the sediments within stratigraphic units. Key geological and geophysical logs from three boreholes have been selected to illustrate the benefits of an integrated approach. Borehole BH05 is characterised by glaciolacustrine mud and muddy diamicton, BH13 is dominated by glaciolacustrine mud, and BH14 intercepted gravel, sand and mud. Thinner beds of overconsolidated sandy silt diamicton and variably dolostone, gypsum and shale bedrock were also observed.

Gamma and induction responses are sensitive to changes in the proportion of sand, silt and clay within both diamicton and glaciolacustrine deposits. Potentially water-bearing sandy units are clearly distinguished by high magnetic susceptibility and low conductivity values while the reverse records units rich in clay-sized grains. On the Niagara Peninsula, it can be difficult to distinguish between glaciolacustrine mud and muddy till. However, decreases in velocity correspond to a change from grounded ice to a glaciolacustrine depositional setting, while increases in magnetic susceptibility relate to ice-rafted debris. The integrated examination of sediment cores and geophysical logs together provides an improved understanding of the complex local geological processes, and thus aided in the search for aquifers and the characterization of regional aquitard units.

A 3-D Geologic Model of the Paleozoic Bedrock of Southern Ontario

Carter[1], Terry; Frank R. Brunton[2], Jordan Clark[3], Lee Fortner[4], Charles E. Logan[5], Hazen A.J. Russell[5], Maria Somers[3], and Kei Yeung[2]

[1] *Geological consultant, 35 Parks Edge Crescent, London, ON N6K 3P4 terry.carter@cartergeologic.com*

[2] *Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development and Mines, Sudbury, ON P3E 6B5*

[3] *Oil, Gas, & Salt Resources Library, 669 Exeter Road, London, ON N6E 1L3*

[4] *Petroleum Operations Section, Ministry of Natural Resources & Forestry, 659 Exeter Road, London, ON N6E 1L3*

[5] *Geological Survey of Canada, Natural Resources Canada, 601 Booth Street, Ottawa, ON K1A0E8*

The regional 3-D geological model of the Paleozoic bedrock of southern Ontario will be published in 2019. The model encompasses all 110,000 km^2 of the western St. Lawrence Lowlands region of south-western and south-central Ontario, except for Manitoulin Island.

The model is constructed in Leapfrog© Works (Aranz Geo Limited) - an implicit modelling application, with 56 layers representing 70 Paleozoic bedrock formations, the Precambrian basement, and overlying unconsolidated sediments. Layers were constructed using formation depth data from 26,900 petroleum borehole records in the Ontario Petroleum Data System (OPDS), supplemented by hundreds of deep bedrock boreholes compiled by OGS. Formation depth data in the borehole records comprise the primary data input for the 3-D model. Model layers are based on a new lithostratigraphic chart prepared for this project. A new digital bedrock topography surface has also been constructed and is combined with a new digital subcrop geology map to assemble a grid of 3-D points that approximate and constrain the subcrop surface of each modelled formation and better align the layers with expert knowledge and mapped geology.

Model development was an iterative cycle of interim model construction, expert geological appraisal to identify errors/inconsistencies in both the model construction and borehole database, followed by QA/QC editing of formation depth data using well records, geophysical logs, drill cuttings and drill core. QA/QC issues included; incorrect borehole location coordinates, data entry errors, missing / inconsistent / incorrect formation contact picks, sparse data, extrapolation issues beneath Lake Huron, mismatch of digital bedrock topography and bedrock geology, and need for improved data filtering algorithms for calculation of formation bottom depths in individual wells.

This project has generated a robust lithostratigraphic model which is a logical next step in the evolution of regional geological mapping. It illustrates the geological connections and continuity between the surface and subsurface; a necessary precursor for understanding hydrogeological links between surface water systems and groundwater, and provides a physical basis for future development of a full hydrostratigraphic model for the area. Other practical applications of the model include; natural resource extraction (e.g., water, gypsum, salt, gas, oil, aggregate), site selection for nuclear waste disposal, exploitation of geothermal energy, public outreach and education, identification of gaps in data and knowledge, and shortcomings in modeling algorithms. Users must recognize that the model is a data-driven algorithmic representation of the actual bedrock geology and is not a substitute for detailed geological mapping. The model is considered a work-in-progress subject to future improvements as new and improved data, modeling software, data processing tools, and geological interpretations become available.

The availability of OPDS well database was a critical component in the development of the 3-D model. Model development QA/QC has, in turn, improved the quality of the borehole and related databases.

Geospatial Distribution of Chemical, Bacteriological and Gas Parameters in Southern Ontario Groundwater

Colgrove, Laura M. and Stewart M. Hamilton
Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development and Mines, Sudbury, ON P3E 6B5 • laura@ogsrlibrary.com

Groundwater Resources Study 17 is a recent publication by the Ontario Geological Survey that delineates wide regions in southern Ontario wherein individual chemical constituents are elevated in groundwater including arsenic, barium, boron, fluoride, nuisance gases (methane, hydrogen sulphide, hypoxic gas), iodide, nitrate, chloride, selenium and uranium. With several exceptions, these regions are explainable as combinations of the natural influence of (1) bedrock lithology, (2) marine sediments, (3) glacial sediment thickness and (4) bedrock topography. Marine influence, particularly in eastern Ontario, is apparent in the distribution of chloride, sodium, iodine, boron, selenium and methane. Drift thickness and/or bedrock topography influences the distribution of chloride, selenium, methane, barium and to a lesser extent, iodine. Bedrock lithogeochemistry controls, or partly controls, the distribution of arsenic, selenium, barium, uranium and chloride.

Shales and carbonate rocks of Devonian age host groundwater that is almost universally elevated in fluoride, making this the only constituent that is spatially related to the age of the host formations. Nitrate is one of several mapped parameters that shows human influence in its distribution; which combines with the influences of coarse grained glacial sedimentary cover and karst in bedrock. The spatial incidence of fecal and total coliform bacteria is also discussed in GRS 17. The occurrence of karst appears to an overwhelming factor in the distribution of coliform bacteria in bedrock. Another anthropogenic influence is chloride from road salting, which has a widespread but intermittent distribution. It can be easily differentiated from natural chloride by comparing molar ratios against those for bromide. The data used to generate the polygons in GRS-17 were derived from the OGS Ambient Groundwater Geochemistry database.

Applications of Borehole Geophysical Logs in Groundwater Studies

Crow[1], Heather ; Abigail Burt[2], Ross D. Knight[1], Riley Mulligan[2], André J.-M. Pugin[1], and Hazen A.J. Russell[1]

[1] *Geological Survey of Canada, Natural Resources Canada, 601 Booth St., Ottawa, ON K1A 0E8 heather.crow@canada.ca*

[2] *Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development & Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5*

Over the past 5-year program cycle, the Geological Survey of Canada (GSC) has completed downhole geophysical logging to i) support regional stratigraphic studies, ii) conduct velocity analyses for seismic reflection surveys, iii) support hydrogeophysics studies, iv) adopt new methodologies, and v) maintain a national calibration facility. The geophysical logs provide in situ information on physical and chemical properties of sediment and rock, and of borehole fluid parameters to support groundwater studies through improved lithological characterization. Using examples from different project settings across southern and eastern Ontario, the benefits of an integrated approach to geophysical, geological, geochemical, and hydrogeological datasets will be discussed.

In collaboration with the Ontario Geological Survey's 3D Quaternary sediment mapping projects in Southern Ontario, the GSC collected geophysical logs in 20 cored boreholes in the Niagara and central Simcoe County regions. The integration of sediment core examination with geophysical logs supported an enhanced understanding of local complex geological processes. While significant changes in log responses at key stratigraphic boundaries helped to distinguish potentially water-bearing coarse-grained units from fine-grained aquitards, logs yielded equally useful information about subtle changes in grain sizes, mineralogy, and velocity structure related to depositional conditions.

At two sites east of Toronto, geophysical logs were interpreted together with chemostratigraphic data to identify geochemical changes in the sediment column. Elemental variations were well aligned with geophysical log responses and changes in grain size. Geophysical logs also identified non-chemical changes in sediment, such as variations in porosity/density, or pore fluid chemistry, providing highly complementary datasets for detailed litho-stratigraphic analyses.

Over the past few years, new technologies have been applied in GSC bedrock and sediment calibration boreholes. The use of a GSC-developed controlled frequency vibratory source is allowing for selection of source parameters fine-tuned for different geological settings. This is showing great potential for high-resolution downhole velocity testing, supporting optimized reflection seismic velocity conversions. An experimental deployment of slim-hole borehole magnetic resonance (BMR) tools in calibration holes around Ottawa was conducted in bedrock and post-glacial sediments. These instruments are designed to measure formation porosity and pore size distribution without the use of radioactive sources. Although the influence of magnetite-bearing minerals from Shield-derived sediments is a topic of ongoing study, early qualitative results from the tests are encouraging. The evaluation of new tools using calibration datasets is an important driver for the ongoing work to update geophysical calibration facilities.

Monitoring Groundwater Changes in Southern Ontario Using GRACE Satellite Gravity Measurements

Crowley, John W.

Canadian Geodetic Survey, Surveyor General Branch, Natural Resources Canada, 588 Booth Street, 2nd Floor Ottawa, ON K1A 0Y7 • john.crowley@canada.ca

The Gravity Recovery and Climate Experiment satellite mission(s) (GRACE) have been measuring variations in the Earth's gravitational field since 2002. Changes in groundwater, melting glaciers, ocean circulation, and large deformations associated with post-glacial rebound, continental tectonics and earthquakes all produce signals that can be detected and monitored. In this talk, I will provide an introduction to the GRACE missions, briefly mention some new analysis methods being developed at the Canadian Geodetic Survey, and show some new results related to groundwater variations in Southern Ontario. The new method uses watershed regions from the Canadian National Frameworks Dataset to build mascons (regions of interest) for Canada, ensuring that the boundaries of the numerical method correspond to real hydrological boundaries and reducing leakage between adjacent watersheds. Three distinct mascons are designed using watershed geometry that include Lake Huron, Lake Erie, and Lake Ontario and estimates of total water storage (TWS) change are obtained using GRACE data from the Center for Space Research (U. of Texas at Austin) spherical harmonic Release 5 dataset. These TWS estimates are split into a contribution from surface water (SW) change and a common large-scale background signal across Southern Ontario that represents groundwater, soil moisture, snow and ice. The surface water changes are almost entirely due to lake level changes within the Great Lakes and can be compared to water level observations from gauges on the lakes provided by the Canadian Hydrographic Service. The GRACE derived and observed lake level changes agree well with correlations of 0.95, 0.92, and 0.82 for the Lake Huron, Erie, and Ontario regions, respectively. The amplitudes also agree well and, to our knowledge, this is the first study to effectively detect the changing water levels of the different Great Lakes using GRACE. The common background signal is found to have peak to peak variations of ~20 cm equivalent water thickness (EWT) and is compared to 301 wells from across Southern Ontario (data from the Provincial Groundwater Monitoring Network). The signals agree well with a correlation of 0.85. This result has important implications for the relative size and/or dynamics of the groundwater and remaining surface terms (soil moisture, snow and ice). Furthermore, variations in water storage from groundwater are found to be comparable to variations in water storage from the Great Lakes themselves – highlighting the importance that groundwater plays in any water budget of the Great Lakes system. Comparisons between individual groundwater wells and that of GRACE reveal the spatial extent of wells that show regional signals (high correlation) and those that show more local variability (poor correlation). Wells that correlate poorly reveal additional spatial patterns and the influence of local topography, geology, and water usage.

Intersections of Wildfire, Water and Land: Using Groundwater Science to Reduce Risks to Water Supplies

de Jong[1], Shona; Matthew Leybourne[1,2], Hazen A.J. Russell[3], Hannah DeGeer[1], and Lisa Strychar[1]

[1] *Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, ON K7L 3N6 • shona.dejong@gmail.com*

[2] *Queen's Facility for Isotope Research, Department of Geological Sciences and Geological Engineering, Queen's University, Canada*

[3] *Geological Survey of Canada, Natural Resources Canada, 601 Booth St., Ottawa, ON K1A 0E8*

For over three weeks, fire suppression teams sought to control the 2018 Parry Sound 33 Wildfire (covering 11,362 hectares in northeastern Ontario). Following the fire, the wide spread concern has been the impact of the Parry Sound 33 Wildfire upon the Key Harbour First Nation's and Henvey Inlet First Nation's water security. This in turn has sparked groundwater geochemistry questions. Our research seeks to understand one question: *how can the post-Parry Sound 33 fire water quality research provide guidance for future ground water research in Southern Ontario and across Canada?*

Informed by research from i) post fire mobilization of contaminants into surface water resources; ii) short term impacts of fire events on karst; and iii) community based fire management, this project has several objectives:

a) Provide gap analysis of the post-fire groundwater for drinking water quality research
b) Detail how Canadian universities and research institutions take a strategic view of post-fire water quality research to support land use planning and public health and safety initiatives
c) Document actionable information products created to communicate to communities how to manage post fire water quality

This paper presents preliminary results of our research, noting:

- Contamination of high quality potable water in groundwater can occur through natural events such as wildfires because wildfires modify the surface environment by combusting vegetation and changing soil properties
- Most prior research on post-fire water quality research has focused on surface water to determine fire-prone forested water source areas.
- The emerging field of post fire contamination of water sources is receiving considerable attention, evidenced by the 2018 NSERC funded Water Institute/University of Waterloo project. But there is little research being done to understand the vulnerabilities of groundwater aquifers to post fire debris, sediment and chemical constituents (indicators that could be included in future assessments)

This paper is intended to inform discussions on the preparation of suitable post fire water management plans in order to maintain drinking water quality in a cost-effective manner.

The Ambient Groundwater Geochemistry Program: Northeastern Ontario Pilot Project

Dell, Kayla M.

Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development & Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5 • kayla.dell@ontario.ca

A northern Ontario component of the Ambient Groundwater Geochemistry Program (AGGP) was initiated to determine if the methods employed in this project in southern Ontario could be successful in delineating the effect of Precambrian host rock lithology on groundwater chemistry. This third season of the AGGP in northern Ontario was completed in 2018 in the North Bay area and follows two others in 2016 in Sudbury and 2017 along the north shore of Lake Huron and Manitoulin Island. Together, they provide a broad band of samples across north central Ontario at a relatively uniform density. In total, 105 overburden and 337 bedrock wells were sampled and analyzed for metals, anions, bacteria, nitrogen parameters, tritium, $\delta^{2}H$ and $\delta^{18}O$, and radionuclides. With the 2018 project in North Bay, a sufficient sample density and distribution exists to create a detailed characterization of groundwater trends across northeastern Ontario. This poster illustrates some of the regional trends and groundwater characteristics observed in the northern Ontario AGGP data thus far.

Our preliminary interpretation suggests that groundwater geochemistry is influenced by host lithology, hydrogeological flow conditions, drift thickness and drift composition. The Precambrian geologic province from which the groundwater originates may be a factor controlling certain regional variations in groundwater chemistry that have been observed. Samples collected from Southern Province rocks of the Huronian Supergroup and the Sudbury Basin show relatively high Co, As, Pb and Cu concentrations versus the Grenville Province. However, preliminary interpretation of some parameters also reveals anomalies coincident with surficial geologic features. In the North Bay area, wells completed in bedrock with overlying Pleistocene clay yield groundwater with higher concentrations of TKN and NH_4. These may have originated from the overlying clays because of breakdown of proteinaceous organic matter within the clay. Areas with overlying clay units also have higher gross beta concentrations which may be caused by an enrichment of the naturally occurring ^{40}K isotope in the clays.

Ratios of Cl-Br show a subset of samples with a measurable influence from deep brine water and another subset where surface contamination is indicated; either from road salt or septic sources. Groundwater samples indicating brine mixing have higher Li, Ca, F- and Br- concentrations suggesting longer residence times in the aquifer; and this is supported by lower average tritium (half life = 12.3 years) content. Preliminary interpretation of the 2016 and 2017 data indicate that radon in water is controlled by availability of uranium in the host aquifer. Uranium concentrations, on the other had, are controlled by redox conditions and ion complexing and may not have a strong relationship with uranium concentration in the rocks. Future work will seek to further characterize the controls on groundwater chemistry, employing tools such as multivariant analysis and sulphur and strontium isotopes to trace the sources of solutes.

A Development of a fully Integrated Groundwater – Surface-water Modelling Platform for the Phanerozoic Basin Region of Southern Ontario

Frey[1,2], Steven; Omar Khader[1], Amanda Taylor[1], Hazen Russell[3], David Lapen[4], Steven Berg[1,2], and Ed Sudicky[1,2]

[1] *Aquanty Inc, 564 Weber St N, Waterloo, ON N2L 5C6 • sfrey@aquanty.com*

[2] *Department of Earth and Environmental Sciences, University of Waterloo, 200 University Ave. W. Waterloo, ON N2L 3G1*

[3] *Geological Survey of Canada, 601 Booth St, Ottawa, ON K1A 0E8*

[4] *Agricuture and Agri-Food Canada, Ottawa Research and Development Centre, 960 Carling Ave, Ottawa, ON K1A 0C6*

In early 2018, construction began on a HydroGeoSphere (HGS) fully-integrated GW-SW modelling platform for Southern Ontario, with high resolution subsurface hydro-stratigraphy based on the GSC-OGS 3D geological modelling initiative.

In total, four HGS models were constructed, using a combination of coarse (41,000 nodes per layer) and fine (133,000 nodes per layer) unstructured finite element meshes, and with the full Phanerozoic sequence (represented by 21 hydrostratigraphic/soil layers) as well as a version with the Phanerozoic sequence cut off at the sulfur-brine interface (represented by 16 hydrostratigraphic/soil layers). During model construction, extensive effort was devoted to characterizing and reducing model structural uncertainty, with the end result being a heterogeneous subsurface parameterization (which includes effective representation of key karst units) underlying a temporally and spatially varying land surface that incorporates key driving factors for overland flow and evapotranspiration.

Results from validation and testing demonstrate that the models can successfully capture the spatially varying transient behavior of the coupled SW and GW flow system at the regional scale, based on simulated vs observed surface water flows and groundwater heads at a respective 27 hydrograph locations and 300 monitoring well locations dispersed across the model domain. Further comparison of the simulation results from the different models combined with the different levels of temporal forcing (steady-state vs. transient) provides insight on how model spatial and temporal resolution can influence simulated heads and stream flows, and can thus be used to help determine prudent use cases for models incorporating varying levels of detail.

With the proof-of-concept now near completion, there are numerous applications for the modelling platform and its underlying database to be used to further develop our understanding of regional scale hydrologic processes within Southern Ontario, as well as to inform smaller scale investigations that would benefit from insight on how regional flow systems may be influencing localized areas of interest. Furthermore, the platform will also serve as a tool to help identify current limitations in our knowledge of regional groundwater flow, to help guide future data collection initiatives, and to quantitatively test hypotheses relating to how different conceptual model realizations of subsurface hydrostratigraphy can influence hydrologic behavior.

This presentation will provide a brief overview of the methodology employed towards model construction, followed by a discussion of model performance and spatial-temporal sensitivities, and will finish with a set of example applications targeting questions relating to how groundwater – surface water interactions govern inflow to the Great Lakes under different climate conditions.

Applications of a Regional-scale Integrated Modelling Platform Towards Watershed-level Hydrologic Insights

Frey[1,2], Steven; Graham Stonebridge[1], Steven Berg[1,2], Derek Steinmoeller[1], David Lapen[3], Omar Khader[1], Andre Erler[1], and Ed Sudicky[1,2]

[1] *Aquanty, 564 Weber St N. Waterloo, ON N2L 5C6 • sfrey@aquanty.com*

[2] *Department of Earth and Environmental Sciences, University of Waterloo, 200 University Ave. W. Waterloo, ON N2L 3G1*

[3] *Agricuture and Agri-Food Canada, Ottawa Research and Development Centre, 960 Carling Ave, Ottawa, ON K1A 0C6*

Persistent questions exist on how a regional scale model, such as the one developed for Southern Ontario, can be employed as a tool to address local level questions. While the spatial resolution of the regional model may be high enough for big-picture applications, it is arguably not high enough to provide useful insights on highly-dynamic small-scale hydrologic behavior or operational aspects of watershed management. In order to meet the needs of smaller scale applications, a set of HydroGeoSphere (HGS) fully-integrated groundwater – surface water models has been constructed for the 12 major watersheds that lie within the bounds of the regional model. These models have been constructed with a much higher level of spatial resolution than the regional model (i.e. with Strahler order 2 stream networks as opposed to Strahler order 3) and with full representation of the surface water features as channel elements within the model, which creates a more representative depiction of watershed and sub-watershed scale hydrologic behavior. As the underlying database upon which the watershed models are constructed is amalgamated across Southern Ontario, these models all share a consistent hydrostratigraphy, soil, and landcover representation, which in turn creates a uniform simulation framework that aligns with regional model behavior. However, in recognition of the fact that higher resolution model construction data may be available and/or required for smaller scale applications, the watershed models can be efficiently reconstructed using data in standard GIS formats.

In addition to being able to use each of the 12 watershed models as a pre-built standalone fully-integrated model for individual watersheds, the full set of models is now running operationally as a surface water forecasting system for the whole of the Southern Ontario model domain. Using an ensemble set of weather forecasts and an advanced monitoring data assimilation scheme, surface water forecasts are being generated at daily frequency for a two week forecast interval for 100’s of locations across Southern Ontario. Already, a demonstrated strength of the platform is that flows at ungauged locations (as well as known gauging locations) can be predicted with some certainty given that HGS employs a physics-based mass conservative approach for simulating water movement within the highly dynamic GW-SW system in Southern Ontario.

In order to disseminate output from the hydrologic forecasting platform to watershed stakeholders, a cloud based portal has been developed with watershed-level dashboards and on-the-fly analytic functionality. While surface water flows are currently the only forecast endpoint, platform development is ongoing, with plans to release operational forecasts for other components of the hydrologic cycle in future releases.

Hydrogeology of the Deep Flow System within Quaternary Sediments, South-central Ontario

Gerber, Richard E.
Oak Ridges Moraine Groundwater Program, 5 Shoreham Drive, Downsview, ON M3N 1S4
rgerber@owrc.ca

Aquifers utilized for private and municipal water supply within south-central Ontario occur within Early to Middle Wisconsinan sediments, specifically the Thorncliffe and Scarborough Formations. These formations, including the Sunnybrook Drift, are often and herein referred to as Lower sediments. These deep sediments are replenished by vertical groundwater flow through overlying aquitards including the Newmarket Till and/or silt-clay rhythmites of the late Thorncliffe Formation. Also, channelization episodes characterized by fining-upward sequences have locally breached the Newmarket Till sediment. Recent work, including detailed geologic and hydrogeologic analysis of cored sediment locations, and isotopic analysis of porewater and groundwater, has led to a refinement of the conceptual hydrogeological model of the Lower sediment package.

Based on high-quality seismic, geologic and hydrogeologic data, a revised conceptual model of the 'Yonge Street Aquifer' (YSA) has been postulated. The YSA in the Greater Toronto Area has been utilized since the mid-1900s. The current municipal water supply system consists of nine wellfields installed between 1957 and 1991. Data reveal two generations of roughly north-south channels: older pre-Newmarket Till channels within Lower sediments (termed Thorncliffe channel) and younger post-Newmarket Till ORM-related channels (termed ORM channel) that incise both Newmarket Till and Lower sediments. The YSA is interpreted to occur within a Thorncliffe channel, with possible vertical connection to younger ORM channels and lateral connection to inter-channel Lower sediments. These channel deposits consist of fining upward transitions from coarse gravel, to sand, to rhythmically bedded silt and clay interpreted to be deposited within a channel-esker-subaqueous fan complex.

The Thorncliffe Formation contains a wide range of facies assemblages characterized by contrasting permeabilities. The deposits with highest permeability occur within up to 80 m thick gravel and sand sequences at the base of the Thorncliffe channel. The response of piezometric levels to hydraulic stress confirms longitudinal connection along the channel with muted lateral hydraulic response in sediments outside channels. The YSA is considered a semiconfined (leaky) strip aquifer with observed transmissivities between 1000 to 4500 m^2/d, in contrast to regional aquifer transmissivities that are generally less than 500 m2/d. Thorncliffe channels are interpreted to be up to 20 km long and approximately 2 km wide.

This presentation discusses the development and current state of the hydrogeological conceptual model related to Lower sediments within the study area, and how it can assist in future endeavours. It is anticipated that this refined conceptual model can inform groundwater exploration and development for aquifers to be utilized for water supply or geothermal energy. Also discussed will be efforts to disseminate hydrogeologic knowledge in a format useful to public works, planning and scientific practitioners (e.g. 'groundwater problem area' mapping). A key process in the evolution of the conceptual model is that it is continuously subject to refinement as new data and information becomes available.

Optimization of Low Impact Development Placement through Shallow Subsurface Characterization

Harvey, Tara and Mike Wilson
Lake Simcoe Region Conservation Authority, 120 Bayview Pkwy, Newmarket, ON L3Y 3W3
t.harvey@lsrca.on.ca

Urban stormwater is estimated to account for approximately 30% of the phosphorus loading to Lake Simcoe. In addition to phosphorus, urban stormwater from impervious surfaces can contribute sediment, hydrocarbons, and metals to local water features and urbanization can cause reduced recharge to groundwater systems. As a result, the Lake Simcoe Protection Plan (2009) calls for improvements to the management of stormwater for both existing and future development with a goal to decrease phosphorous loadings and to minimize changes to the water balance. Improved urban stormwater management can be accomplished through several means including retrofitting existing development with low impact development (LID) and using LID for future development projects. As a direct result of the Plan, LID implementation has increased within the watershed in recent years.

Determining the most suitable locations for LID placement requires an understanding of the shallow subsurface including the geology and hydrogeology, as well as current land use and policy limitations. To help guide LID placement, the Shallow Subsurface Characterization Project aims to provide an improved understanding of the shallow subsurface through the development of a GIS layer that prioritizes possible locations for LID projects within the East Holland River subwatershed. The GIS layer has been developed using geologic and static water level data provided by the Regional Municipality of York and available through the Oak Ridges Moraine Groundwater Program.

Based on this improved understanding of the shallow subsurface environment, the final product is a single easy-to-use GIS layer that characterizes the watershed into areas that are deemed to be of low, medium, or high priority for LID placement. This will allow for a simple desktop evaluation of the most appropriate locations for LID retrofits, even for staff or members of the public that have limited hydrogeologic knowledge. The long term goal is for the layer to be available on the LSRCA website to municipalities, stormwater engineers, planners, students, and anyone interested in LID within the East Holland River subwatershed.

Comprehensive Groundwater Data Management & Analyses – Raising the Bar

Holysh, Steve; Rick Geber, Mason Marchildon, Mike Doughty, and Britt Smith
Oak Ridges Moraine Groundwater Program, 5 Shoreham Drive, Downsview, ON M3N 1S4
sholysh@trca.on.ca

“What matters gets measured” “You can’t manage what you don’t measure”.

When it comes to Ontario’s groundwater resources these old adages certainly strike a chord. What do we really know about our groundwater systems? Have we been sufficiently measuring and monitoring the resource? Do we effectively integrate some 50 years of previous knowledge into day to day decision making?

Since 2001, the long standing Oak Ridges Moraine Groundwater Program (ORMGP – formerly referred to as YPDT-CAMC Groundwater Management Program) has been working to: i) assemble a comprehensive and reliable source of groundwater related data; ii) bring critical analyses to the data; and iii) construct a geological and hydrogeological framework into which new drilling and information can be incorporated. The results of this work are being made available through an interactive website where numerous ‘themed’ maps (e.g. geology, water levels, documents, etc.) intuitively provide ready access to the program’s data and interpretive geological and hydrogeological framework. As an integral part of the program’s over-arching goal of improving upon water management decision-making in Ontario, an ongoing process is to engage practitioners on a variety of levels to arrive at a point where regular contributions of data, insight and information are returned back to this ‘actively managed’ program, thus improving the hydrogeological knowledge-base for the broader community.

Are we on the Right Track? A Panel Discussion on the Future Direction of Groundwater Management in Ontario

Holysh[1], Steve; Jennifer Stephens[2], Dave Belanger[3], Jim Buttle[4], Tessa Di'Iorio[5], Victor Doyle[6], David L. Rudolph[7]

[1] *Oak Ridges Moraine Groundwater Program, 5 Shoreham Drive, Downsview, ON M3N 1S4 sholysh@trca.on.ca*

[2] *CTC Source Protection Region, Toronto and Region Conservation Authority, 5 Shoreham Drive, Downsview, ON M3N 1S4*

[3] *City of Guelph, 1 Carden Street, Guelph, ON N1H 3A1*

[4] *School of the Environment, Trent University, 1600 West Bank Drive, Peterborough, ON K9L 0G2*

[5] *City of Ottawa, 110 Laurier avenue west, Ottawa, ON K1P 1J1*

[6] *Former MMAH Planner*

[7] *Earth and Environmental Sciences, University of Waterloo, 200 University Ave., Waterloo, ON N2L 3G1*

This panel discussion will focus on whether, as a Province, Ontario is adequately planning for the future of our water resources. Recent developments related to the Greater Golden Horseshoe Growth Plan, the Greenbelt Plan, the Niagara Escarpment Plan and the Oak Ridges Moraine Conservation Plan, as well as the expected impacts of climate change, will all figure into the conversation. Although the dialogue among panelists is expected to look broadly at water management and the current state of efforts to prepare for the future, there will be an emphasis on groundwater resources. Decisions affecting water resources are made by policy makers, technical staff, and those responsible for issuing approvals on a daily basis. These decisions range from land use planning to water allocation targets to wastewater treatment requirements.

It has been almost 20 years since the tragic events of Walkerton highlighted additional needs for improved management of Ontario's water resources and in particular its groundwater. With the passing of the Clean Water Act in 2006, the past decade has seen considerable investment, primarily through the Drinking Water Source Protection program. This investment has ranged from the collection of water related data, the technical synthesis of these data, in many cases into sophisticated numerical groundwater models, and an overall improvement in our understanding of how water moves through Ontario's watersheds. In the current transition to a new government with a focus on curtailing public expenditures, what is the most appropriate way forward to capitalize on this investment and to ensure that future practitioners do not lose the knowledge gained from these activities? Is it even in danger of being lost?

Panel members bring a diverse range of views and expertise to the discussion and will be prepared to offer their insights into some of Ontario's key ongoing and upcoming water related challenges and opportunities.

- Are Ontario's water related policies and programs being effectively implemented to support long-term sustainability of the resource?
- How are we monitoring the impact of our decisions?
- Are our actions pro-active or reactive?
- Is the acquisition of water related data sufficient to inform decision-making?

- Are the data adequately managed and readily accessible to those making planning and technical decisions?
- Is research headed in the right direction?
- Are agencies at the Federal, Provincial and Municipal levels sufficiently engaged and coordinated?
- Being blessed with a seemingly abundance of water, has Ontario been too complacent in how we currently make decisions with respect to our water resources?
- Following introductory comments from panel members, there will be an engaging and insightful discussion surrounding the future of water management in Ontario.

Geochemistry of Southern Ontario Quaternary Sediments

Knight[1], Ross, D.; Andrew F. Bajc[2], Bruce A. Kjarsgaard[1], Heather Crow[1], Daniel A.J. Stepner[1], David R. Sharpe[1] and Hazen A.J. Russell[1]

[1] *Geological Survey of Canada, Natural Resources of Canada, 601 Booth St., Ottawa, ON K1A 0E8 ross.knight@canada.ca*

[2] *Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development and Mines, Sudbury, ON P3E 6B5*

Geochemical analysis constrained by stratigraphic units with detailed sampling of continuous core is rare in glaciated basins. The up to 200 m plus thickness of surficial sediment cover across 74,000 km^2 area of southern Ontario (S-ON) and the presence of many hundred continuously cored boreholes provided an opportunity to investigate the chemostratigraphy of a large glaciated basin. The S-ON basin setting over Phanerozoic sedimentary carbonate and shale, and bounded by igneous and metamorphic rocks of Canadian Shield, provides an ideal setting for geochemical provenance studies and methods development. Geochemical analysis of 3,815 surficial sediment samples from 53 boreholes have been analysed via portable X-ray fluorescence spectrometry (pXRF) and traditional laboratory geochemical analytical methods.

Comparison of geochemistry from ICP-ES/MS and with pXRF indicates good characterization of the basin chemistry by the laboratory and pXRF analysis methods. Significant changes in elemental concentrations within individual cores are identified in multiple contexts, i) across formation contacts, ii) internally within formations, iii) absence of change across formation boundaries. These likely represent changes in depositional processes and provenance between Precambrian Shield and Paleozoic sources. Changes in elemental concentrations are commonly not correlated between boreholes at either the formation or sub formation level. On a regional scale, the geochemical ratio of $CaO+MgO/SiO_2+Al_2O_3$ provides a Provenance Indicator (PI) to determine elemental contributions from a Paleozoic carbonate source relative to contributions from Precambrian Shield sources. As calcium and magnesium occurs in markedly higher concentrations in Paleozoic carbonate rocks, a higher PI value reflects greater input of material derived from these Paleozoic sedimentary rocks. Examination of the Newmarket Till using this PI shows a correlation between the amount of carbonate-derived material in the till-matrix and sampling distance relative to the shield margin indicates the deposition of increasingly carbonate-rich surficial sediments to a maximum at approximately 80-100 km south of the Shield-margin. Additionally to the PI, a geochemical distinction is observed between sediments deposited east (carbonate dominated) and west (dolomite dominated) of the Niagara Escarpment. Elevated MgO and CaO west of the Niagara Escarpment (Catfish Creek Till) indicates sourcing of Silurian dolomite, whereas east of the Escarpment (Newmarket Till) CaO-rich till is due to sourcing of Ordovician limestone.

The geochemical study of Quaternary sediments in southern Ontario has not found any evidence of elemental concentrations that might adversely affect groundwater quality and human health.

InSAR Measurement of Surface Deformations in South Ontario

Li[1], Junhua; Shusen Wang[1], Cassandra Michel[2,3], and Hazen A.J. Russell[3]

[1] *Canada Centre for Mapping and Earth Observation, Natural Resources Canada, 560 Rochester Street, Ottawa, ON K1A 0E4 • Junhua.Li@canada.ca*

[2] *Environment Climate Change Canada,*

[3] *Geological Survey of Canada, Natural Resources of Canada, 601 Booth St., Ottawa, ON K1A 0E8*

Detection of surface deformation can be measured using InSar, a geodetic technique that calculates the interference pattern which results from a difference in phase between images acquired by synthetic aperture radar (SAR). Ground surface deformation, in particular land subsidence is caused by numerous factors, such as: tectonic motion, sediment compaction, thawing permafrost, increased surface loading, Glacial Isostatic Adjustment (GIA), hydro-chemical erosion of karst, decomposition of organic material in soils, mining, anthropogenic fluid withdrawal and surface water/drainage management. Groundwater applications have commonly been completed in areas of extreme subsidence due to dehydration and collapse of fine grained sediment textures; such as in the central valley of California, Nevada, and the Mexico city area. This study examines whether there is potential application of this technique to measure changes in surface elevation in southern Ontario and whether it can be related to changes in groundwater storage. For the southern Ontario study five datasets were used to assess the ground surface deformation and the hydrogeological/hydrologic conditions within the imagery extent. Datasets included: a set of 40 Radarsat-2 images spanning five years, GPS weekly solutions, Real-time kinematic (RTK) gps data, groundwater levels, terrestrial water storage data derived from GRACE satellites and hydrologic data from the Provincial Groundwater Monitoring Network (PGMN).

Differential synthetic aperture radar interferometry (D-InSAR) has sub-centimetre precision and high spatial resolution over a large area. To eliminate some of the noise and to reduce geometrical distortions (multilook) images were averaged to a 50 m resolution. A stable reference site RTK TWOO was used a reference point. The TWOO GPS measurements were then added to the InSAR time series deformation maps.

Obtaining a coherent signal was difficult and resulted in clustering of signal return from urbanized areas. The roofs and corners of the buildings in urbanized areas can form permanent scatterers, resulting in a more coherent signal. Across the study area, an annual rate of 1 mm to 10 mm of subsidence is observed. The greatest amount of subsidence (> 8 mm/year) is observed along the shore of Lake Ontario. In the absence of a field campaign to support validation the study has concluded that any viable signal attributed to specific geological – hydrogeological controls is within the signal-noise ratio of the study.

Opportunities and Challenges Provided by Regional-scale LiDAR Data Sets

Lindsay, John B.
Geomorphometry and Hydrogeomatics Research Group (GHRG), Department of Geography, Environment and Geomatics, University of Guelph, 50 Stone Rd. Guelph, ON N1G 2W1
jlindsay@uoguelph.ca

Light detection and Ranging (LiDAR) systems are now widely regarded as the preferred source data for a range of terrain mapping applications owing to their high spatial accuracy, dense surface sampling, and the ability of laser scanners to map topography beneath forest and other vegetation covers. In the past, the prohibitive expense and difficulty involved in LiDAR acquisition meant that these data were most often collected in response to project-specific needs and for relatively small spatial extents. In most jurisdictions, the patchwork of LiDAR data that were publicly available were unlikely to allow for regional-scale analyses and applications. However, the decreased cost of acquisition that has occurred over the past decade, and the proliferation of LiDAR data providers, has changed this situation significantly. An increasing number of municipal, regional, provincial and federal governments have been involved in large-scale LiDAR data acquisition campaigns, the result of which has been the availability of regional-scale fine-resolution digital elevation models (DEMs) for use by researchers, practitioners, and other stakeholders. For example, a recent LiDAR acquisition project carried out in Ontario will soon make aerial LiDAR data publicly available in large portions of the province.

The recent availability of extensive LiDAR data sets has been marked by a period of exploration, as practitioners work to replace older topographic data with LiDAR and as novel applications of these data emerge. The unique characteristics of these data provide many opportunities to improve existing workflows and processing methods in a wide range of terrain-related fields of study. For example, LiDAR data have been used for soils mapping, forest canopy modelling, stream mapping, sediment erosion modelling, solar potential modelling, and many other applications involving accurate topographic and canopy modelling. However, the properties of LiDAR data also present numerous and significant challenges for end-users and at present practitioners are commonly struggling to take full advantage of their LiDAR data sets. In addition to the technical issues associated with managing large data volumes, researchers and practitioners are also commonly confronted with problems associated with the extremely fine detail of surface representation. For instance, LiDAR DEMs often include microtopography and excessive surface roughness that can complicate the measurement of the surface parameters (e.g. slope, orientation, curvature, topographic position, surface flow) that are common inputs for other upstream modelling workflows. This presentation will introduce potential solutions to some of these issues, as well as describe their role in enabling large-scale applications of these unique data.

Deconstructing the Newmarket Till in South-central Ontario

Mulligan[1,2], Riley P.M.; Andrew F. Bajc[1], and Carolyn Eyles[2]

[1] *Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development & Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5 • riley.mulligan@ontario.ca*

[2] *Department of Environmental Sciences, McMaster University, Hamilton, ON*

The Newmarket Till (NT) records the advance of the Laurentide Ice Sheet over south-central Ontario during the Late Wisconsin. The till occurs across a wide area of the province, including three prominent physiographic regions. The NT caps and flanks the Niagara Escarpment, a regional scale bedrock scarp 200-300 m high, and occurs across drumlinized sediment-cored uplands underlain by >150 m of pre-Late Wisconsin sediments as well as beneath intervening lowland plains and tunnel valleys incised into pre-Late Wisconsin sediments and Paleozoic bedrock. Detailed surficial mapping over 3750 km^2 in Simcoe County and surrounding areas has identified consistent internal facies within the uplands, but significant variability, both spatially and vertically, in matrix texture, colour, consolidation, and clast content, fabric and lithology characterizes the NT within the lowlands and in areas along the Niagara Escarpment. This variability led to previous interpretations of multiple till sheets involving repeated glacier advance and retreat phases during the Late Wisconsin. Combined analysis of internal sedimentology, stratigraphic information gained from 58 continuously-cored boreholes, and morphological data from recently-released high-resolution terrain models, indicates that the NT sediment package is characterized by a wide variety of distinct diamict units and interbedded stratified sediments that are linked to changes in substrate lithology and topography. The varying composition of the NT records evolving subglacial erosional and depositional conditions related to fluctuating subglacial stress regimes, porewater pressures and meltwater drainage. The wide range of properties that characterize the NT has significant implications for understanding and predicting its local hydraulic function as a 'leaky aquitard'.

In the future, the groundwater initiative aims to enhance integration of its three core activities thereby providing a holistic approach to assessments of the provincial groundwater resource. Continued investigations will allow for the synthesis of information from individual regional studies to scales.

The Ontario Geological Survey's Groundwater Initiative: Highlights from the Past Two Decades

Priebe, Elizabeth, H.; Andy F. Bajc, Frank R. Brunton, Abigail K. Burt, Kayla M. Dell, Stewart M. Hamilton, and Riley P.M. Mulligan

Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development & Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5 • elizabeth.priebe@ontario.ca

The Earth Resources and Geoscience Mapping section of the Ontario Geological Survey (OGS) has a groundwater-focussed initiative as part of its core mapping function. The OGS groundwater initiative involves the collection, interpretation and dissemination of high-quality geoscience data to enhance characterization of the subsurface with three mapping activities; 3-D Paleozoic bedrock mapping, 3-D Quaternary sediment mapping, and ambient groundwater geochemistry mapping. Although the OGS has been collecting data that supports groundwater studies for over a century, these efforts were ramped up in the early 2000's following the Walkerton tragedy, with an enhanced OGS mandate adopted in 2007. The enhanced mandate emphasized the need for high quality geoscience data in 3-D.

The OGS groundwater mapping initiative has generated new insights into groundwater quality, quantity and vulnerability and has supported water policy development in the province. Some examples include: supporting public health and the agricultural industry by identifying naturally occurring elements at levels above provincially mandated drinking water limits; helping several municipalities explore for new groundwater resources with a predictive geological framework, saving them millions of dollars; and providing essential geological and geochemical information to support the protection and management of municipal drinking water sources throughout Ontario. From a policy perspective, OGS geoscience data and knowledge have been integrated into recent government initiatives including: the potential growth of the Greenbelt in the outer ring of the Greater Golden Horseshoe; the development of Provincial Watershed Planning Guidance for municipalities; bedrock groundwater vulnerability/karst; and a research project to examine the capacity and constraints of water and wastewater systems in the Greater Golden Horseshoe.

As we look to the future, the OGS aims to continue providing geoscience information that supports science-based groundwater management decisions and policy development for decades to come. Recognizing groundwater as one of the earth's resources deserving of dedicated geoscience mapping was an insightful move for the OGS in the 2000's, and one that will continue to benefit the people of Ontario for generations to come.

Using 222-Radon Surveys and Regional Scale Groundwater Models to Evaluate Groundwater Discharge to Lake Simcoe

Robinson[1], Clare; Hayley Wallace[1], E.J. Wexler[2], and Spencer Malott[2]

[1] *Civil and Environmental Engineering, University of Western Ontario, London, ON N6A 5B9*
crobinson@eng.uwo.ca

[2] *Earthfx Incorporated, Toronto, ON M4N 2M6 Canada*

Groundwater discharge can be an important pathway for delivering pollutants to large lakes, but this pathway is often overlooked. To understand the potential impact of groundwater inputs on lake water quality, the volume of groundwater discharge, the spatial distribution of this discharge, and the history of the discharging groundwater must be quantified. This study uses offshore 222-radon surveys together with regional scale numerical groundwater models to evaluate groundwater discharge to Lake Simcoe. In-lake 222-radon concentration data was first used to identify groundwater discharge hotspots along the shoreline and quantify groundwater discharge rates. The 222-radon results, which compared well with the regional scale numerical model results, were then used to provide insights into hydrogeological factors controlling groundwater discharge to Lake Simcoe. Key factors included the permeability of nearshore sediments, proximity of the shoreline to moraine recharge areas, absence of streams along the shoreline, and presence of tunnel channel aquifers. Finally, the numerical model along the north shoreline of Lake Simcoe was applied to characterize groundwater discharge pathways, evaluate the land use in the recharge areas, and assess potential impacts of the groundwater inputs on lake water quality trends. The study presents a robust approach for regional scale evaluation of groundwater discharge to large lakes.

Groundwater Research in Southern Ontario by Environment and Climate Change Canada

Roy, James, W; John Spoelstra, Dale R. Van Stempvoort, and Victoria Propp
Water Science and Technology Directorate, Environment and Climate Change Canada, 867 Lakeshore Rd., Burlington, ON L7S 1A1 • jim.roy@canada.ca

Over the past decade, the groundwater-specific research of Environment and Climate Change Canada has focused on groundwater transport of pollutants to surface waters. Within southern Ontario, the key pollutant of interest has been phosphorus, due to its link to eutrophication and harmful algal blooms of the Great Lakes and its watershed. Our work has targeted point sources, such as domestic wastewater septic systems, as well as broader-scale inputs within both urban and rural landscapes. Other contaminants have also received interest, including chloride (road salt), metals, and both legacy and emerging organic contaminants (e.g., pharmaceuticals, per- and polyfluoralkyl substances (PFAS), organophosphate flame retardants, etc.), especially in urban environments. A new study is looking at a range of these chemicals in old, closed landfills, of which thousands reside across southern Ontario. These substances pose a toxicity risk to aquatic ecosystems in the receiving environment and may spread more broadly from there.

This work has largely employed two methodological "tools", i) surface water receptor-targeted groundwater sampling, and ii) the analysis of artificial sweeteners. The former allows for rapid acquisition of a large number of samples at relatively moderate expense in comparison to the use of wells. It also provides more exact information on the concentrations or mass of contaminants impacting the receptor. Artificial sweeteners can serve as a tracer of wastewater and landfill leachate, thus being a proxy for the possible presence of other wastewater or leachate contaminants and allow some quantification of their potential inputs. Their presence can also guide targeted sampling of more costly analytes. Here we provide a brief overview of our recent research in southern Ontario with some key examples of how these two tools have provided important results on the risks posed by groundwater-sourced pollutants to Great Lakes ecosystems.

A Renaissance in Regional Hydrogeology

Rudolph, David L.
Dept of Earth & Environmental Sciences, 200 University Ave. W. Waterloo, ON N2L 3G1
drudolph@uwaterloo.ca

Over the last five decades hydrogeologic research has evolved through a series of different core areas. The focus has changed based on significant scientific breakthroughs within the emerging discipline and on societal priorities that have influenced funding opportunities. In recent years, significant attention and research activity have refocussed on regional groundwater assessment, one of the foundational topics in modern hydrogeology. This renewed emphasis is related to a deterioration in the apparent resilience of groundwater systems due to chronic influences of legacy contaminants, overexploitation and increased variability within the water cycle. The recent water quantity crises in the USA and western Canada, and the Source Water Protection work underway in Ontario, have illustrated some of the significant impacts on regional groundwater resources within the North American context. Emerging sensor technology, modeling platforms and increasing access to large data sets is enhancing the understanding of key processes and providing unprecedented quantitative insight within the entire hydrologic cycle at the watershed scale. Challenges remain with the optimal integration of data streams into modeling platforms to ensure appropriate parameterization and minimize uncertainty associated with the results. In this presentation, the increasing emphasis on regional hydrogeologic assessment will be discussed within the context of how it may influence the Government awareness and prioritization of groundwater in Canada as a strategic, economic and yet vulnerable resource.

OGS – GSC Collaboration on Regional Groundwater Studies 2014 – 2019: Conclusion

Russell[1], Hazen A.J. and Richard D. Dyer[2]

[1] *Geological Survey of Canada, Natural Resources Canada, Ottawa, ON K1A 0E8 hazen.russell@canada.ca*

[2] *Earth Resources and Geoscience Mapping Section, Ontario Geological Survey, Sudbury, ON P3E 6B5*

The Ontario Geological Survey (OGS) and Geological Survey of Canada (GSC) groundwater collaboration in Southern Ontario will be complete at the end of March 2019. The objective of the collaboration was to maximize technical and human resources to meet objectives of the OGS groundwater initiative and the GSC Groundwater Geoscience Program. To that end the initial collaborative effort involved a GAP analysis in March 2015 which provided guidance for aspects of the subsequent 4 year collaboration. In November 2015 a workshop was held with other provincial ministries, conservation authorities and academia to review a path forward on an improved data framework for sustainable groundwater management. The overall project was orientated along the following principal themes i) Framework for Sustainable Groundwater Use, ii) Supporting Great Lakes Water Accords, iii) Methods Development for Regional Groundwater Studies, iv) 4. Case Studies, v) Science and Technology Exchange.

Recognizing the extensive work completed as part of provincial Source Protection Program the project focused on development of two regional three-dimensional geological models of the bedrock and surficial geology. These models support a fully coupled regional groundwater – surface-water model being developed with Aquanty Inc. The models are supported by OGS, GSC and other provincial, private sector, and academic work and provide a framework for past and future datasets and groundwater understanding. To support this work a number of data collection studies (reflection seismic, downhole geophysics, chemostratigraphic analysis, hydrochemistry) data collation (Municipal well attributes, OGS section data, borehole logs), and data QA and QC activities were completed. To address concerns about groundwater – surface-water in the Great Lakes Water Accord a conceptual framework was developed as a management guide for watershed practitioners. Methods development focused on a number of areas related to remote sensing and soil moisture downscaling, application of portable X-ray fluorescence spectrometry to determine regional geochemistry, stochastic modelling methods at a watershed scale, and reflection seismic and downhole geophysics. In addition, in the South Nation River watershed a hydrogeophysics study was initiated to investigate the propagation of hydraulic properties through an esker cross-section by the integration of geophysical and hydraulic data within a machine learning environment.

A key concern raised in the gap analysis was science and technology communication by the OGS and GSC. In response to that concern an annual open house was initiated in late winter of the four subsequent years and coordinated with Conservation Ontario. This was complemented by coordination with academia on a special issue of the Canadian Journal of Earth Sciences on surficial geology and applications to groundwater. A final summary volume of GSC work will be published in the spring of 2019 as a GSC publication. The OGS and GSC will continue to publish after the formal collaborative project ends, through their respective online sites GeologyOntario, GeoScan, and the Groundwater Information Network (GIN).

Hydrogeological Terrains and Typical Settings of Southern Ontario

Sharpe[1], David, R. and Andrew Piggott[2]

[1] *Geological Survey of Canada, Natural Resources Canada, Ottawa, ON K1A 0E8*
david.sharpe@canada.ca

[2] *Consultant*

Groundwater is an important component of the hydrologic cycle of southern Ontario, which is significant to water supply and to groundwater discharge to surface water. To improve our understanding of groundwater, we develop a framework of typical terrains or hydrogeological settings that use geologic and topographic controls to describe how water moves through the southern Ontario landscape. Surface sediment and bedrock types, permeability, physiography and topographic gradients yield distinctive regional hydrogeological settings. Hence, we review a small number of hydrogeological settings, which contribute to a simple characterization of regional surface water and groundwater conditions across southern Ontario. Climate, stream and well monitoring data are integrated with local terrain information to assess the hydrological and hydrogeological response of typical settings. In each setting, the movement of water has differences in fluxes and temporal patterns as it flows across the surface and through the subsurface. We describe seven hydrogeological settings: five in sediment (clay, sand, till upland, till complex, and gravel); and two in bedrock. The selected hydrogeological settings characterize ~90% of all terrain at the regional scale based on a simplified geological map of southern Ontario. The identified settings cover large areas, and include several different sediment/ bedrock landscapes of the Paleozoic basin and Shield margin. It is expected that the main hydrogeological characteristics and hydrologic behaviour of these settings are represented in the hydrograph trends for each terrain.

Hydraulic Tomography Analysis of Municipal Well Operation Data with Geology-Based Groundwater Models at the Mannheim Wellfield in Kitchener, Ontario, Canada

Tong[1], Xin; Walter A. Illman[1], Steven J. Berg[1,2], and Ning Luo[1]

[1] *Department of Earth & Environmental Sciences, University of Waterloo, Waterloo, ON, Canada x23tong@gmail.com*

[2] *Aquanty, Inc., Waterloo, ON, Canada*

The sustainable management of groundwater resources is essential to municipalities worldwide due to the increasing water demand from dramatic population growth. Planning for the optimized use of groundwater resources requires a sound understanding of hydrogeology and reliable estimation of hydraulic parameters such as hydraulic conductivity (*K*) and specific storage (S_s). Traditionally, *K* estimates are obtained through the application of empirical formulae to representative grain sizes, laboratory analysis of core samples, slug/bail tests and pumping tests. Reliable estimates of S_s are difficult to obtain and are typically obtained through the analysis of pumping tests. The interpretation of pumping tests with analytical solutions with various simplifying assumptions has become the de facto standard in the consulting industry; however, research has shown that in non-idealized real-world applications, biased K and S_s estimates may be obtained which can lead to poor predictions of independent stress events. Thus, there is a critical need for more robust methods to estimate hydraulic parameters.

A new approach using hydraulic tomography (HT) to estimate *K* and S_s has been applied at the Mannheim East wellfield in Kitchener, Ontario. In particular, four different geological models with homogeneous geological layers are calibrated by coupling HydroGeoSphere (HGS) (Aquanty, 2018) and the parameter estimation code PEST (Doherty, 2005) using water-level variation records in observation wells collected during municipal well operations. The four geological models are well calibrated and yield reliable estimates that are consistent with previously estimated values for the shallower layers where most data points are collected. However, *K* and S_s estimates for deeper layers with fewer observation points vary more significantly among the models. The comparison of simulated and observed draw down for both model calibration and validation reveals that all four groundwater flow models with varying geology can capture the water-level fluctuation pattern quite well. However, rapid water-level variations at some wells are not captured very well, which could be due to the presence of high *K* pathways and heterogeneity not captured by these geological models. Currently, we are developing a HT approach based on geostatistics to handle this issue for both unconsolidated and fractured geologic media.

Overall, our research reveals that: 1) the HT analysis of municipal well records is feasible and yields reliable K and Ss estimates of individual geological units where drawdown records are available; 2) these estimates are obtained at the scale of its intended use of municipal well operations, unlike small-scale estimates typically obtained; 3) characterization and estimation can be conducted using existing data, thus removing the need for dedicated pumping tests which leads to substantial cost savings; and 4) data collected during municipal well operations can be used for parameter estimation and groundwater modeling, thus they are critical and should be archived.

Presenters, Authors, and Key Participants

NAME				
LAST	FIRST	TITLE	AFFILIATION/ADDRESS	EMAIL
Bajc	Andrew	Geologists	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury ON P3E 6B5	**andy.bajc@ontario.ca**
Belanger	Dave	Hydrogeologist	City of Guelph, 1 Carden Street, Guelph, ON N1H 3A1	**dave.belanger@guelph.ca**
Belitz	Kenneth	Hydrogeologist	United States Geological Survey, Carlisle, MA 0174	**kbelitz@usgs.gov**
Brodie-Brown	Heather	Hydrogeologist	Ministry of Environment and Climate Change, Foster Bldg., 9th Floor, 40 St Clair Ave W, Toronto, ON M4V 1M2	**heather.brodie-brown@ontario.ca**
Burt	Abigail	Geologist	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury, ON P3E 6B5	**abigail.burt@ontario.ca**
Buttle	Jim	Hydrologist	School of the Environment, Trent University, 1600 West Bank Drive, Peterborough, ON K9L 0G2	**jbuttle@trentu.ca**
Carter	Terry	Geologist	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury, ON P3E 6B5	**terry.carter@cartergeologic.com**
Colgrove	Laura	Hydrogeologist	Earth Resources & Geoscience Mapping Section, Ontario Geological Survey, Ministry of Northern Development & Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5	**laura@ogsrlibrary.com**
Crow	Heather	Geophysist	Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8	**heather.crow@canada.ca**
Crowley	John	Engineer	Canadian Geodetic Survey, Surveyor General Branch, Natural Resources Canada, 588 Booth Street, Ottawa, ON K1A 0Y7	**john.crowley@canada.ca**
de Jong	Shona	Research Scientist	Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, ON K7L 3N6	**shona.dejong@gmail.com**
Dell	Kayla	Geochemist	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury, ON P3E 6B5	**kayla.dell@ontario.ca**
Doyle	Victor	Planner	Formerly with Ontario Ministry of Municipal Affairs	**doylevic@gmail.com**
Di Iorio	Tessa	Hydrogeologist	City of Ottawa, 100 Constellation Drive, Nepean, ON K2G 6J8	**tessa.diiorio@ottawa.ca**
Ford	Donald	Hydrogeologist	Toronto and Region Conservation, 5 Shoreham Drive, Downsview, ON M3N 1S4	**dford@trca.on.ca**
Frey	Steven	Hydrogeologist	Aquanty Inc, 564 Weber St N, Waterloo, ON N2L 5C6	**sfrey@aquanty.com**
Gerber	Richard	Hydrogeologist	Oak Ridges Moraine Groundwater Program, 5 Shoreham Drive, Downsview, ON M3N 1S4	**rgerber@owrc.ca**

Presenters, Authors, and Key Participants (cont.)

NAME				
LAST	FIRST	TITLE	AFFILIATION/ADDRESS	EMAIL
Hamilton	Stewart	Geochemist	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury, ON P3E 6B5	**stew.hamilton@ontario.ca**
Harvey	Tara	Hydrogeologist	Lake Simcoe Region Conservation Authority, 120 Bayview Pkwy, Newmarket, ON L3Y 3W3	**t.harvey@lsrca.on.ca**
Holysh	Steven	Program Manager	Oak Ridges Moraine Groundwater Program, 5 Shoreham Drive, Downsview, ON M3N 1S4	**sholysh@trca.on.ca**
Illman	Walter	Hydrologist	Dept of Earth & Environmental Sciences, University of Waterloo, 200 University Ave. W, Waterloo, ON N2L 3G1	**willman@uwaterloo.ca**
Knight	Ross	Applied Geochemist	Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8	**ross.knight@canada.ca**
Li	Junhua	Remote Sensing	Canada Centre for Remote Sensing, Natural Resources Canada, Rochester St. Ottawa, ON K1A0E8	**junhua.li@canada.ca**
Lindsay	John	Hydrologist	Geomorphometry and Hydrogeomatics Research Group (GHRG), Department of Geography, Environment and Geomatics, University of Guelph, 50 Stone Rd. Guelph, ON N1G 2W1	**jlindsay@uoguelph.ca**
Mulligan	Rilley	Geologist	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury, ON P3E 6B5	**riley.mulligan@ontario.ca**
Priebe	Elizabeth	Hydrogeologist	Ontario Geological Survey, MNDM, 7th Floor, 933 Ramsey Lake Rd., Sudbury, ON P3E 6B5	**elizabeth.priebe@ontario.ca**
Robinson	Clare	Environmental Engineer	Civil and Environmental Engineering, University of Western Ontario, London, ON N6A 5B9	**crobinson@eng.uwo.ca**
Roy	James	Hydrochemist	Water Science and Technology Directorate, Environment and Climate Change Canada, 867 Lakeshore Rd., Burlington, ON L7S 1A1	**jim.roy@canada.ca**
Rudolph	David	Hydrogeologist	Dept of Earth & Environmental Sciences, University of Waterloo, 200 University Ave. W, Waterloo, ON N2L 3G1	**drudolph@uwaterloo.ca**
Russell	Hazen	Sedimentologist	Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8	**hazen.russell@canada.ca**
Sharpe	David	Glacial Geologist	Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8	**david.sharpe@canada.ca**
Stephens	Jennifer	Hydrogeologist	CTC Source Protection Region, Toronto and Region Conservation Authority, 5 Shoreham Drive, Downsview, ON M3N 1S4	**jstephens@trca.on.ca**
Tong	Xin	PhD Student	Department of Earth & Environmental Sciences, University of Waterloo, Waterloo, ON, Canada	**x23tong@gmail.com**

Notes