A hydrogeological synthesis for Southern Ontario
A Collaborative OGS – GSC project 2014-2019

Hazen A.J. Russell and Richard D. Dyer
Geological Survey of Canada and Ontario Geological Survey
February 28th, 2018
Training Young Geoscientists

14 students engaged

Employed over 34 semesters cumulatively

University Victoria
Waterloo University
Carleton University
University of Ottawa
University of Guelph
Ecole Polytechnique, Montreal

- Baranova, Natalia
- Benwell, Amanda
- Coffin, Leslie
- Griffith, Matthew
- Landon Brown, Ayesha
- Macdonald, Katie
- Mallozzi, Skyler
- McBride, April
- Moroz, Marek
- Olson, Laura
- Papovic, Natasa
- Reynen, Andrew
- Stepner, Daniel
- Valinquette, Luc

PhD students: 2
MSc students: 2

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Collaboration

- Agriculture and Agri-Food Canada
- Provincial Ministries
  - Ministry Natural Resources and Forestry
  - Ministry of Environment and Climate Change
- Oil Gas and Salt Resources Library
- Conservation Authorities
- Universities
Collaboration

Federal Agencies:
Provincial Ministries:
Conservation Authorities:
Municipalities:
Universities:
Private Sector:

Funding Agencies

OGS, AAFC, CAMC
Outline

1. Introduction

2. Multi-Disciplinary Studies

   1. Building a Knowledge Framework

      1. Data Framework Clarification

   2. Supporting Great Lakes Water Accord

Great Lakes Basin

% world’s fresh surface water: ~18%

% North America fresh surface water: ~84%

GLB water renewed annually by precipitation: < 1%

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Great Lakes Basin

Watershed – 785,400 km²

Percentage of Canada’s economy: 40%

Canadians who live in Great Lakes basin: 1 in 3

Ontarians who live in the Great Lakes basin: 87%

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Supporting Government Priorities

- International Joint Commission (IJC)
- Great Lakes Water Quality Agreement (GLWQA)
- Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
- Transboundary Aquifers
Governance Framework

Standing Senate Committee on Energy, the Environment and Natural Resources - Fourth Interim Report

1. major aquifers are mapped
2. national groundwater database
3. summary document

http://www.parl.gc.ca/Content/SEN/Committee/381/enrg/rep/rep13nov05-e.htm
GSC Aquifer Studies

Completed Projects
1. Gulf Islands
2. Nanaimo Lowlands
3. Fraser Lowlands
4. Okanagan Valley
5. Paskapoo
6. Buried Valleys
7. Milk River
8. Basal Clastic Unit
9. Sonolands
10. Oak Ridge Moraine
11. Waterton Moraine
12. Arpinal Valley
13. Carboniferous Basins
14. AFSOQ - Mirabel
15. Châteauguay
16. Richelieu

Additional Projects
21. Prince Edward Island
22. Esker St-Mathieu
23. South Nation River
24. Lake St. Martin
25. Chaudière
26. St-Maurice
27. Portneuf

Future Projects
5. Shuswap Highlands
8. Upper Cretaceous Sands
10. Judith River
11. Eastend-Ravenscrag
12. Intertill Aquifers
13. Carbonate Rocks
15. Otahuhu Shale
17. Assiniboine Delta
19. Grand River Basin
20. Credit River Basin
22. Upper-Thames Basin

Legend
Aquifer
River
Lake
Hydrogeological Region
Appalachian Highlands
Canadian Shield
Cordillera
Hudson Bay Lowlands
Carboniferous Basin
Perennial
Southern Ontario Lowlands
St. Lawrence Plains
Western Canada Sedimentary Basin

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Southern Ontario

Conservation Authorities in S. Ontario

Source Protection Areas in S. Ontario

People Using Groundwater

32

14

~3 million

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Project Objectives

- Synthesis for sustainable groundwater management
- Framework to support Great Lakes Water Quality Agreement (GLWQA)
- Support and integrate with OGS groundwater geoscience program
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Great Lakes Water Use Issues

Agriculture
Unconventional Energy

Urbanization
Natural Resource Extraction

Oil & Gas
Wetlands

Cumulative Impacts

Source Water Protection

Ecological Sustainability
Drinking Water

Contaminant Migration
Multi-Disciplinary Geoscience

- Sedimentology
- Seismic
- Geological Modelling
- Hydrochemistry
- Borehole Geophysics

Data Management
- Remote Sensing
- Hydrogeology
- Geochemistry
- Numeric Flow Modelling
- Geostatistics
- Stratigraphy

Glacial Geology
- Hydrology

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      1. Science & Technology Exchange
The Research Approach: Basin Analysis

Figure 4.1
Science requirements for groundwater sustainability.

(Council of Canadian Academies, 2009)

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Southern Ontario: Study Area

1. Remote Sensing Field validation
2. Geophysics Simcoe
3. Geophysics Niagara
4. Clarington and Pickering drillholes
5. Newmarket Till cement
6. pXRF transects
7. Modelling domain
8. Thermal imagery
9. Interferometry
Building a Knowledge Framework
Methods Development

1. Soil moisture downscaling
2. Seismic energy source
3. Seismic signal processing
4. Hydrogeophysical parameter estimation
5. Borehole geophysics
Building a Knowledge Framework

Methods Applications:

1. Remote sensing techniques
2. Seismic stratigraphy (architecture)
3. Borehole geophysics (characterization)
4. Aquitard characterization
5. Chemostratigraphic framework
6. Geological modelling
7. Coupled GW-SW numeric flow modeling
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Groundwater Databases

- Water well
- Information System
- Permit to Take
- Water Conservation Associations
- Moraine Coalition
- Land Information Ontario
- Oil Gas and Salt Resource Library
- OGS Ontario Geology
- Provincial Groundwater Monitoring Network
- Source Water Protection
- Groundwater Information Network

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Working to Improve Datasets?

- Provincial
- MOECC
  - PGWMN classification
  - Municipal Wells
  - Water Well Information System
- MNRF
  - Data accessibility
- OGS
  - Serving borehole data
  - Capture of section information

Groundwater Information Network
Data Capture, Consolidation, Classification

- Source Protection
- MOECC Provincial Groundwater Monitoring Network
- OGS mapping reports
- OGS published borehole data
- GSC borehole geophysics
- GSC seismic data

<table>
<thead>
<tr>
<th>Database:</th>
<th>Sections</th>
<th>Boreholes</th>
<th>Total:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surficial Stratigraphy:</td>
<td>621</td>
<td>352</td>
<td>973</td>
</tr>
<tr>
<td>Till Sample Analysis:</td>
<td>228</td>
<td>5</td>
<td>233</td>
</tr>
</tbody>
</table>

412 and counting

29. Building a geological framework to support regional groundwater management: data capture, consolidation, and reclassification in southern Ontario


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3D Geological Model Phanerozoic

Devonian
Geologic Formations: 11
Maximum Thickness: 420 metres

Upper Silurian
Geologic Formations: 18
Maximum Thickness: 500 metres

Lower Silurian
Geologic Formations: 16
Maximum Thickness: 240 metres

Ordovician
Geologic Formations: 10
Maximum Thickness: 774 metres

Cambrian
Maximum Thickness: 175 metres

Precambrian
Crystalline Basement
Maximum Thickness: ~30-40 km

Subsurface Features of the Model
Ontario's Subsurface Geology: by Age

Iteration 5
3D Geological Model Surficial

Simplified Regional Model
- Building from
  - Stratigraphic Framework data
  - OGS 3D models
  - WWIS

Bedrock topography

Existing models
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### GW – SW Framework

#### Evaluating GW/SW interactions (for stream, river, and lake settings)

<table>
<thead>
<tr>
<th>Dynamics of GW and SW systems and ability to interact</th>
<th>Groundwater system characteristics and processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water system characteristics and processes</td>
<td>Interface connectivity and properties</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groundwater/Surface water interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow processes</td>
</tr>
<tr>
<td>Biogeochemical processes</td>
</tr>
<tr>
<td>Biological processes</td>
</tr>
<tr>
<td>Resulting patterns of interactions</td>
</tr>
<tr>
<td>Involving spatial and temporal variability</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impacts on water quantity, water quality, and ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
</tr>
<tr>
<td>Transition zone</td>
</tr>
<tr>
<td>Groundwater</td>
</tr>
</tbody>
</table>

- Characterize SW, GW and interface connectivity
- Evaluate key flow, biogeochemical and biological processes
- Determine spatial and temporal patterns of the interactions
- Consider the potential impacts of the interactions

Brewster et al. submitted
Sensitivity Analysis

What happens when scaling from watershed to regional scale?

The influence of spatial and temporal resolution when simulating groundwater – surface water interactions with a fully integrated model

Frey et al. 2017 GAC
Regional Groundwater Modelling
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S&T Transfer: Client Engagement

2015: GAP Analysis (65 people)
2016: Open House (115 people)
2017: Open House (185 people)
2018: Open House (238 people)
2019: Open House

CJES special issue

OGS summary fieldwork and other activities
Take Home Message

4. Modelling: Regional 3-D models

3. Regime: GW-SW studies, soil moisture

2. Framework: aquitard, geochemistry studies

1. Data consolidation, QA and QC, data classification

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Take Home Message

5. Decision Making

• Supporting Government Priorities and Objectives (GLWQA, IJC, Canada Ontario Agreement)

• Science and Technology Transfer

• Open Data – Open Geoscience

• Client Engagement
Where to Find us!

- http://gin.gw-info.net

GeoScan: