Canada1Water:

A journey: From water modelling of southern Ontario to continental Canada

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Collaborators

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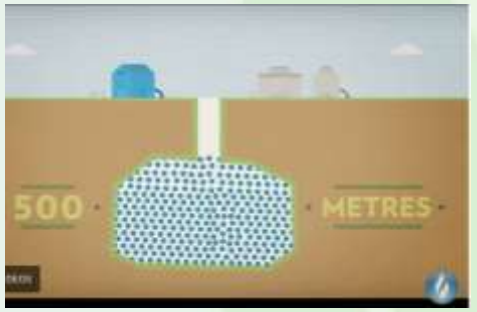
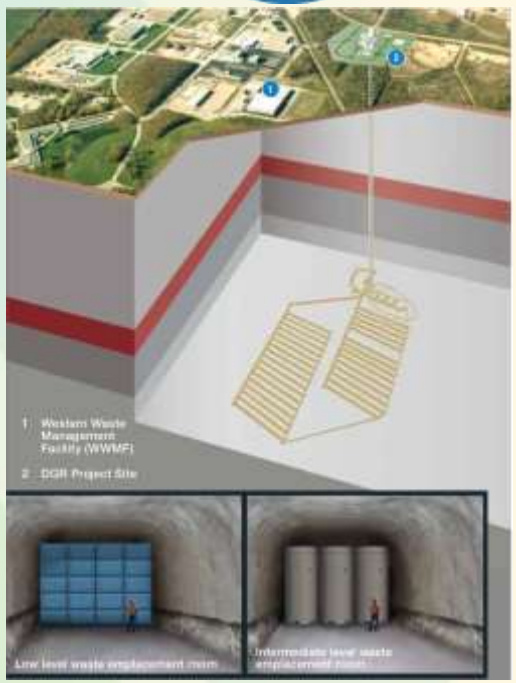
Socio-Economic Issues (S-ON)

- Urban growth (30% population)
- Mining – salt, aggregate
- Petroleum – oil and gas, unconventional?
- Gas in transient storage (~$ 2 billion)
- Geothermal -shallow low temperature
- Disposal – municipal – deep injection
- Nuclear energy and waste disposal
- Potable water / irrigation
- Agricultural (25% Canadian; $ 35 billion)
- Ecological sustainability





Retrospection

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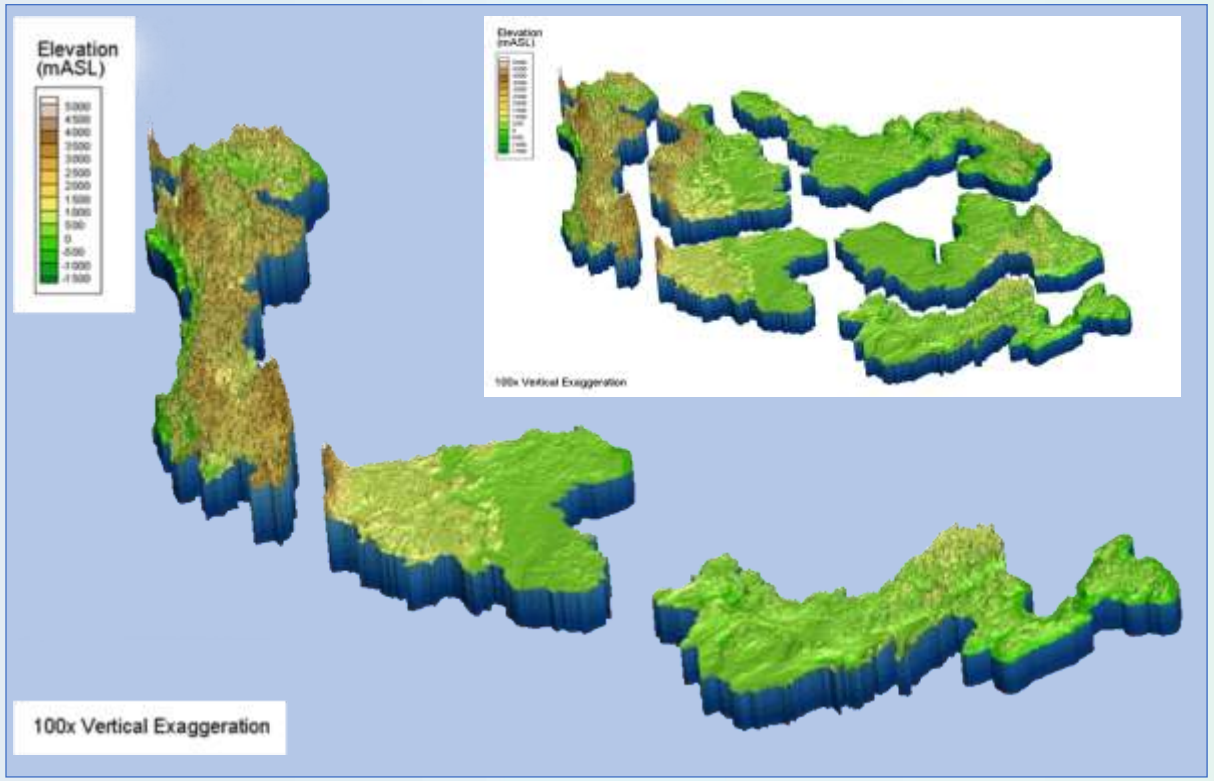
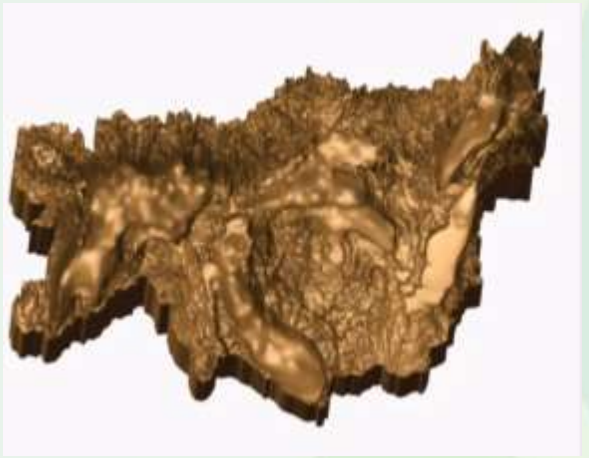
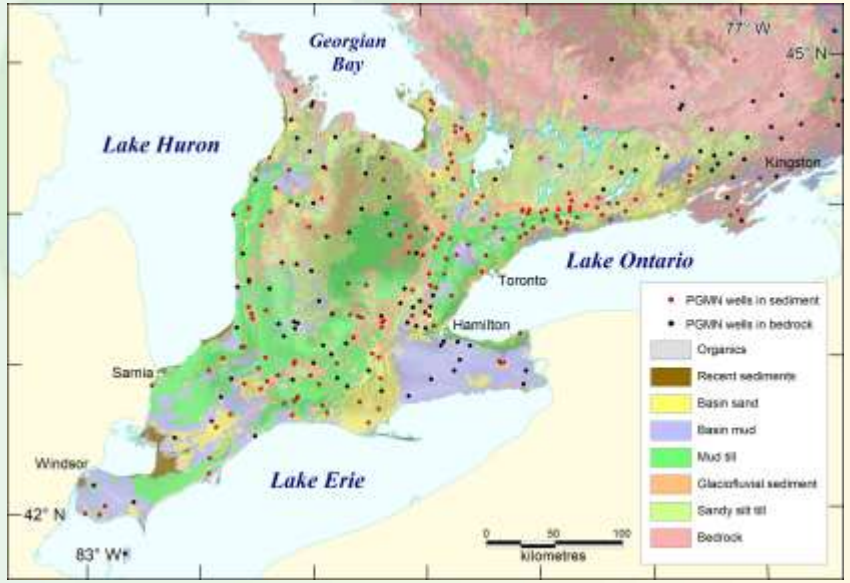


Transboundary watersheds



Great Lakes

Southern Ontario

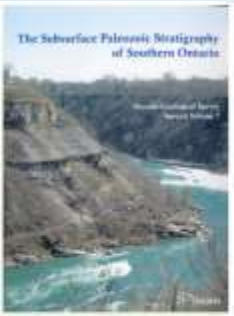


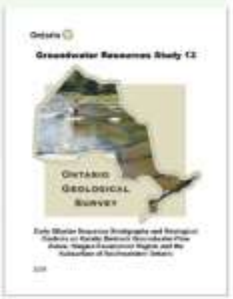
Take away overview

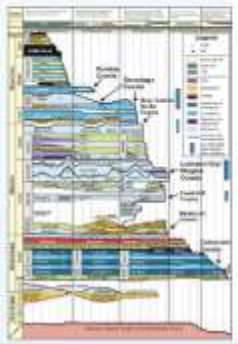
Changes in modeling scales

- Larger geographic scale necessitate
  - reduced mesh resolution
  - results in reduced drainage network capture in model
  - commonly associated with reduced data support
  - progress level of abstraction of the hydrostratigraphy
  - trans-jurisdiction models have data continuity challenges
  - Scale constrains application of models
- Highlights value of data management and data synthesizes
  - value of QA-QC returned to central authority

Southern Ontario



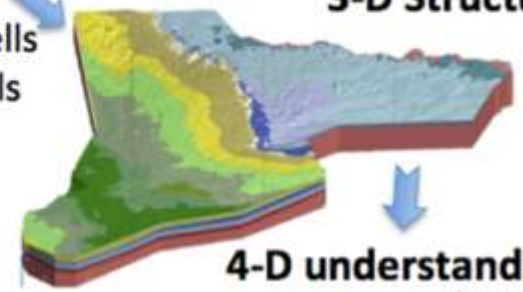




Data Chaos

- > 20,000 bedrock wells
- > 500,000 water wells

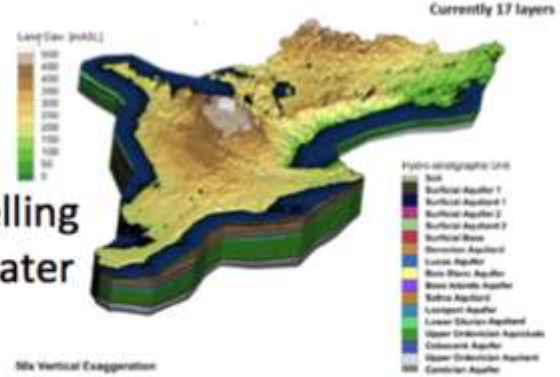
3-D Structure



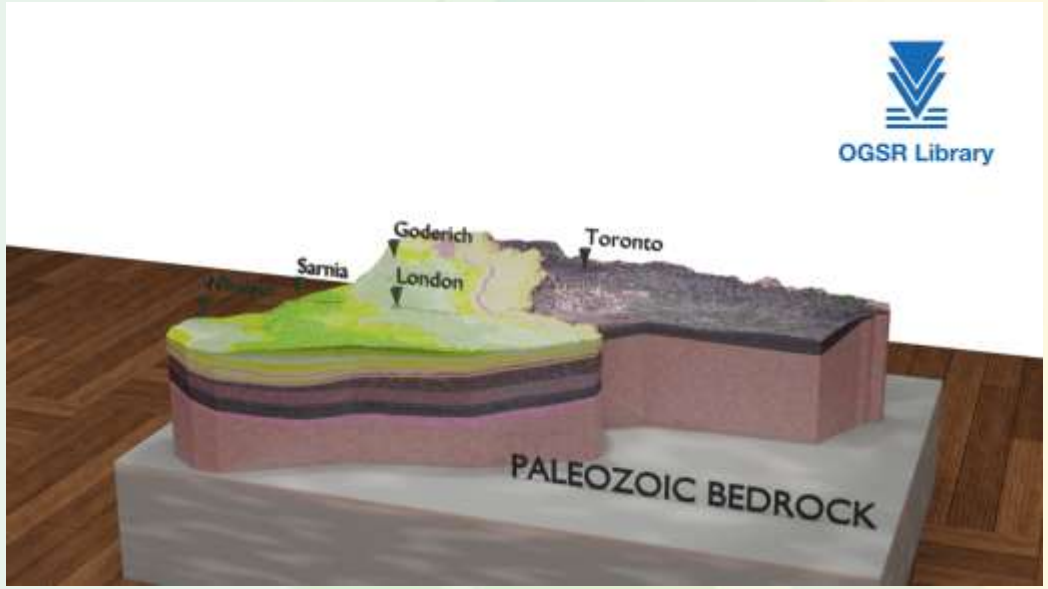
- 7 surficial layers
- 58 bedrock layers

4-D understanding

Currently 17 layers

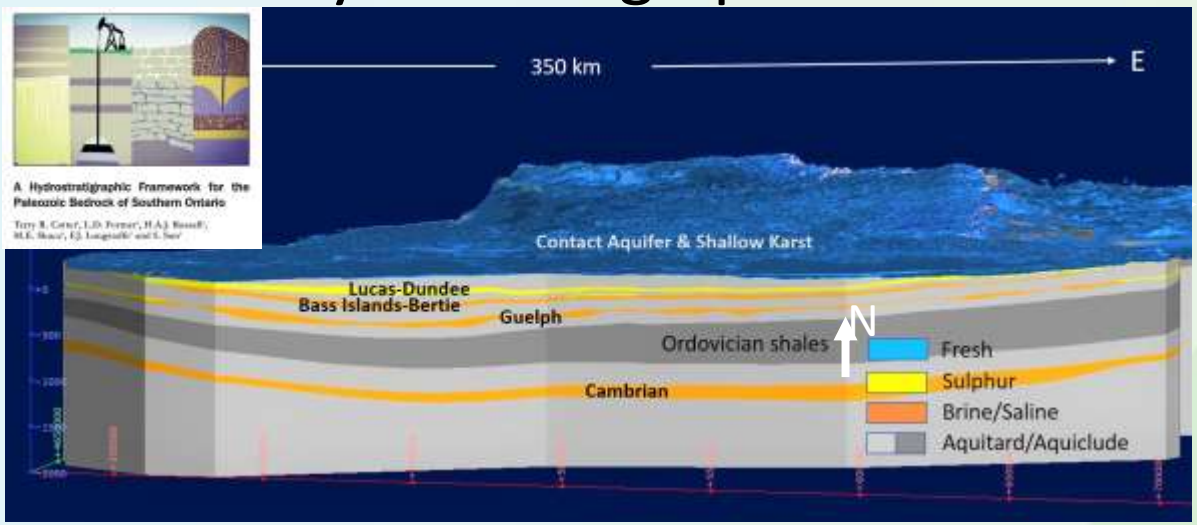


- 17 hydrostrat layers
- dynamic flow modelling
- climate – surface-water and groundwater

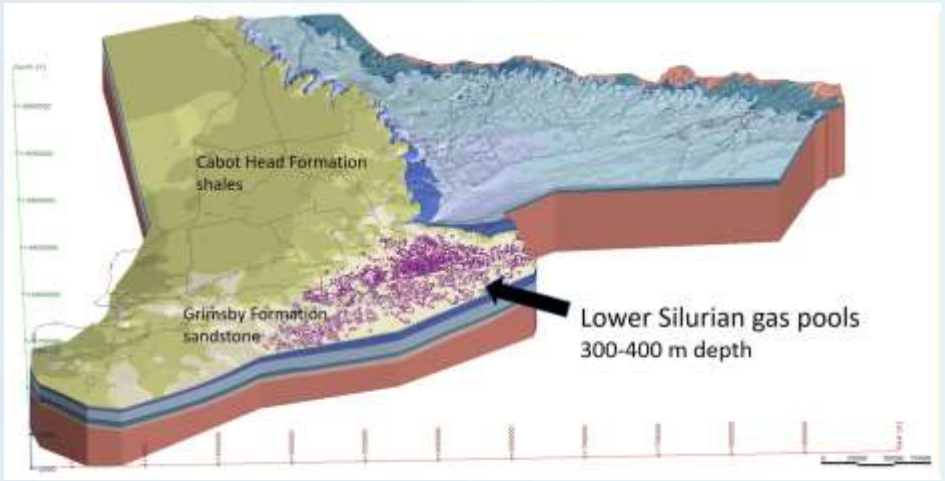


3-D models

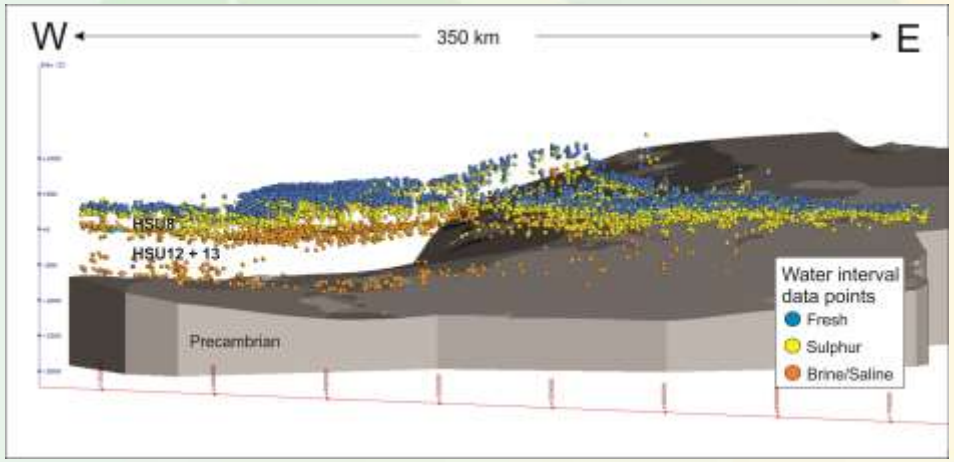
Hydrostratigraphic Model



Geological Model



Hydrochemical Model



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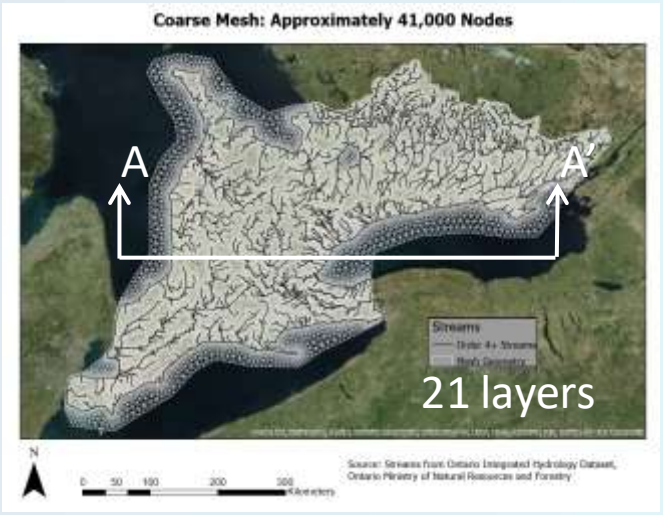
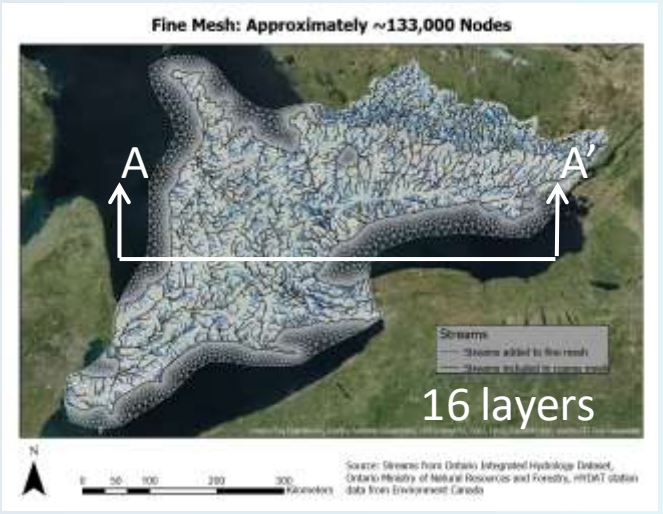
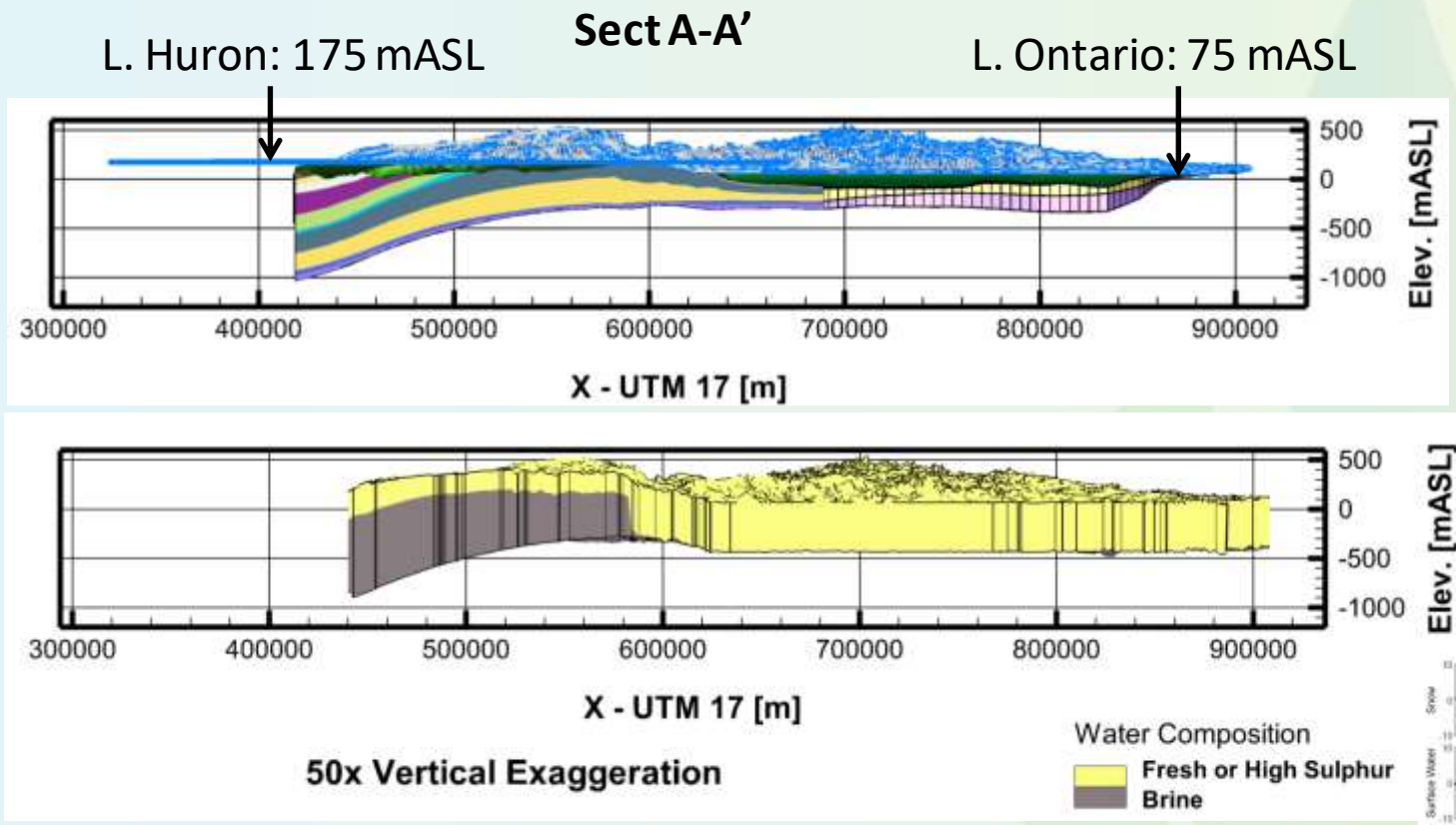
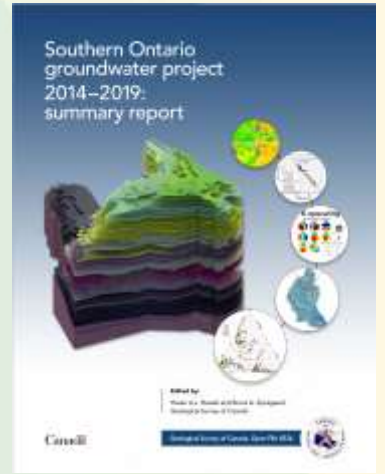
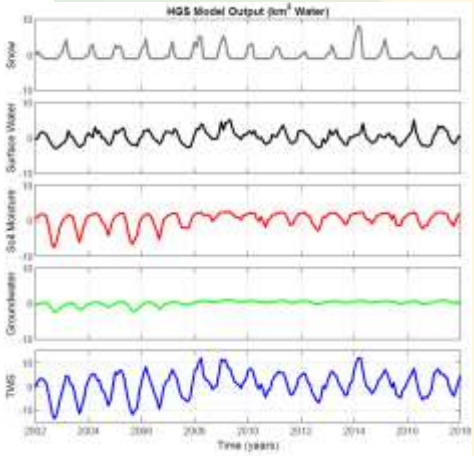
Numeric model S-ON







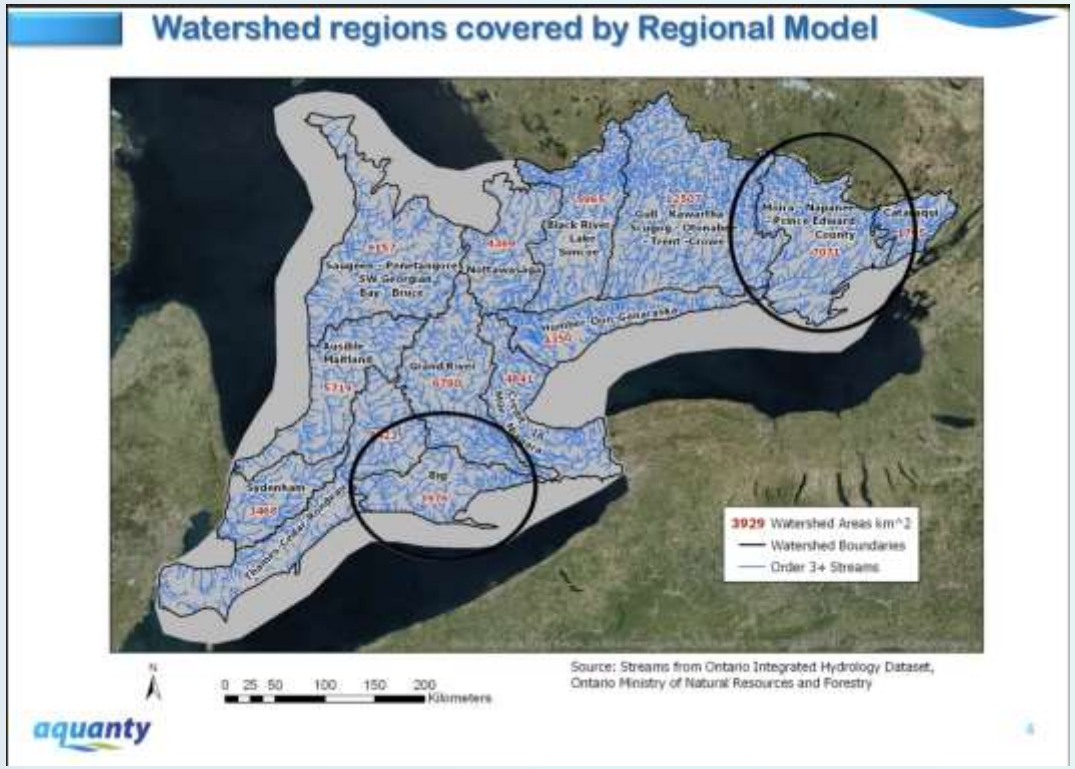


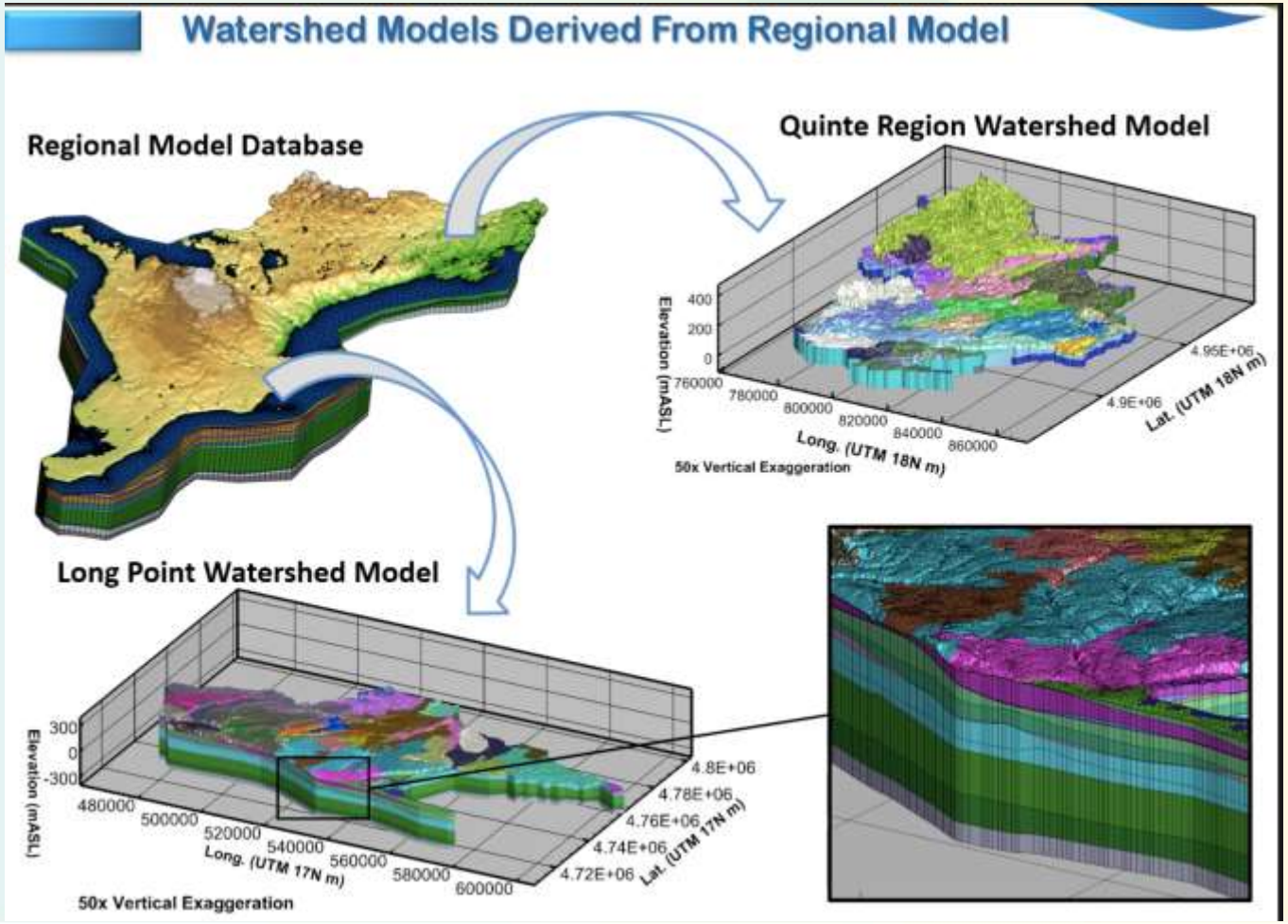


vector segments were resolved 500 m lengths for the high-resolution versions of the model.

Recommended citation: Frey, S.K., Khader, O., Taylor, A., Erler, A.R., Lapen, D.R., Sudicky, E.A., Berg, S.J., and Russell, H.A.J. 2020. A fully integrated groundwater–surface-water model for southern Ontario. In Russell, H.A.J. and Kjarsgaard, B.A. Eds. Southern Ontario groundwater project 2014–2019: summary report. Geological Survey of Canada, Open File 8536, 231-245. https://doi.org/10.4095/321108

Watershed models (MECP)





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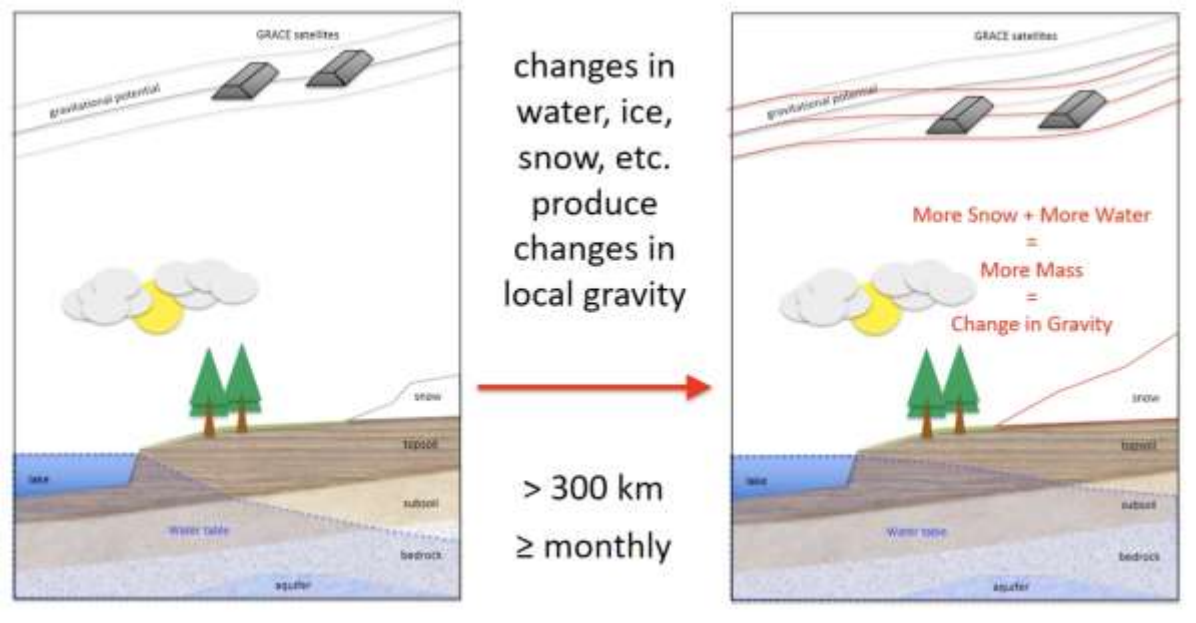
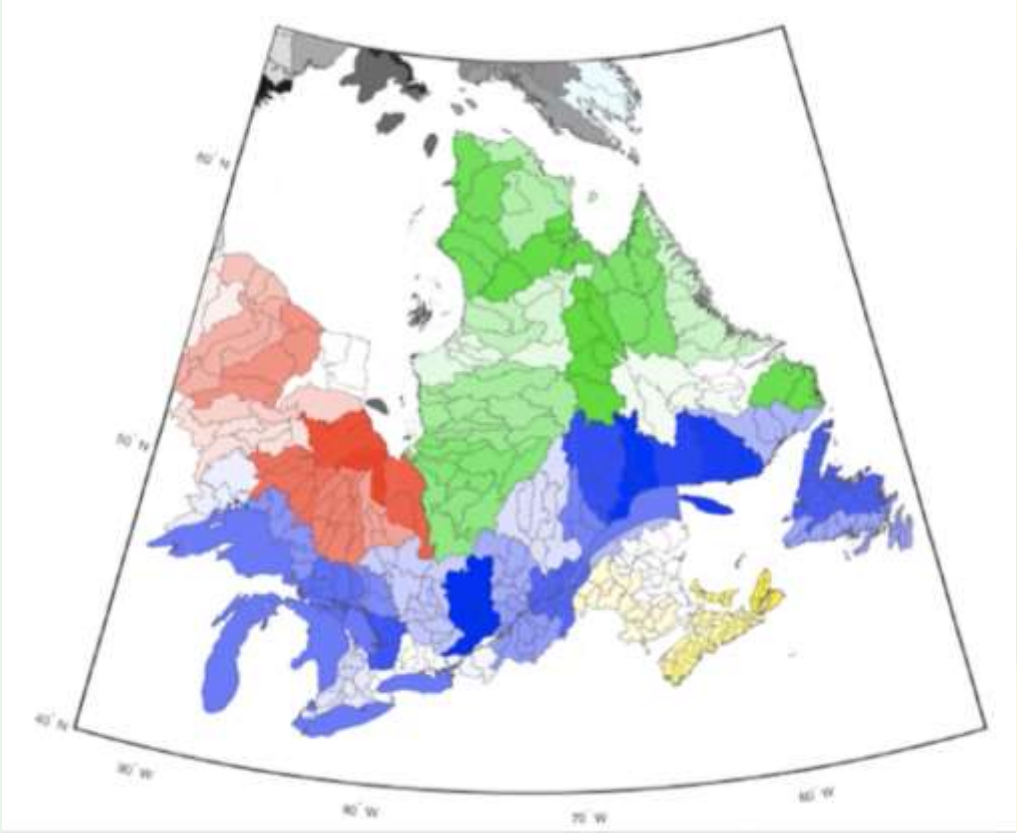
GRACE

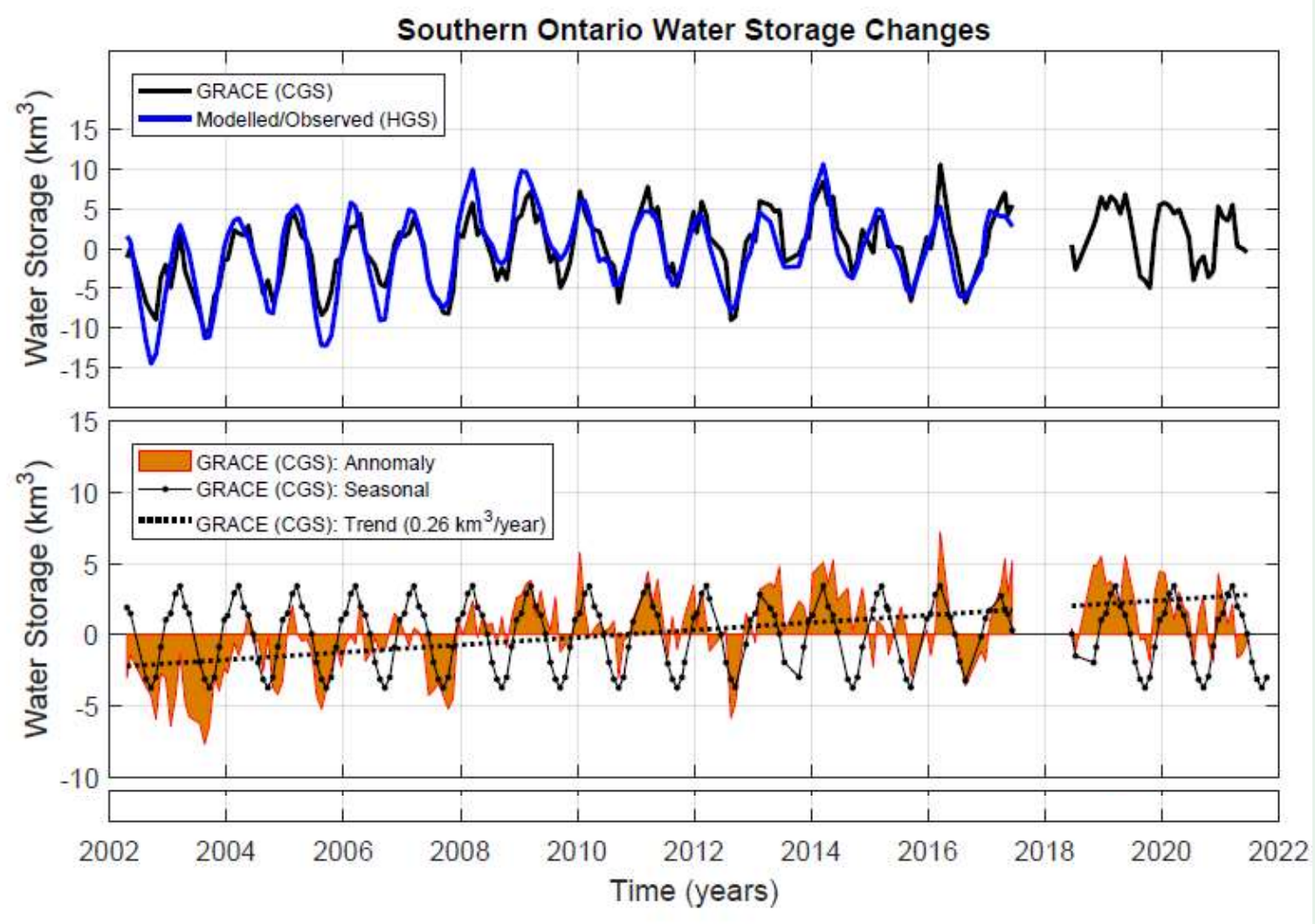
Gravity Recovery and Climate Experiment



Analysis Geometry
Built using drainage basins



Water Storage in southern Ontario



- Excellent agreement over 15 years
- Fairly regular seasonal cycle
- Model results prior to 2007 over estimate amplitude of lows

- Signal can be pasrsed into two components for which correlation differs

- Data has been updated to 2020 for model results

- Close to manuscript submission


Canada1Water
DEVELOPMENT PHASE
FINAL REPORT
Canada needs new tools to face the growing water crisis.
Canada1Water is building them.
Spring 2024
Simulating Canada's water resources for the next 75 years
A complex challenge: Modelling groundwater, surface water and climate together
Simulating Canada's water resources for the next 75 years
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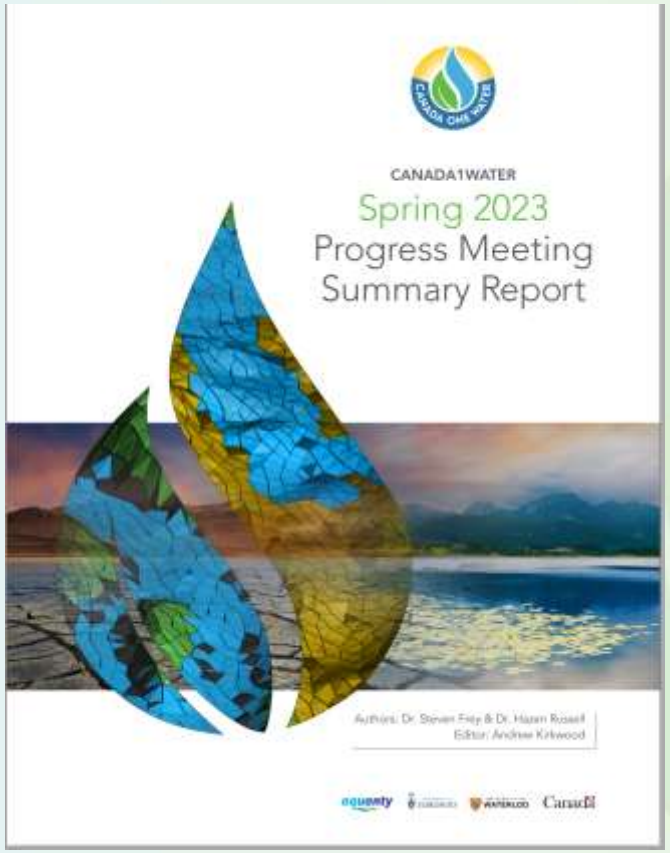
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Progress Meeting
Summary Report
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2022
Progress
Report
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Collaborative – Multidisciplinary Team

Government – Private Sector – Academia

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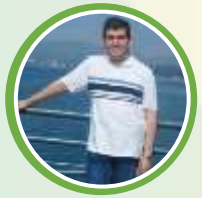
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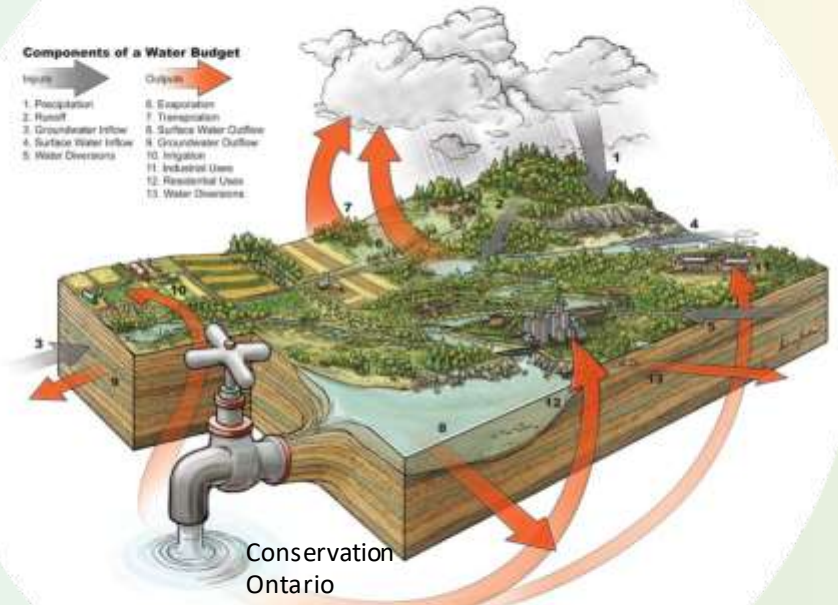
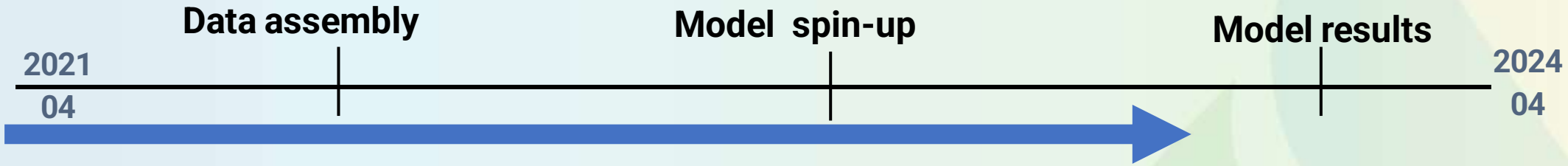
Canada1Water Objectives

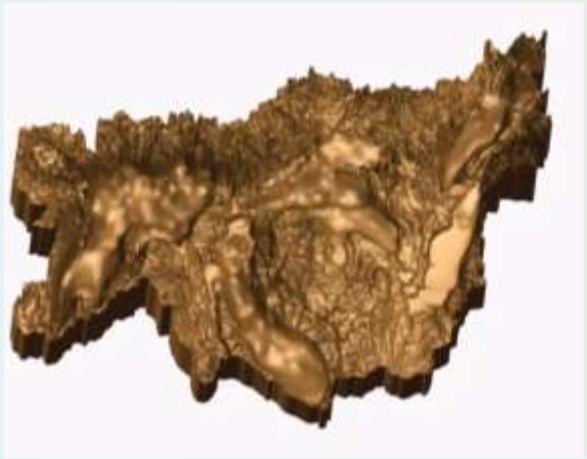
- Model water cycle for continental Canada
- Coupled groundwater – surface water system
- Evaluate the potential influence of Climate Change on water resources (large scale)
- Demonstrate model output into societal-relevant metrics
- Open data licence
- Infrastructure Development

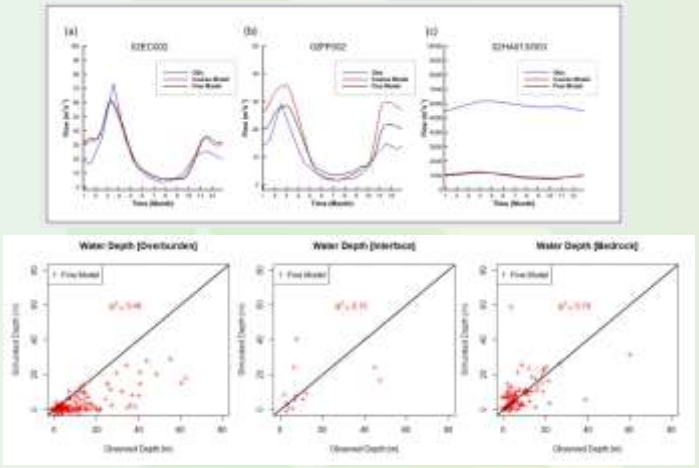
Water Cycle



Project Time Lines



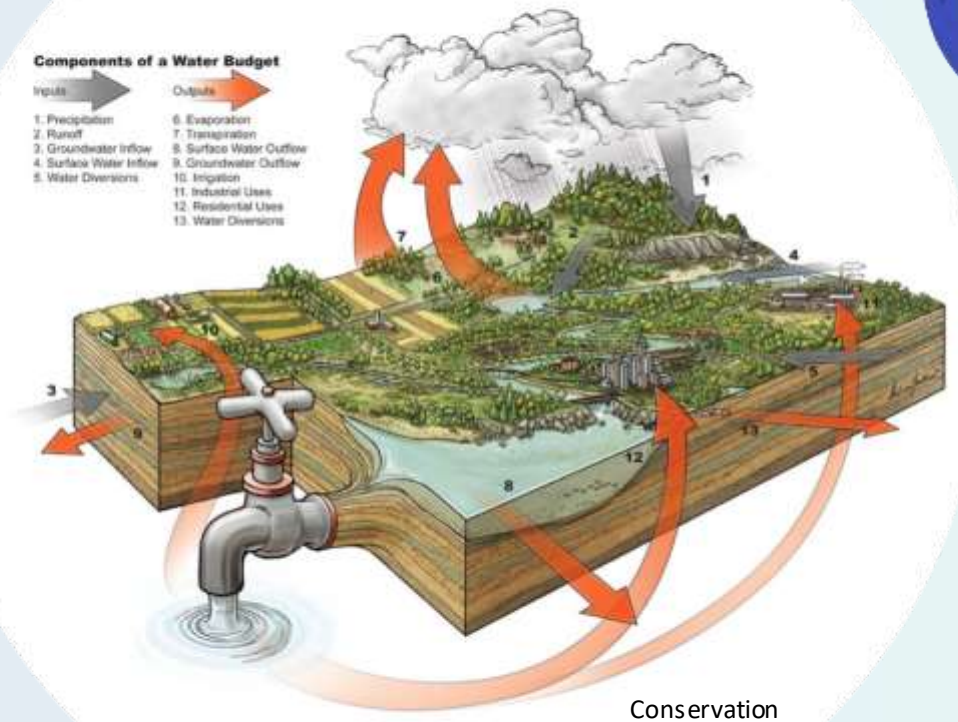




Three year, Research and Development (R&D) Project

Integrated Modelling Framework

Complete Water Budget



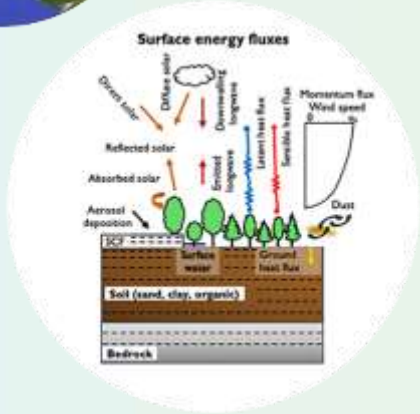
Conservation Ontario

Regional climate modelling

12.5 km resolution

Historic: 1979-2020 • Projections 2050, 2100

Weather Research Forecast Model

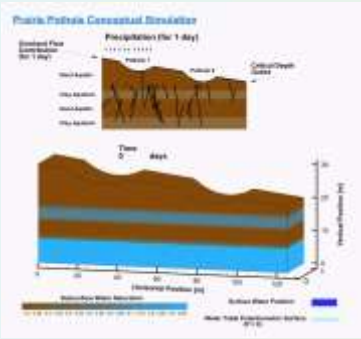


Land surface modelling

5 km resolution

Subsurface parameterization• Re-analysis products

Community Land Model



Groundwater – Surface-water modelling

1 to 5 km resolution

Integrated groundwater • Surface water

HydroGeoSphere

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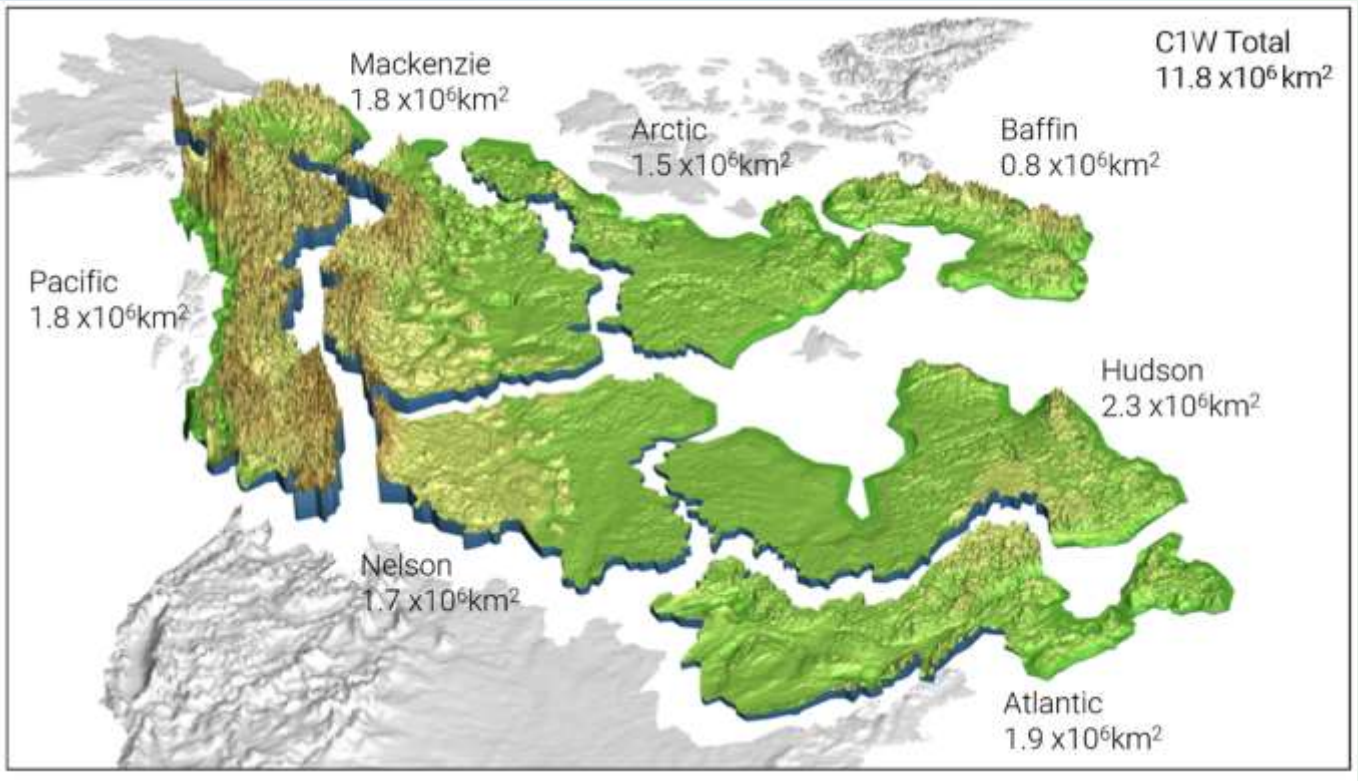
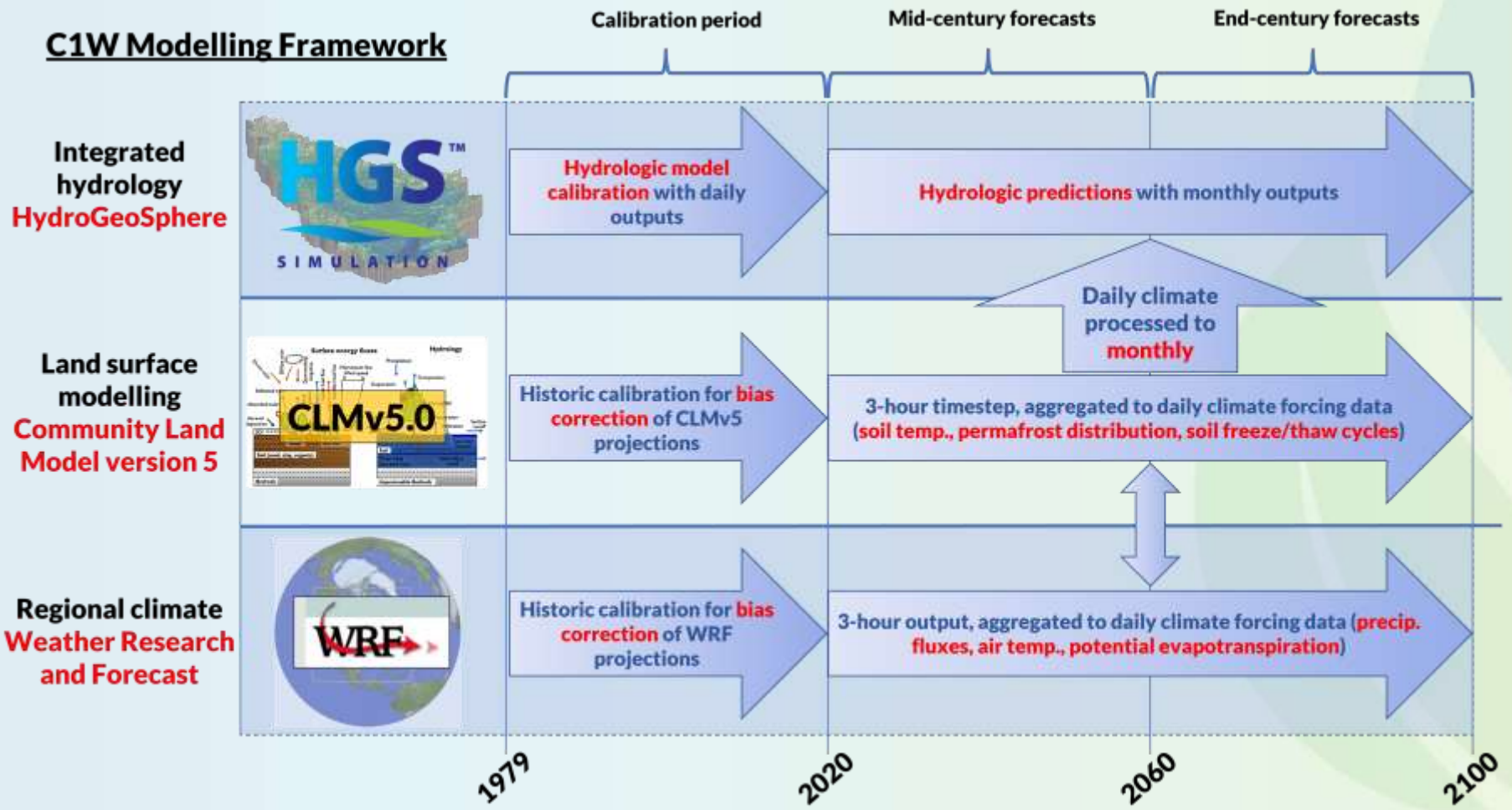
Model Domain



- Seven drainage regions for the continental domain
- Regions are approximately similar in size
- Physiographic characteristics taken into account for drainage basin delineation
- 6 to 8 subsurface layers
- Up to ~5 million finite elements per model

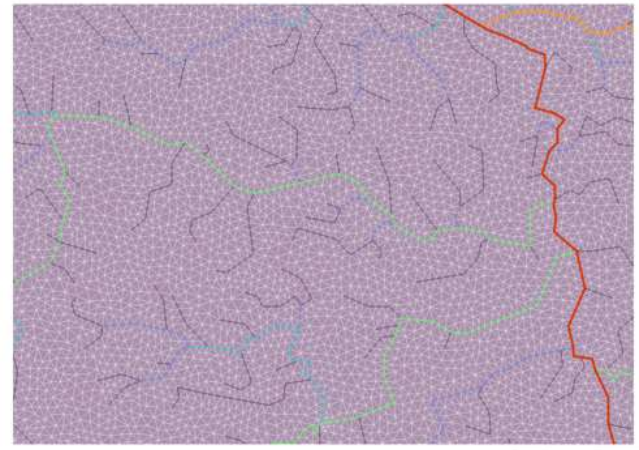
Modelling Time Step

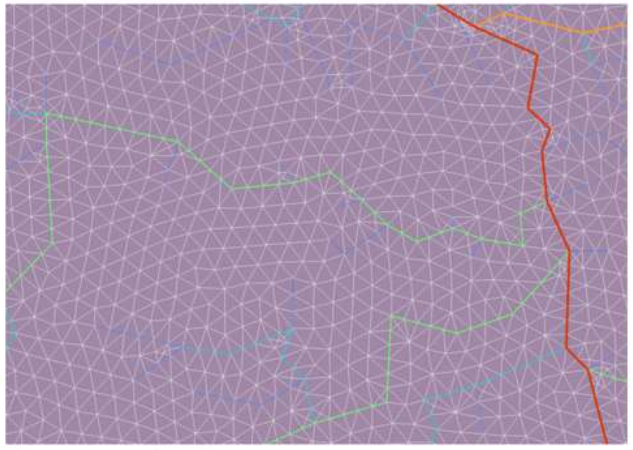


Model Resolution

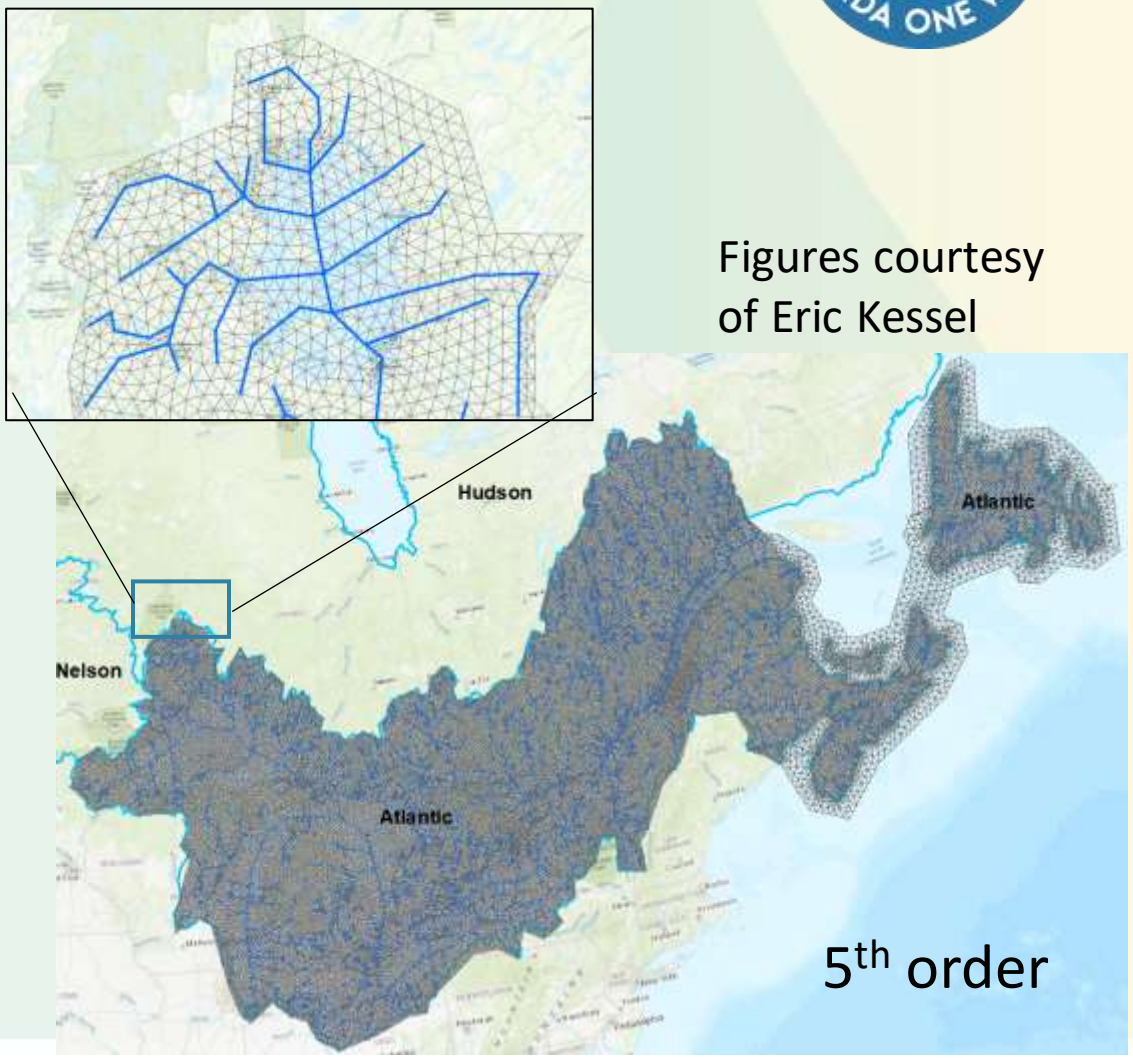
Strahler order 4 and 5

Model	# of Layers	Domain Area (M-km2)	# of 3D FE Elements	# of 3D FE Elements
			Low Res	High Res
Arctic	7	1.5	555,408	2,424,702
Atlantic	8	1.9	857,960	3,621,648
Baffin	7	0.82	252,021	1,117,998
Hudson	7	2.32	829,696	3,948,588
Mackenzie	7	1.81	675,696	3,065,664
Nelson	8	1.65	668,744	3,162,392
Pacific	7	1.81	629,447	2,748,627



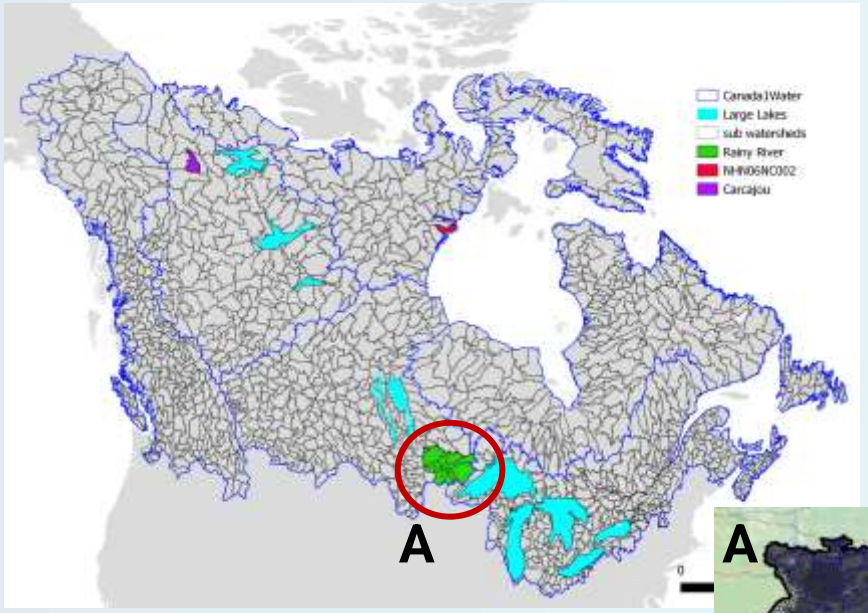


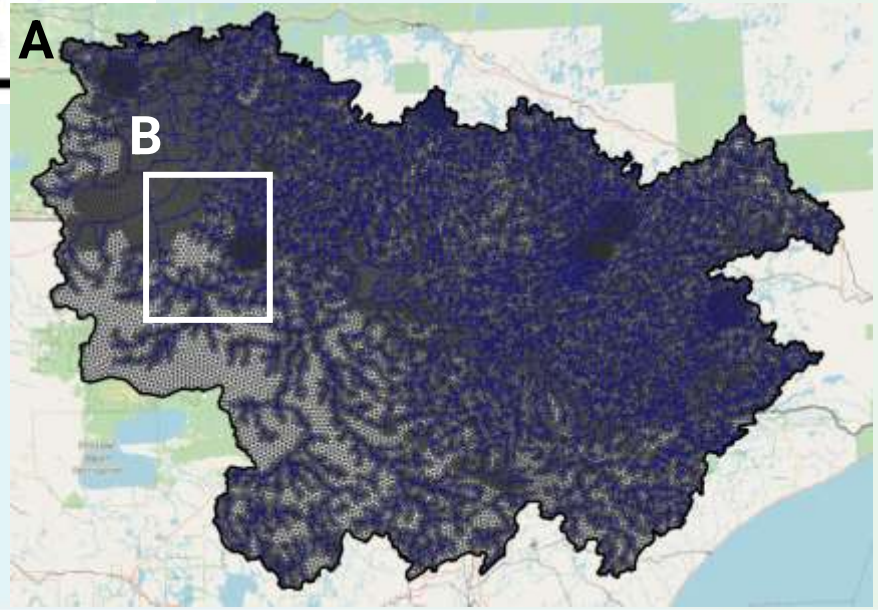
Figures courtesy of Eric Kessel



5th order

Nested Models

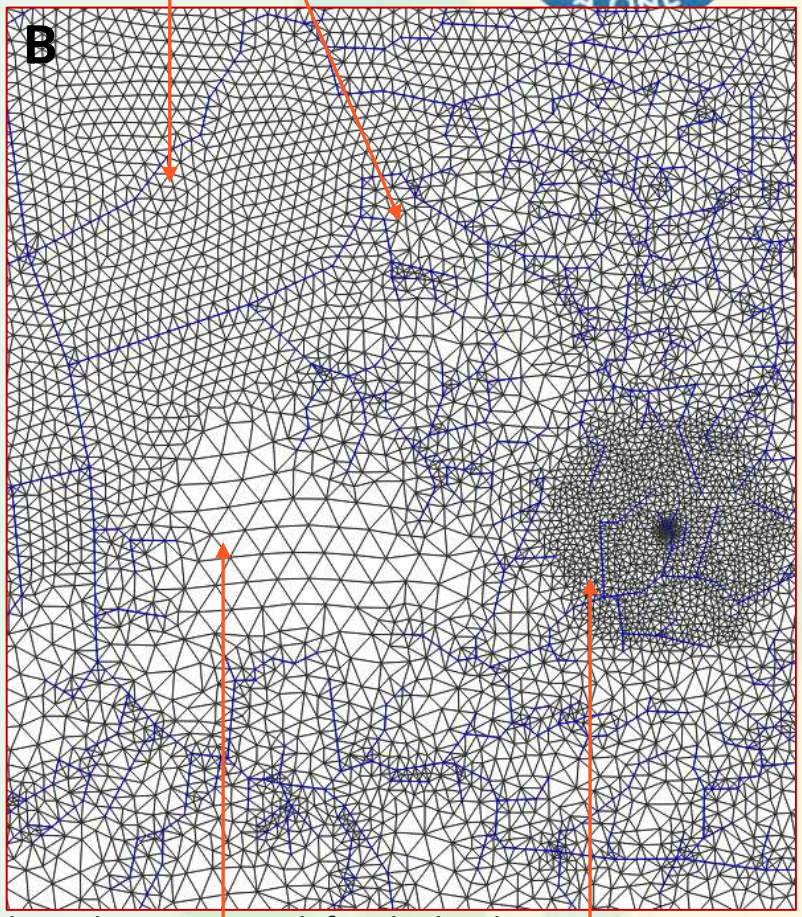




A. Rainy River, western Ontario

2D Mesh: 84,677 Triangular nodes; 167,492 Triangular elements

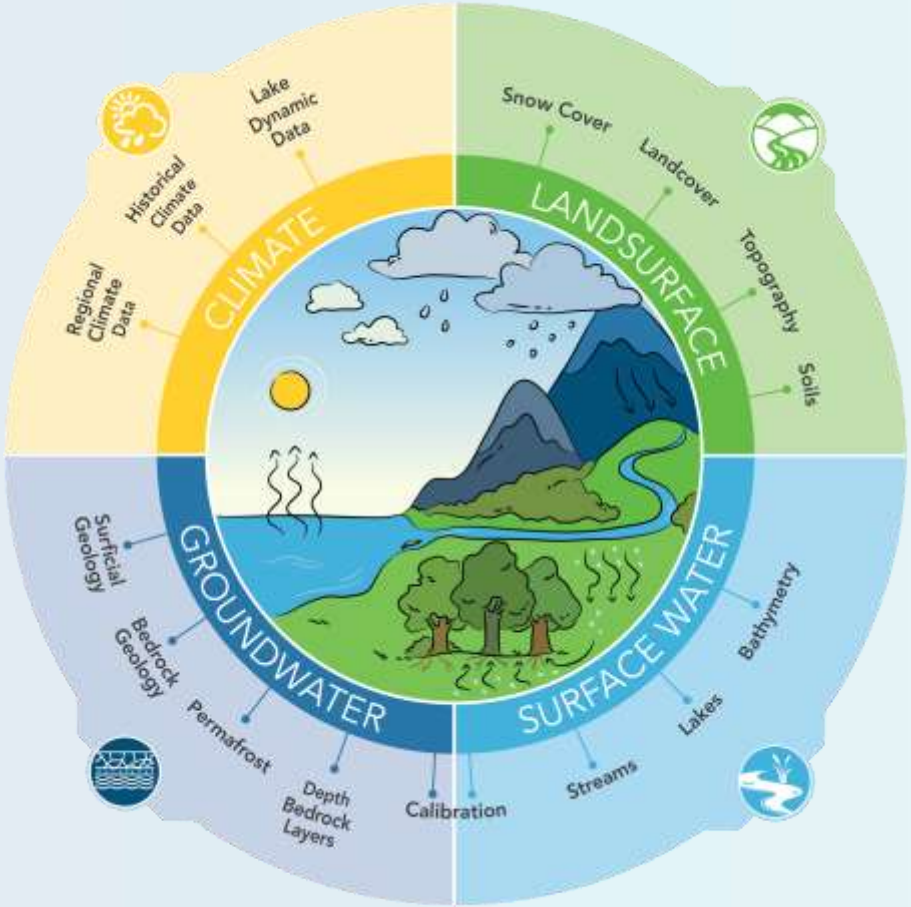
Relatively fine mesh for the lakes (edge length < 1,500 m), and streams (< 800 m)

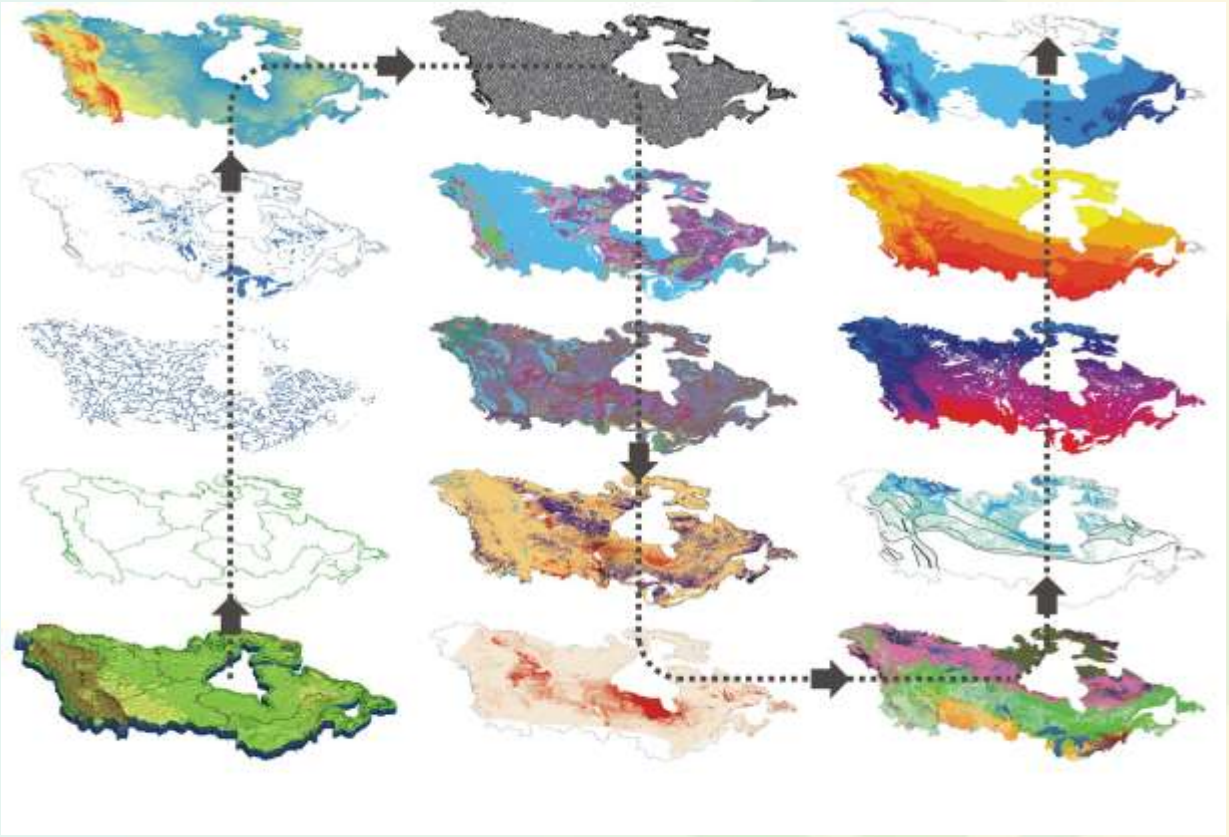


Relatively coarse mesh for the land area with a global max. edge length of 3,000 m

Finest mesh for the mining sites (50 - 800 m)

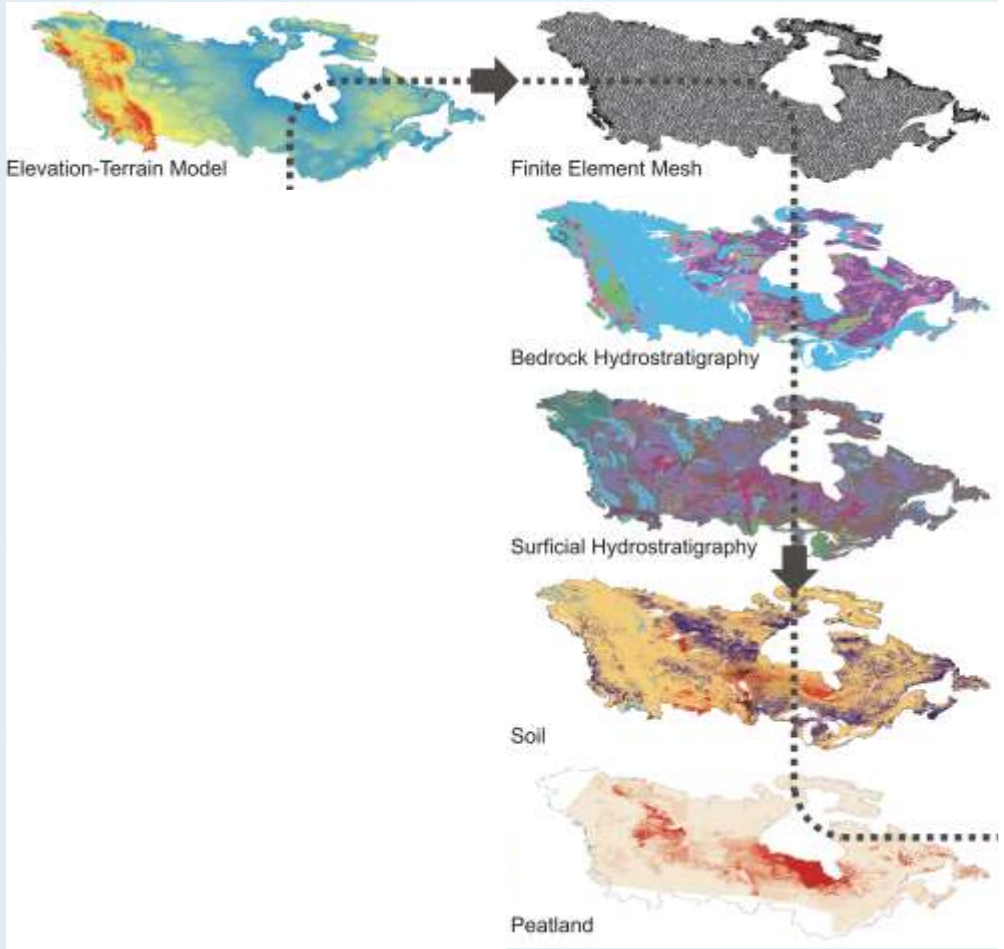
Model Input Datasets

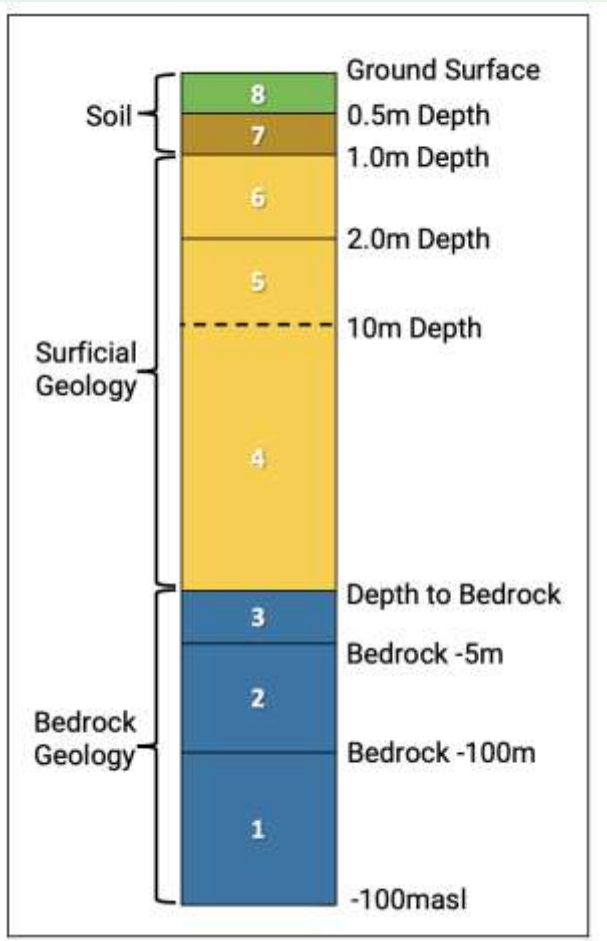




courtesy of Eric Kessell

Hydrostratigraphic Framework





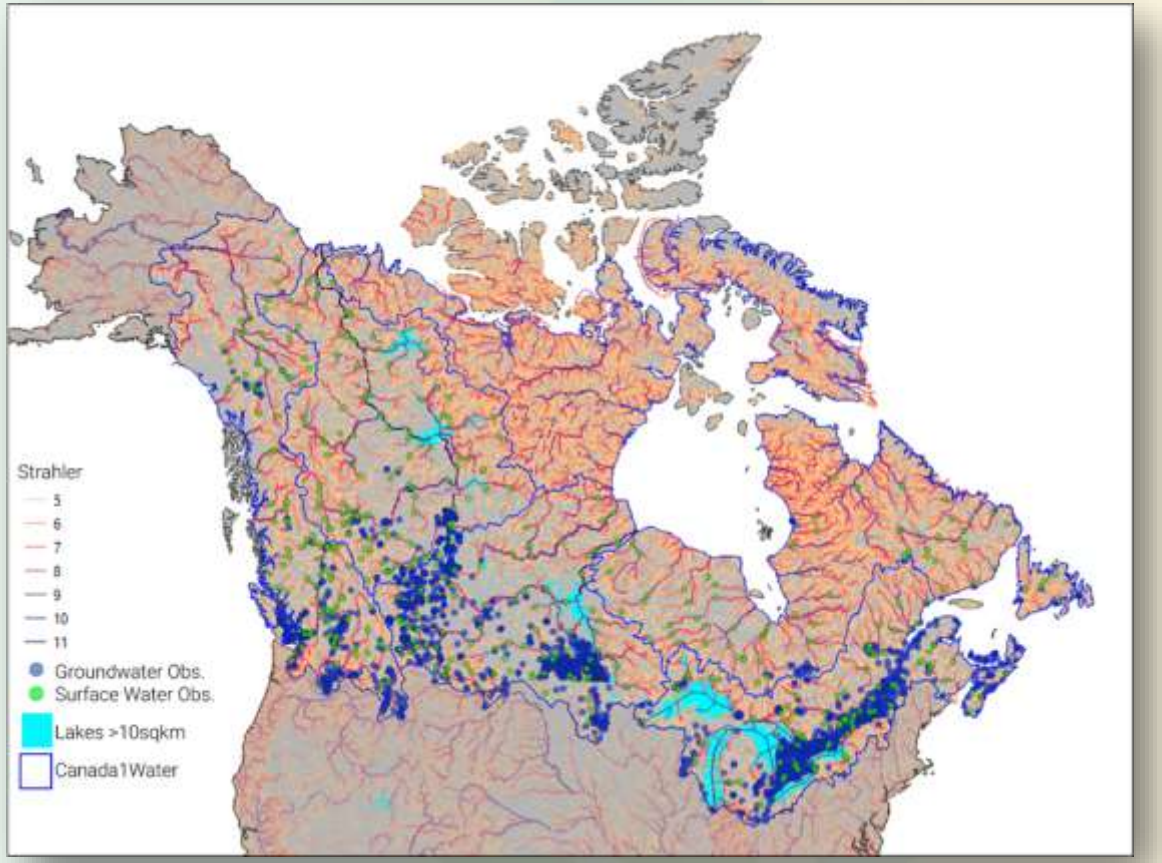
Calibration Targets

- Hydrometric Stations:
  - Canada Water Survey of Canada **WSC**
  - USA National Water Information System **NWIS**

Canada	432
USA	24

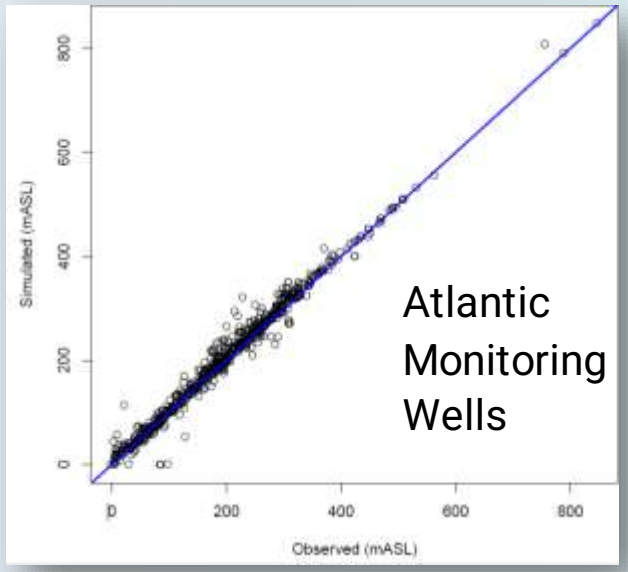
- GW Wells - in all models except Arctic and Baffin.
- Source:
  - Groundwater Information Network **GIN**
  - National Ground-Water Monitoring Network **NGWMN**

Canada	2675
USA	313



Figures courtesy of Dr. Omar Khader

Preliminary Simulation Calibration



Atlantic Monitoring Wells

Wells = 888
Simulated heads are consistent with the observed.
R2 = 0.98

Historic monthly average flow rates

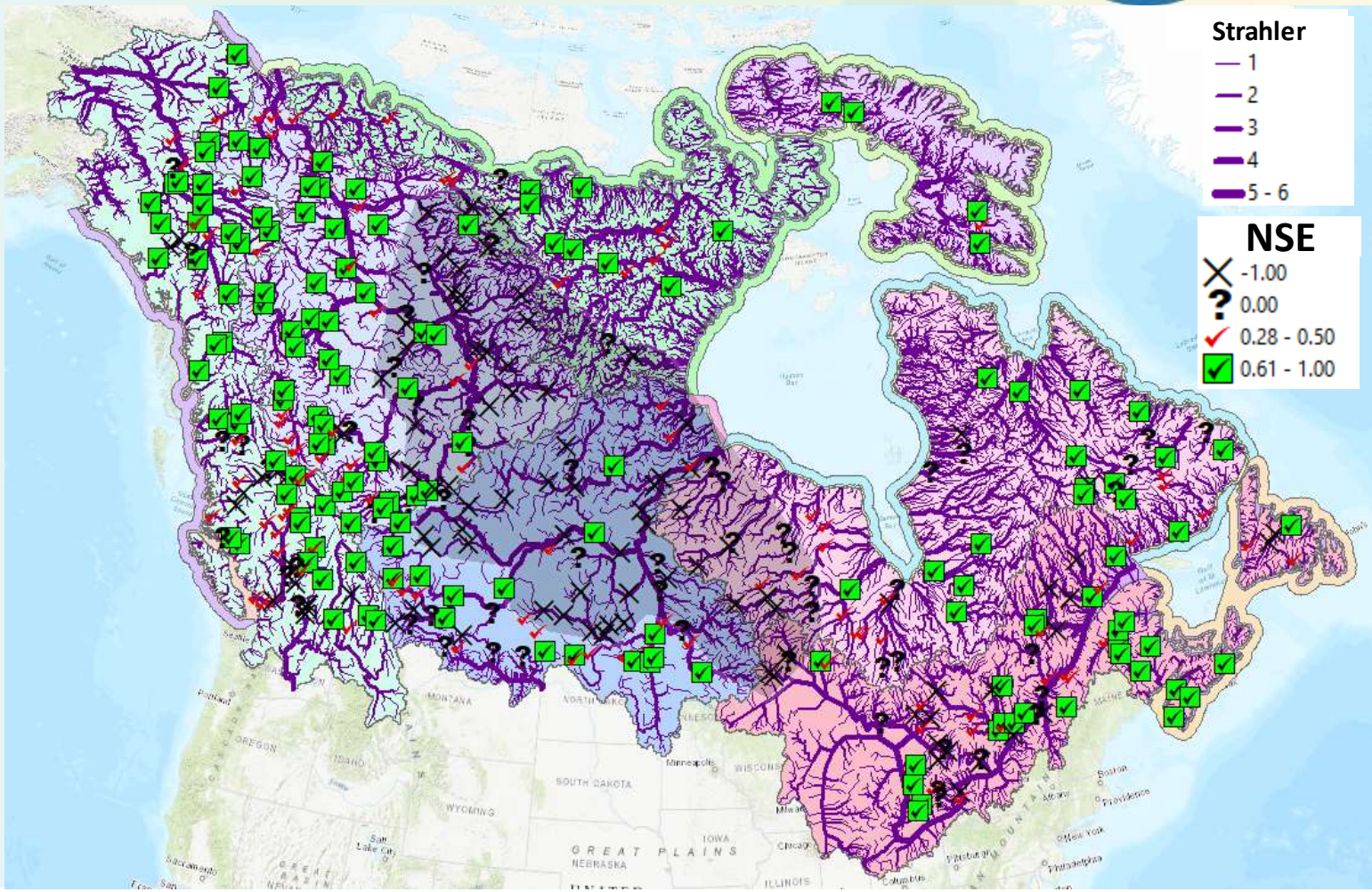


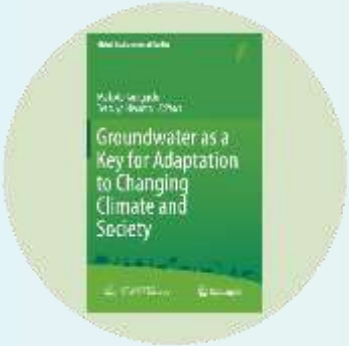
Figure courtesy of Dr. Omar Khader

Community Support

Decision support for sustainable water resource management
Addressing ESG – Environment, Society, and Governance

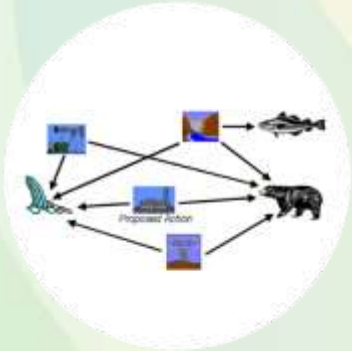
First Nations

Society



Sustainable

Cumulative Effects



Economic

Mining

Forestry

Agriculture

Fisheries

Environmental Flows

aquanty

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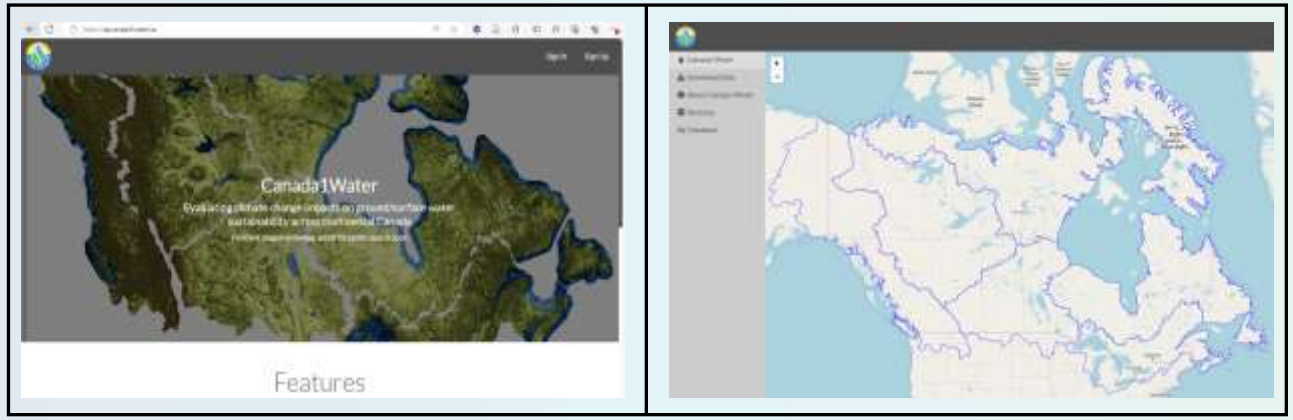
Canada

Cloud-Based Data Portal



Grid-based AOI

- Modern reactive UI/UX - Vue 3 Framework
- Cloud-optimized geotiffs (COGs) for high-performance of map tile loading
- Integrated with Geoserver (open-source tool) for metadata/WMS/WFS/WCS services
- Access full C1W domain, or Area-of-Interest
  - Model construction data
  - Historic and projected climatology
  - Simulation outputs
  - Projected change in:
    - SW, GW and SM storage
    - Hydrologic seasonality
- Fully documented (metadata)

The Future

- Analysis of model outputs
- Scenario development
- Groundtruthing / validation
- Refinement of data layers
  - Hydrostratigraphy
  - Parametrization
- Application of models to other issues
  - Land surface change
  - Salt water intrusion
- Model refinement
  - Local scale refinement and adaptation

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  - GEM-GeoNorth Program
- Agriculture and Agri-Food Canada
  - Environmental Change OneHealth Observatory
- Canadian Forestry Service
- University of Toronto and University of Waterloo
  - NSERC Alliance
- Aquaty
    - Mitac

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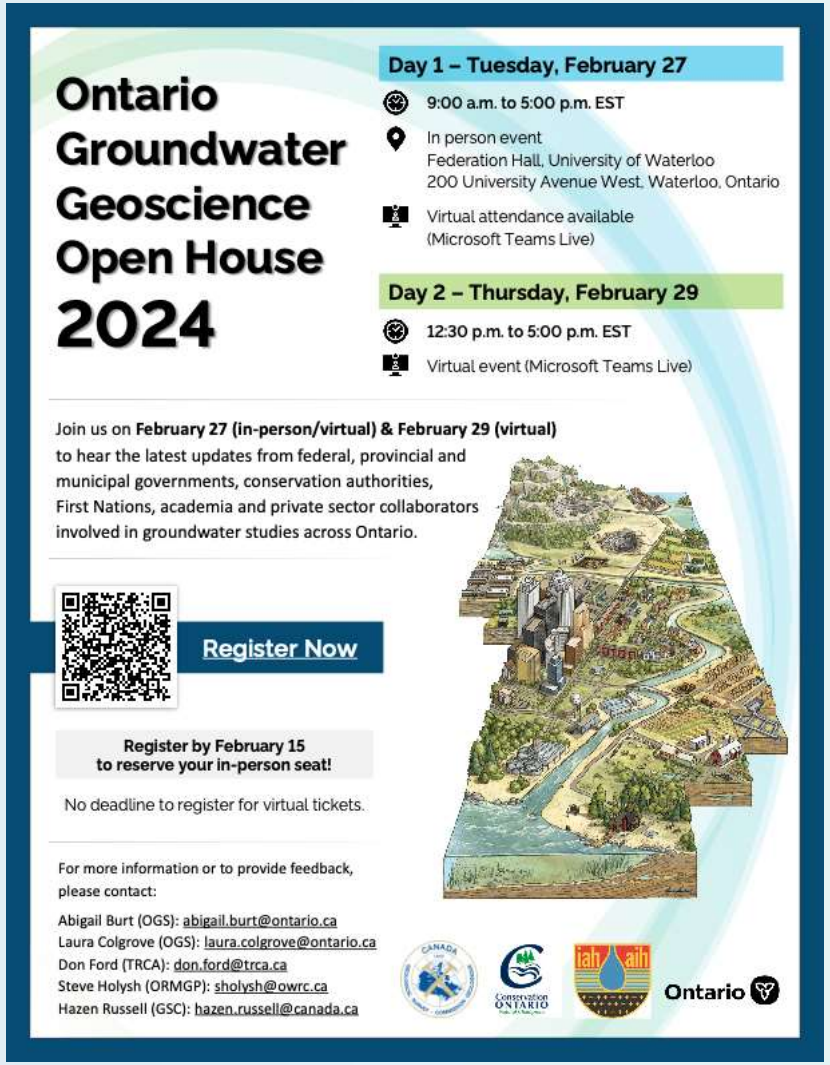

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