A Snapshot of Ontario's Groundwater COA Projects

Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (COA)

Nation Dialogue on Groundwater Committee Meeting

February 14, 2024

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Ontario Ministry of the Environment, Conservation and Parks

Ontario

COA 2021

Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health

Canada-Ontario Agreement on Great Lakes
Water Quality and Ecosystem Health
2021

Annex 9: Groundwater Quality

Purpose:

To understand how groundwater influences Great Lakes water quality and ecosystem health and identify priority areas for action.

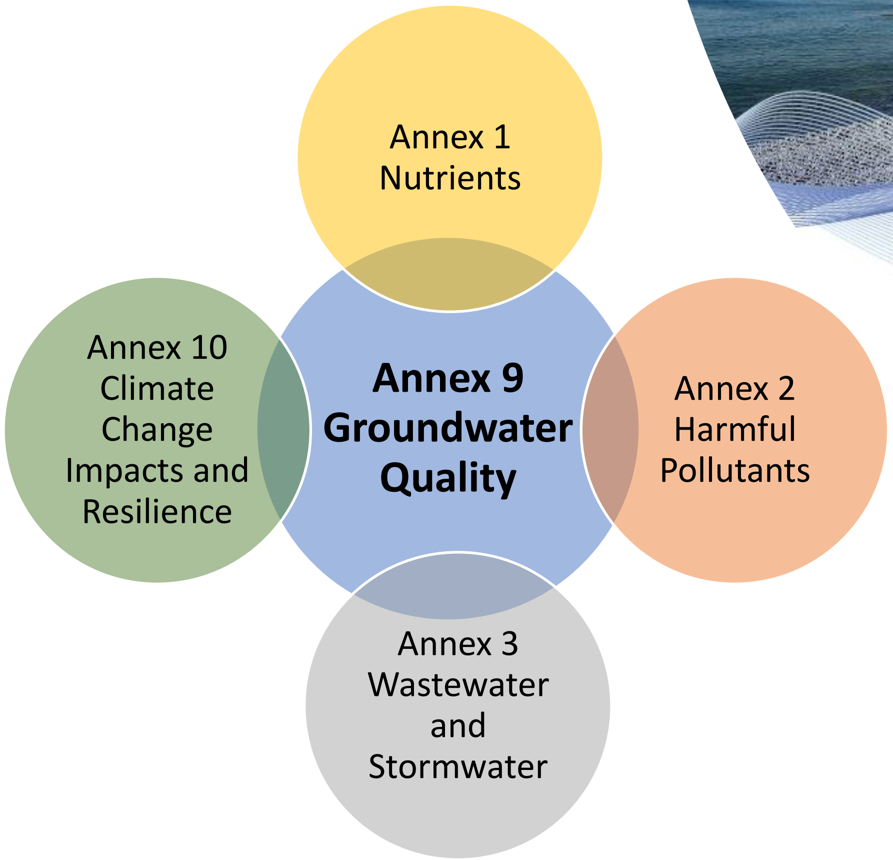
New concepts/actions:

- **The role of good quality groundwater**
- **GW-SW interaction studies and modelling**

Key Actions:

- Improve understanding of groundwater impacts and stressors on Great Lakes water quality and ecosystem health
- Identify priority areas for monitoring, management and action
- Update binational Groundwater Science Report

Connection with other Annexes:



Canada Ontario

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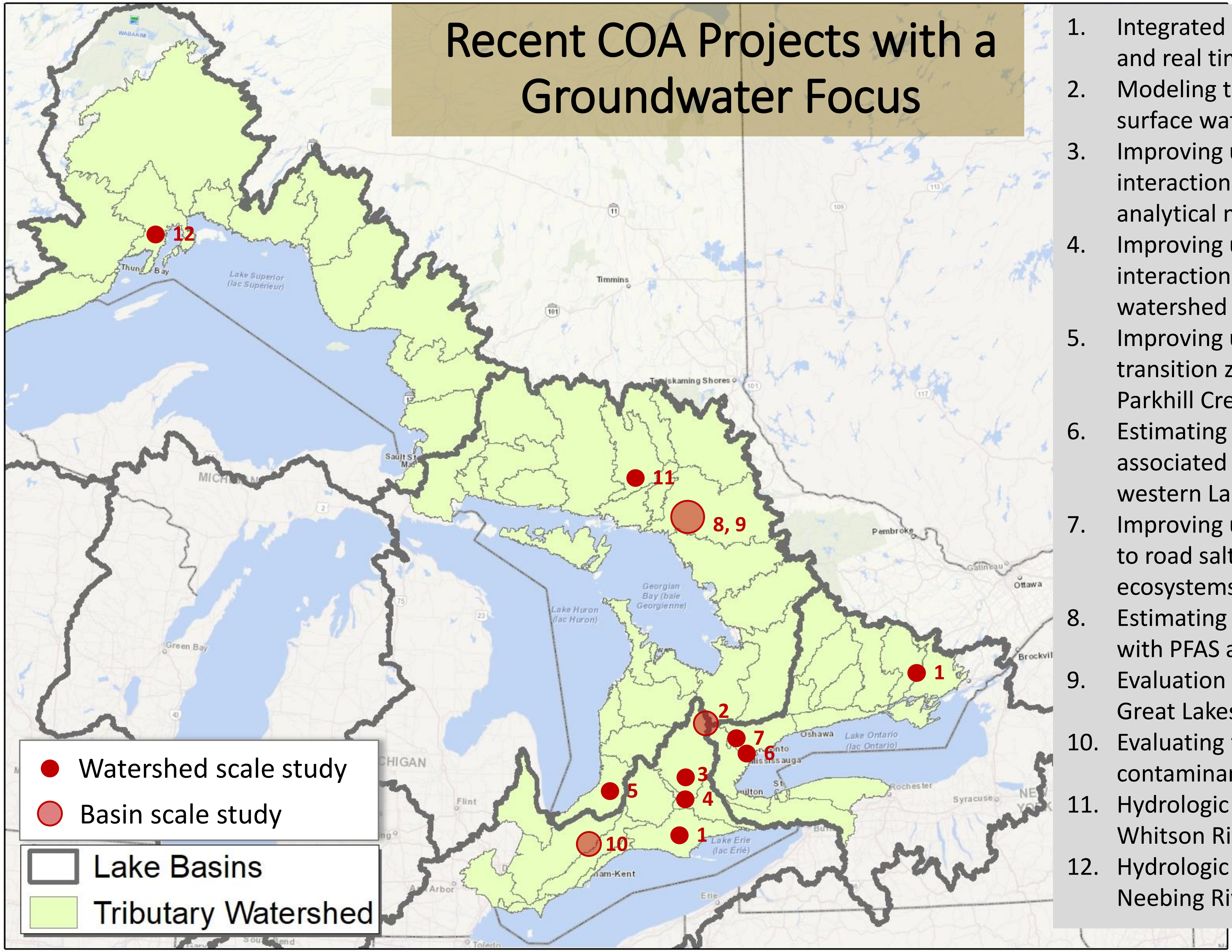
Recent COA Projects with a Groundwater Focus



1. Integrated climate-surface water-groundwater modelling and real time forecasting, Quinte and Long Point CAs
2. Modeling the dynamics of groundwater discharge to surface water receptors, southern Ontario
3. Improving understanding of groundwater-surface water interaction and optimizing field monitoring and analytical methods, Alder Creek watershed
4. Improving understanding of groundwater-surface water interaction and phosphorus transport, Whitmans Creek watershed
5. Improving understanding of nutrient dynamics in the transition zone between groundwater and surface water, Parkhill Creek watershed
6. Estimating direct groundwater discharge and the associated road salt loadings to the northern shore of western Lake Ontario
7. Improving understanding of groundwater's contribution to road salt contamination in surface water and aquatic ecosystems, western Lake Ontario basin
8. Estimating the number of sites potentially contaminated with PFAS across Ontario
9. Evaluation of landfills as a source of contaminants to Great Lakes Waters
10. Evaluating the contribution of septic systems to contaminant loadings to surface waters, Lake Erie Basin
11. Hydrologic function and climate change impact analyses, Whitson River watershed
12. Hydrologic function and climate change impact analyses, Neebing River watershed

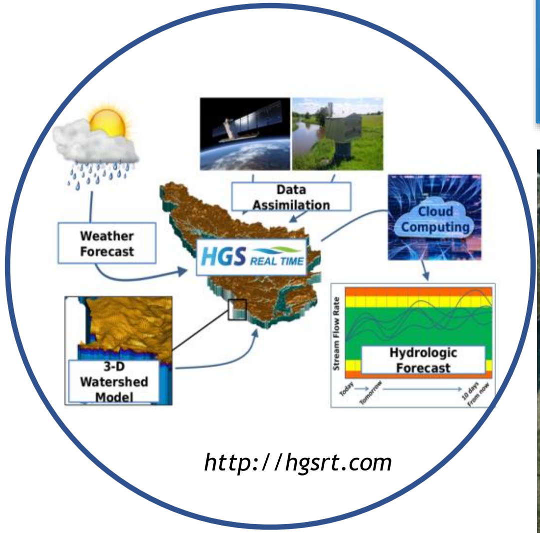
Theme 1:

- The role of good quality groundwater
- Groundwater-Surface Water Interaction and modeling

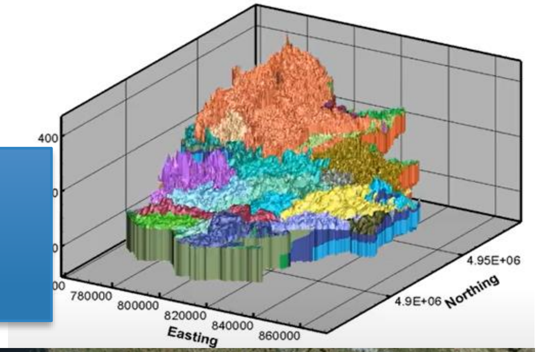
1. Integrated Climate-Surface Water-Groundwater Modelling and Real Time Forecasting at a Watershed Scale

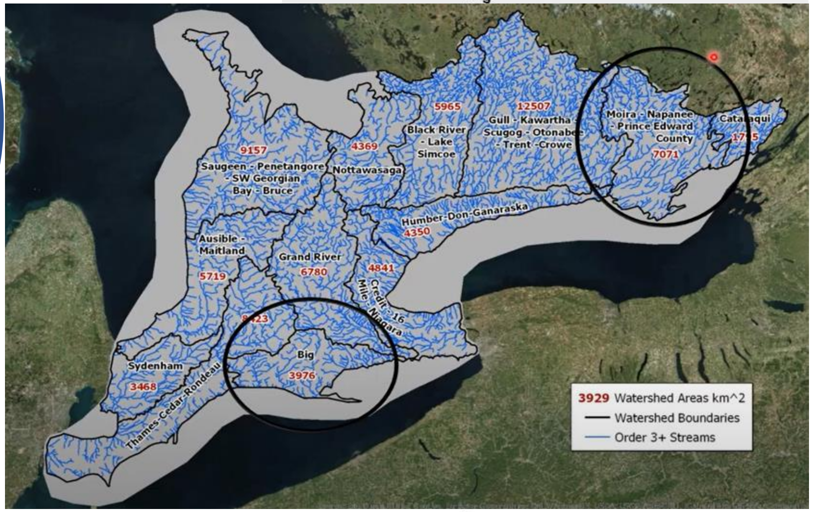
Frey et al. 2021. **Fully-integrated groundwater – surface water forecasting in two contrasting hydrostratigraphic settings within southern Ontario**, *2021 OGS Groundwater Open House*

Method:

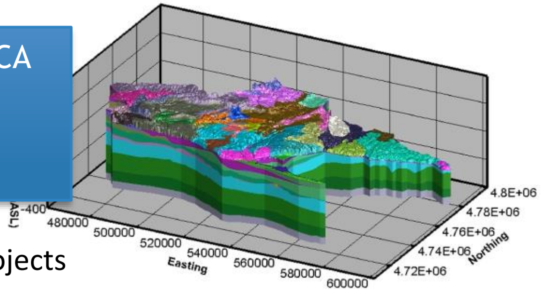


Quinte CA
- bedrock dominated
- drought prone



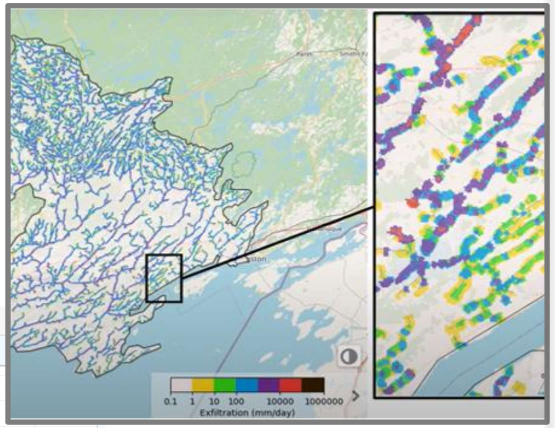


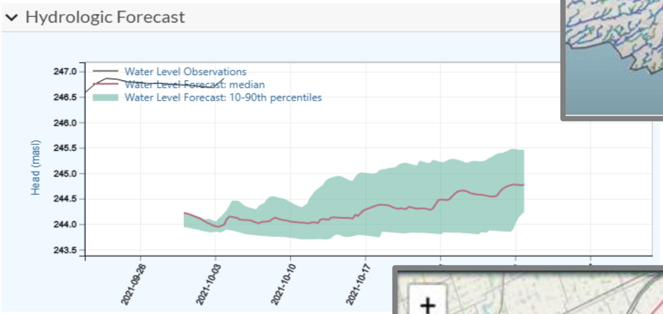
Long Point Region CA
- sand dominated;
- intensive water taking

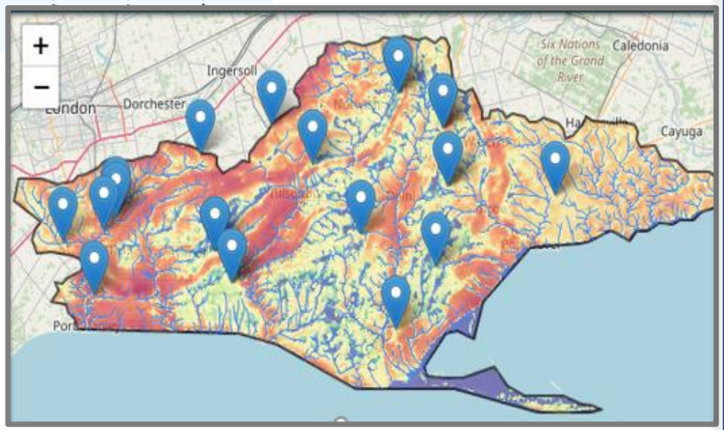


Forecasts:

- Depth to groundwater
- Groundwater recharge
- Groundwater discharge
- Stream levels
- Soil moisture







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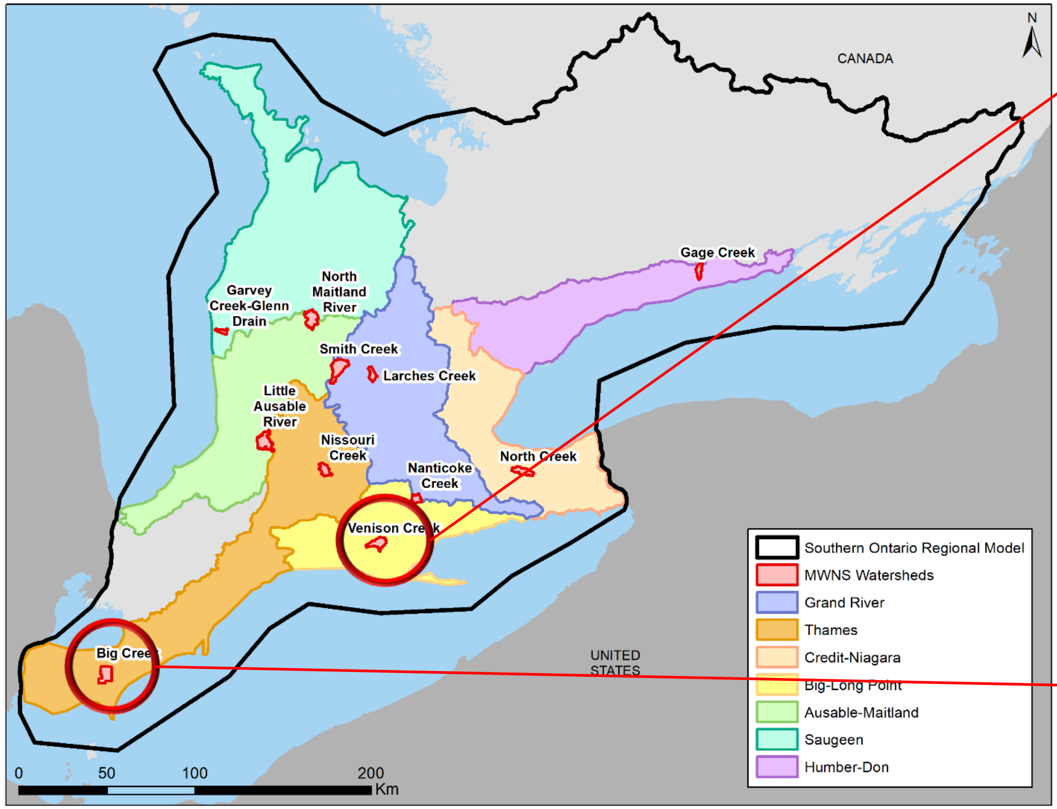
2. Modeling the Dynamics of Groundwater Discharge to Surface Water Receptors in Southern Ontario

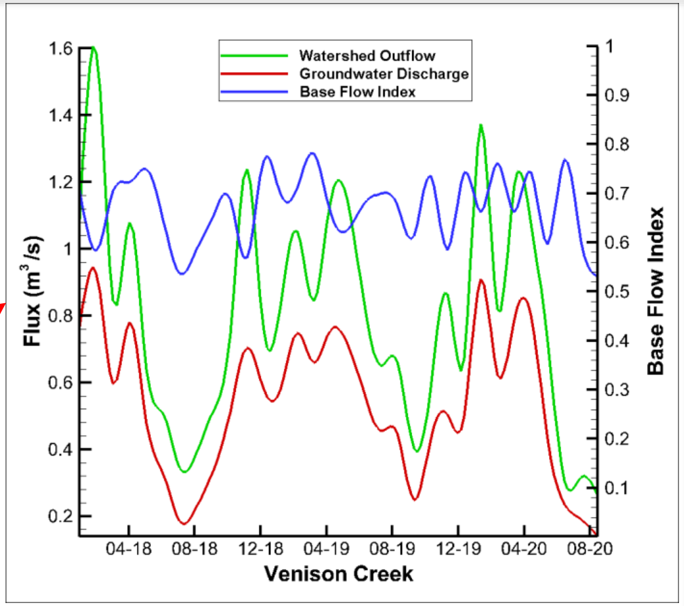
Frey et al. 2023, **Modelling Groundwater Discharge to Surface Water Receptors across Southern Ontario ,** COA Project Report

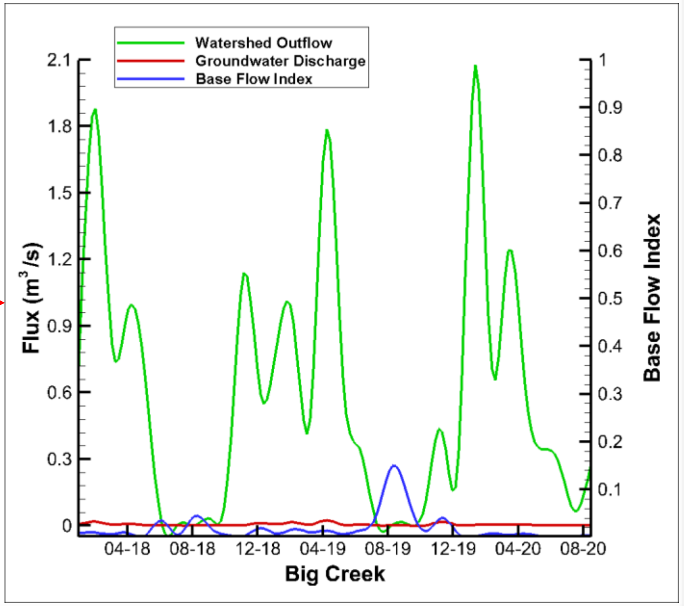
Method:

- Established fully-integrated groundwater – surface water models at catchment, watershed and regional scales across southern Ontario.
- Leveraged data from Multi Watershed Nutrient Study program.
- Simulated groundwater discharge dynamics over 3-year period (2018-2020).
- Evaluated model scaling effects.

Findings:





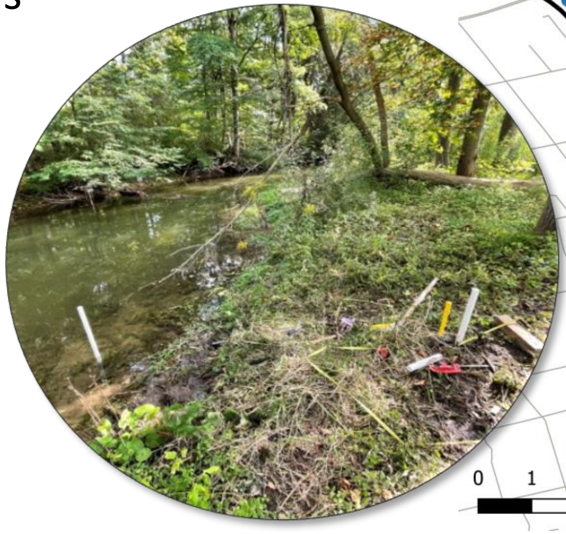


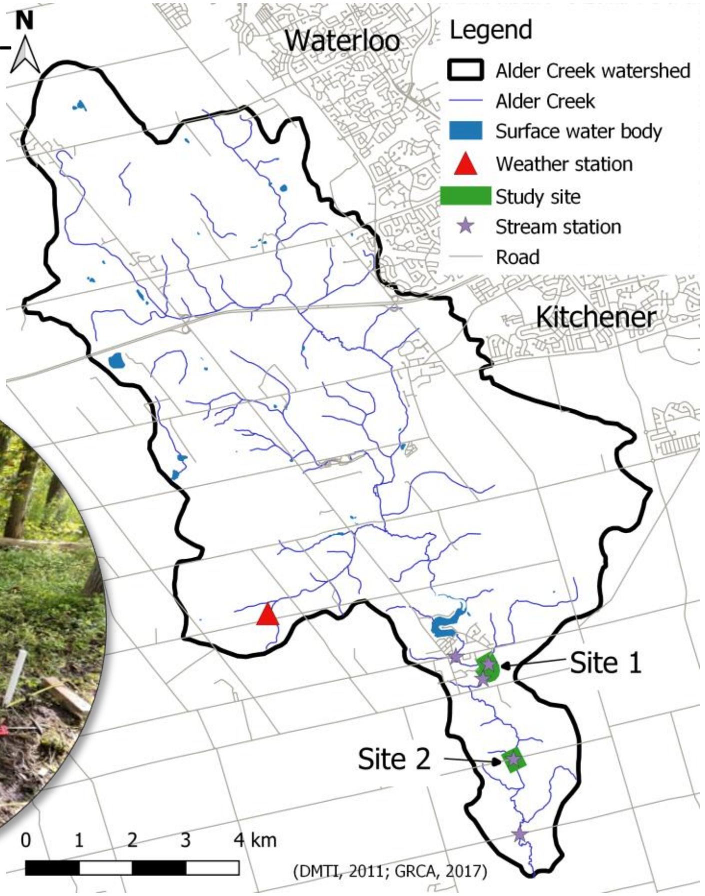
3. Optimizing Field Monitoring and Analytical Methods on Groundwater-Surface Water Interaction

David Rudolph (University of Waterloo) 2023

Goal:

Improving the understanding groundwater-surface water interaction and optimizing field monitoring methods and data analysis strategies to identify key data gaps and needs





Progress Highlights:

- Temperature reconnaissance along Alder Creek with streambed sensor and IR camera (June-Aug 2023) to identify groundwater discharge sites for monitoring
- Installation of monitoring stations
  - Groundwater – 4 stations at each of 2 sites, including Wells, mini-piezometers, streambed temperature sensors, groundwater and surface water level sensors
  - Surface water – 5 stations, including Water level sensors, manual stream gauging, construction of rating curves initiated
  - Climate – 1 meteorological station to measure suite of weather parameters
- Testing of streambed point velocity probe (SBPVP) by University of Kansas collaborators (Oct 2023)

Theme 2:

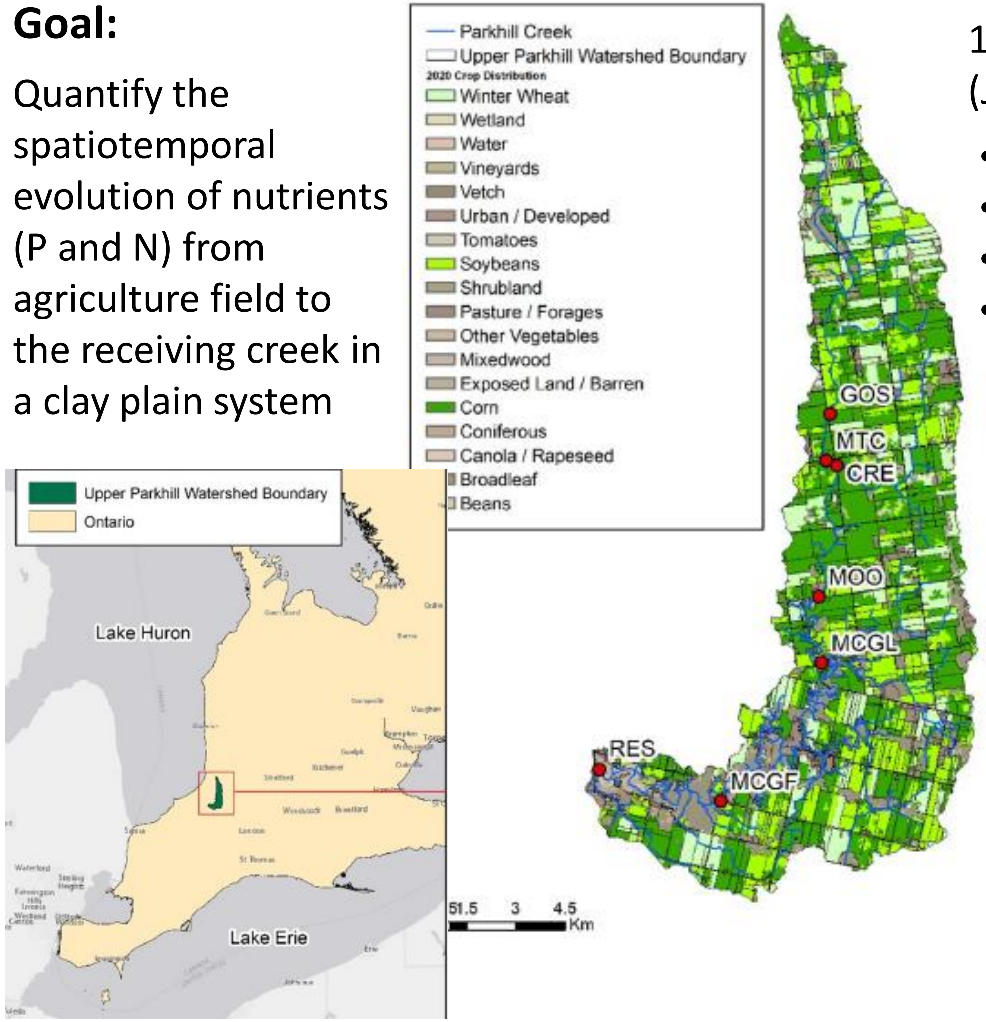
- Nutrient and contaminant migration from groundwater to surface waters
- Identify priority areas for monitoring and action

5. Nutrient Dynamics in the Transition Zone between Ground and Surface Water at Parkhill Creek Sub-watershed

May H. et al 2023. **Investigating relationships between climate controls and nutrient flux in surface waters, sediments, and subsurface pathways in an agricultural clay catchment of the Great Lakes Basin,** Science of the Total Environment 864 (2023) 160979

Goal:

Quantify the spatiotemporal evolution of nutrients (P and N) from agriculture field to the receiving creek in a clay plain system



14-month field monitoring (July 2020-Sept 2021)

- Stream water
- Groundwater
- tile drainage
- sediment

Findings:

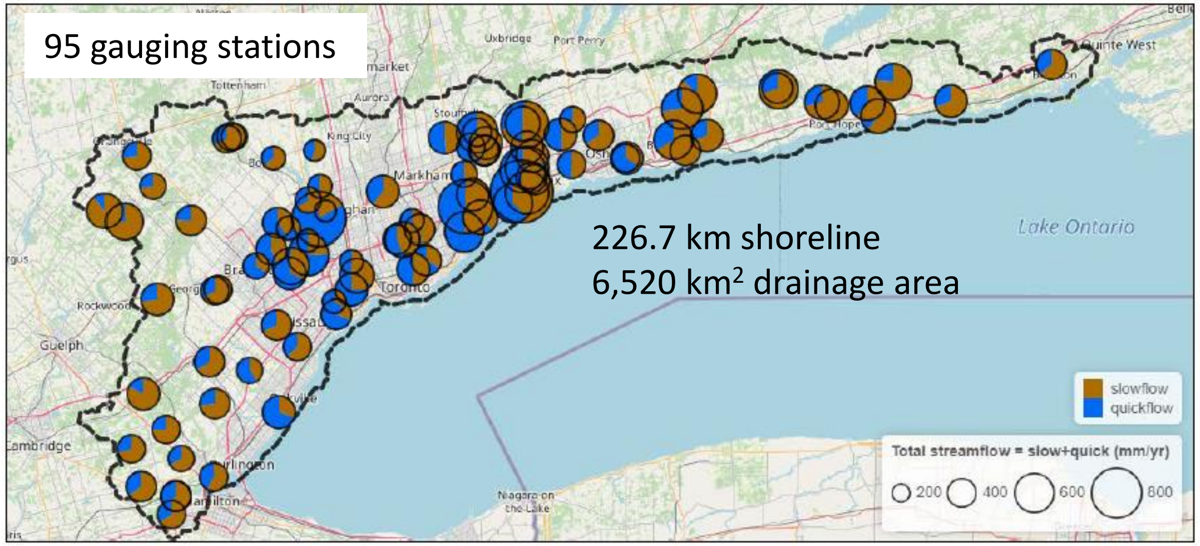
- Nutrient transport is governed by both hydroclimate events and agricultural management practices in flashy clay catchments.
- Nutrients were mobilized with subtle weather events such as freeze-thaw cycles and moderate precipitation.
- Tile drain discharge provides an elevated source of P and N to surface waters mobilizing fresh and legacy nutrient stores.
- P in stream sediments was primarily stored in calcium minerals with little bioavailable fractions.
- Groundwater does not contribute substantial nutrients to surface waters due to low permeability and losing stream condition.

6. Direct Groundwater Discharge and Salt Loading to the North Shore of Lake Ontario

Marchildon et al. 2022, **Estimation of Direct Groundwater Discharge and Salt (NaCl) Loading to the north shore of Lake Ontario,** COA Project Report

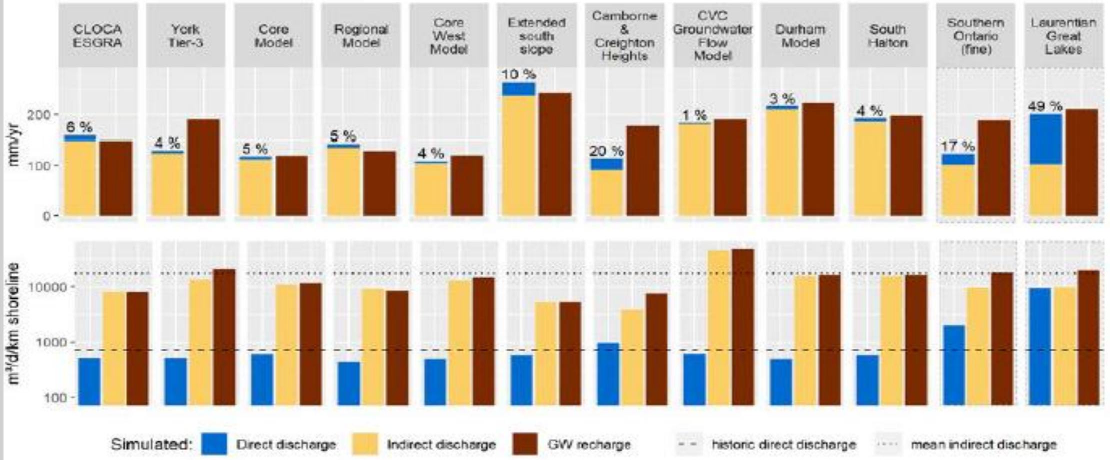
Method:

Desktop study – existing data and numerical models leveraged



Mean indirect groundwater discharge = 218 mm/yr. Median Baseflow Index is 60% - groundwater contribution to the lake greater than overland runoff

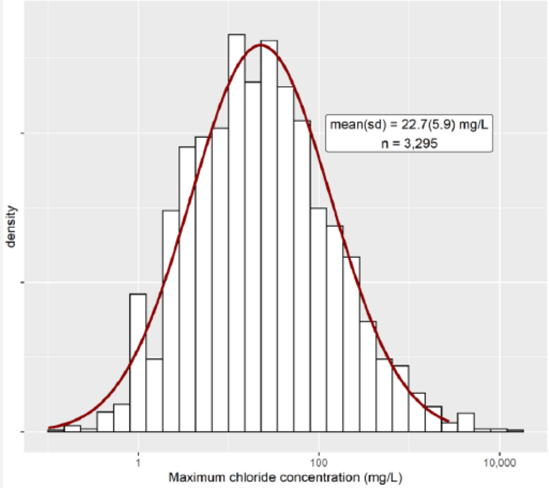
12 numerical models



Mean indirect groundwater discharge = 145 mm/yr
Mean direct groundwater discharge = 18 mm/yr

2,000 sampling locations

Cl$^-$ loading = drainage area x *groundwater discharge* x *Cl$^-$ concentration*



Findings:

12 to 64 kt/year Cl$^-$ (groundwater discharge)
174 kt/year Cl$^-$ (road salt application)

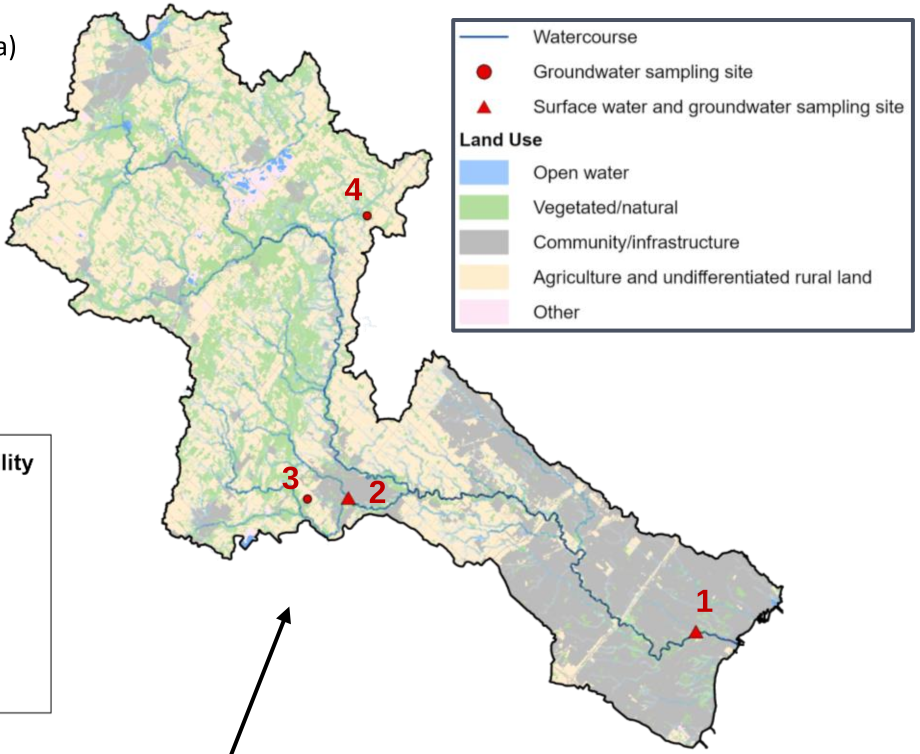
Chloride concentration has not reached a steady state, will continue to increase

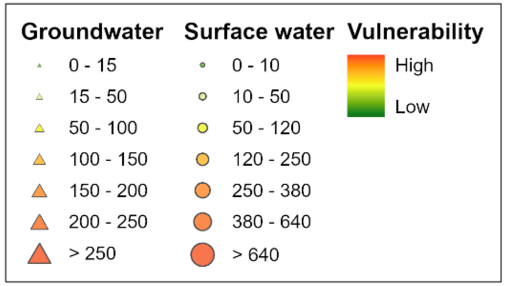
Ontario

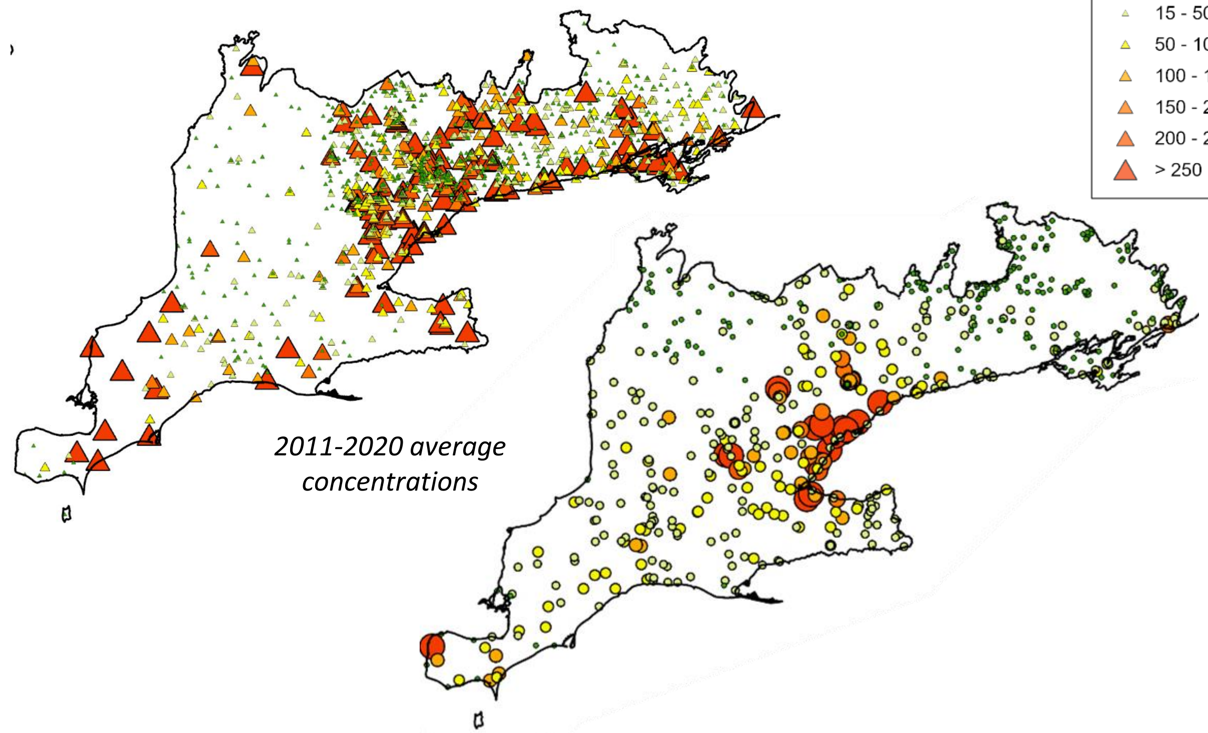
7. Groundwater as a Source and Pathway for Road Salt Contamination in Surface Waters (Method)

Mackie et al. (2022) **Groundwater as a source and pathway for road salt contamination of surface water in the Lake Ontario Basin: A review**. Journal of Great Lakes Research, 48(1), 24–36. https://doi.org/10.1016/j.jglr.2021.11.015
Mackie et al. (2023**) Geospatial Analysis of Chloride Hot Spots and Groundwater Vulnerable Areas in Southern Ontario, Canada**. Journal of Hydrology. In review.

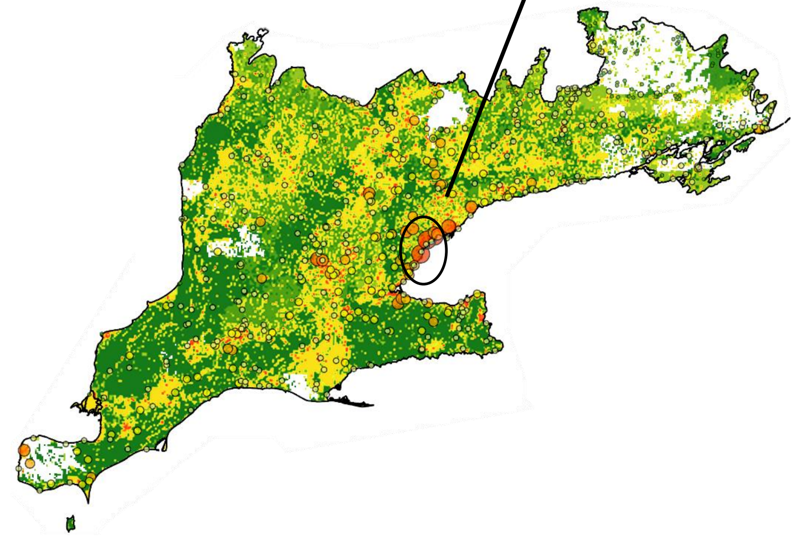
Locations for field monitoring program
(ions, isotopes, continuous data)







2011-2020 average concentrations



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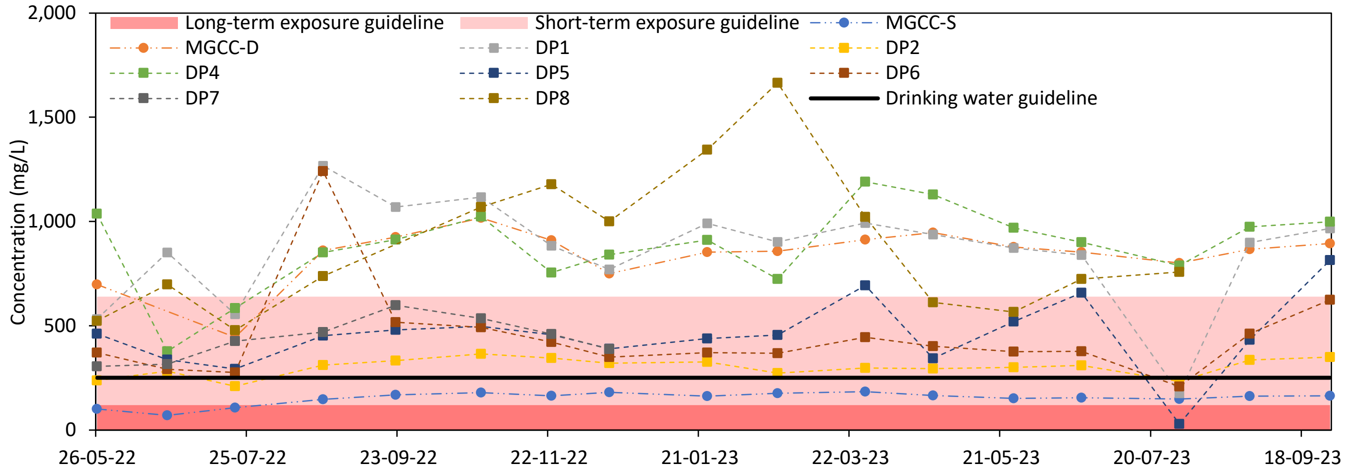
7. Groundwater as a Source and Pathway for Road Salt Contamination in Surface Waters (Findings)

Lackey, R. (2023) **Geochemical Determination of Anthropogenic Sources of Elevated Chloride in Groundwater and Surface Water Across Various Land Uses of an Urbanizing Watershed.** MASc Thesis, University of Guelph

Method	MGCC (1)	Cedarvale (2)	Georgetown (3)	Warwick (4)
Tritium-Helium	GW recharge has a **mix of old and young waters**	N/A	GW recharge has a **mix of old and young waters**	N/A
Deuterium isotopes	**Road salt** is a source of elevated chloride in snowmelt effected waters		N/A	N/A
Chloride/ sodium ratio	**More than one source of Cl** or cation exchange	**NaCl road salt** is the main source of Cl	Possible influence from a NaCl source	Likely no NaCl source
Chloride/ bromide ratios	**Landfill leachate**: MGCC-S; DP-1, -2, -3, -4, -7 **Wastewater or mix of landfill leachate and road salt**: MGCC-D (**basin brine**), SW-2, DP-8, SW-3, and SW-4	All Br conc **below MDL** thus N/A	Possible **wastewater**	All Br conc **below MDL** thus N/A
Iodine	MGCC-S possible **landfill leachate**	N/A	N/A	N/A
Artificial sweeteners	Pre 1990s **landfill leachate** or **wastewater** mixed with **road salt (SACC)**: MGCC-S, DP1, -4, -5, -6, -8 **Wastewater** or post 1990s **landfill leachate (ACE):** SW1-4, DP-8	Conc indicative of **background urban noise** (20-30 µg/L)	Conc **below MDL**: no wastewater or landfill leachate source	Conc **below MDL**: no wastewater or landfill leachate source

1



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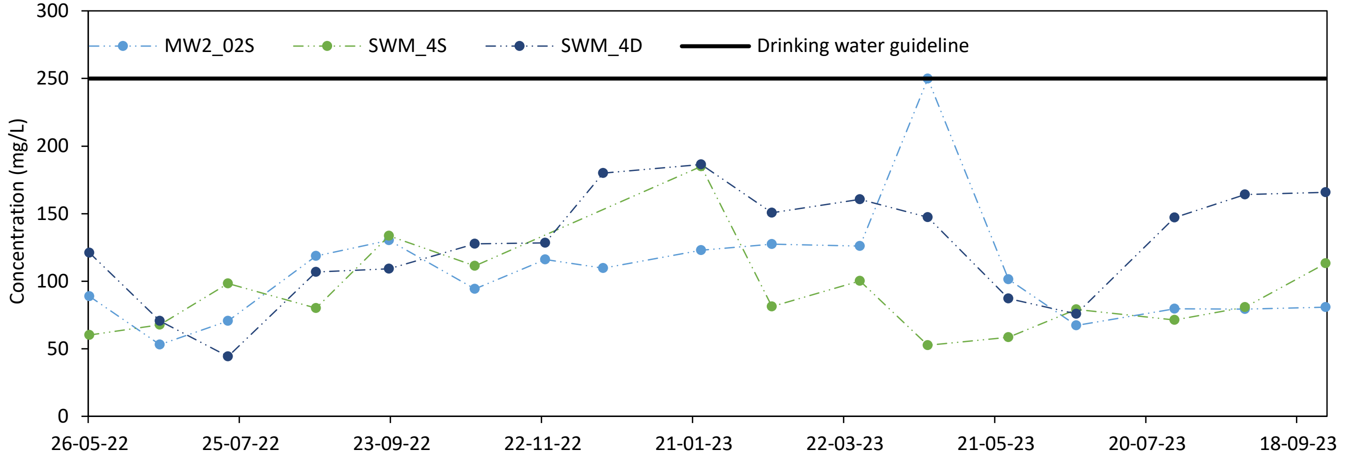

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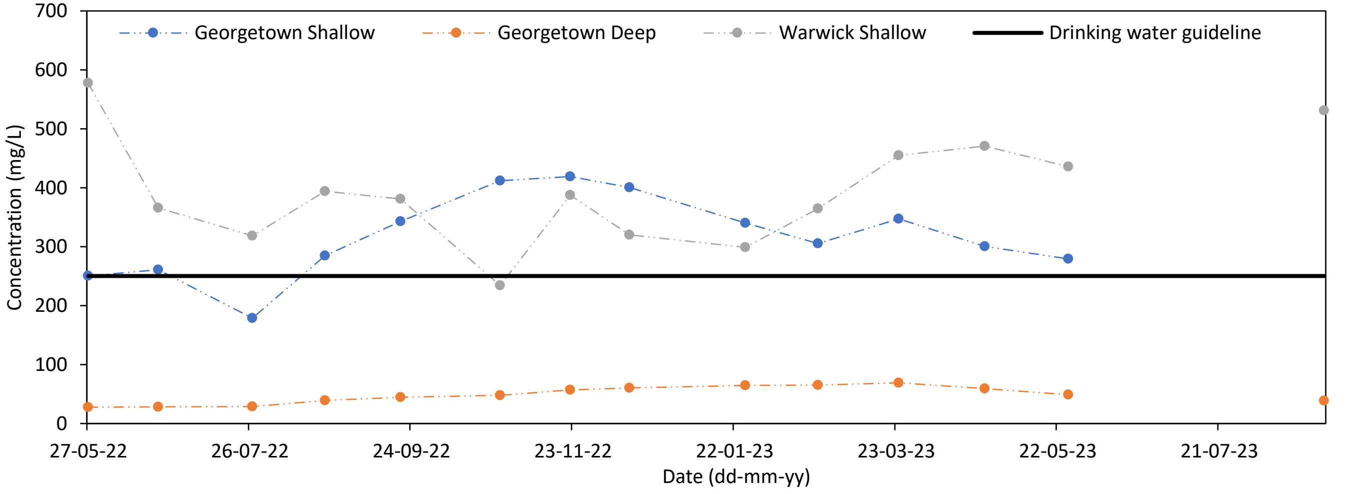
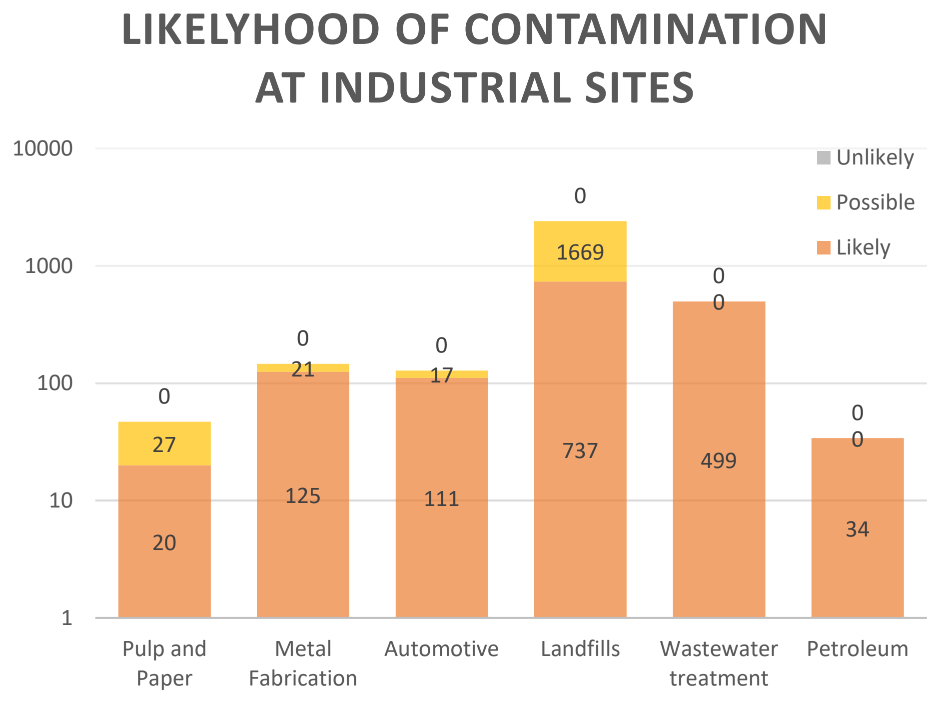


8. Estimating the Number of Industrial Facilities as Per- and Polyfluoroalkyl Substances (PFAS) Point Sources in Ontario

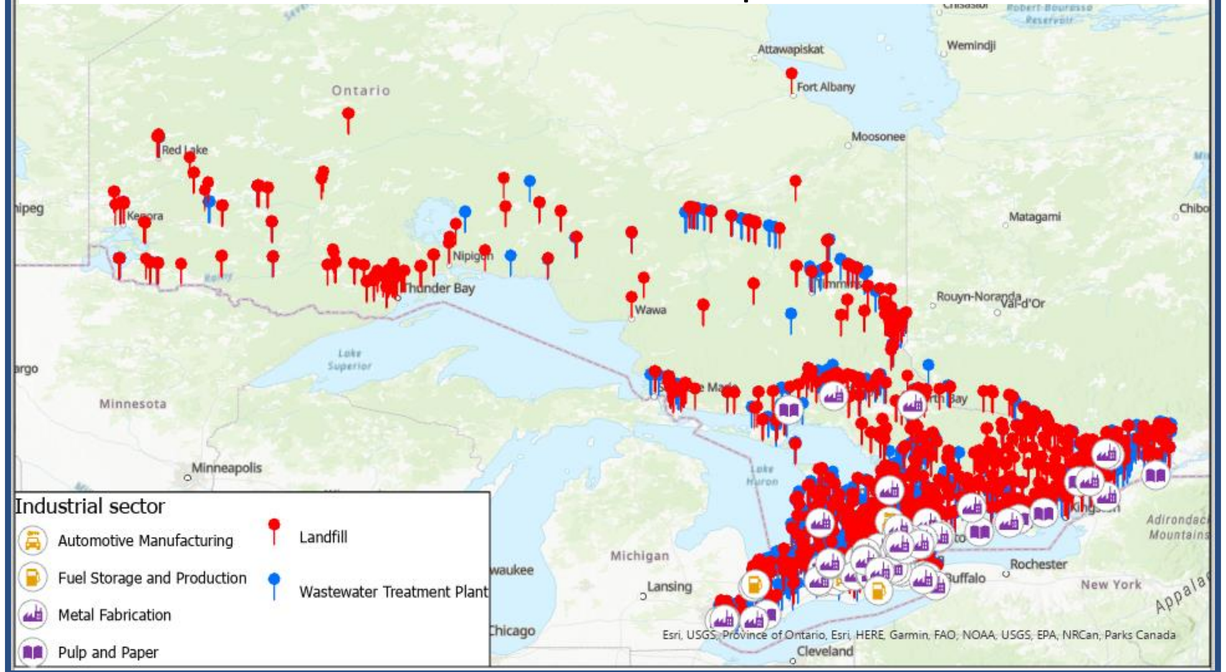
Weber, K.P., Roberts, D., Koch, I. **Identifying Ontario groundwater PFAS sources as a threat to Laurentian Great Lakes,** IAGLR Presentation, May 2023

Objective: Identify and evaluate industrial sites from six industrial sectors on their likelihood of PFAS contamination sources

Method: Each site was evaluated using an industry specific decision-making framework and classified into one of three outcomes:
1) PFAS Contamination Likely
2) PFAS Contamination Possible
3) PFAS Contamination Not Likely



Sites of possible and likely PFAS contamination within 1 km of domestic or municipal wells



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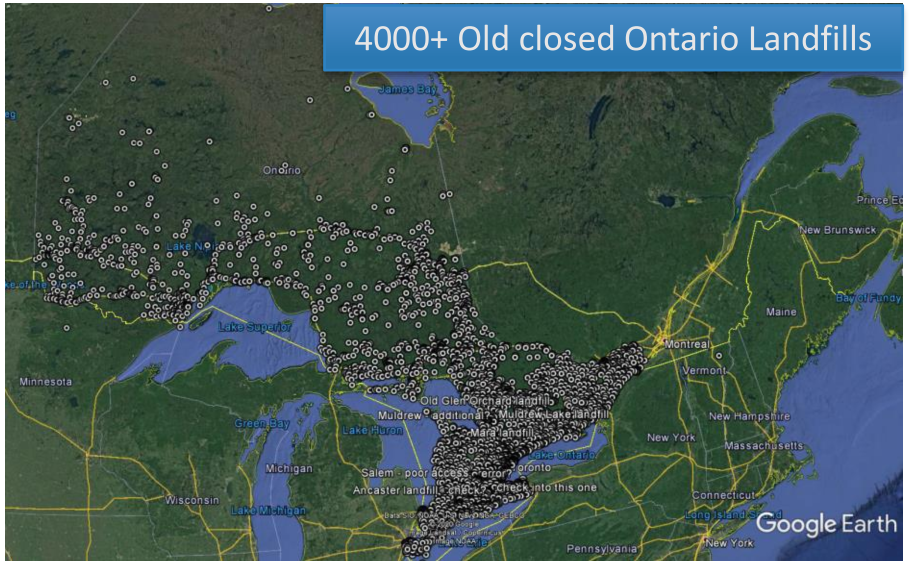
9. Evaluation of Landfills as a Source of Contaminants to Great Lakes Waters (Method)



Roy, et all. 2020. **Emerging contaminants in leachate of old closed landfills.** *Geoconvention 2020.*

20 Old closed municipal landfill sites located across Ontario assessed for CEC* prevalence in leachate-impacted groundwater.

*CECs investigated:
- PFAS
- organophosphate Esters (OPE)
- bisphenols A and S
- artificial sweeteners
- sulfamic acid
- cotinine

Samples from:
- Leachate containment system or culvert
- Existing wells in / beside landfill
- Seeps at surface by the landfill
- Shallow discharging groundwater from riverbed / lakeshore / pond

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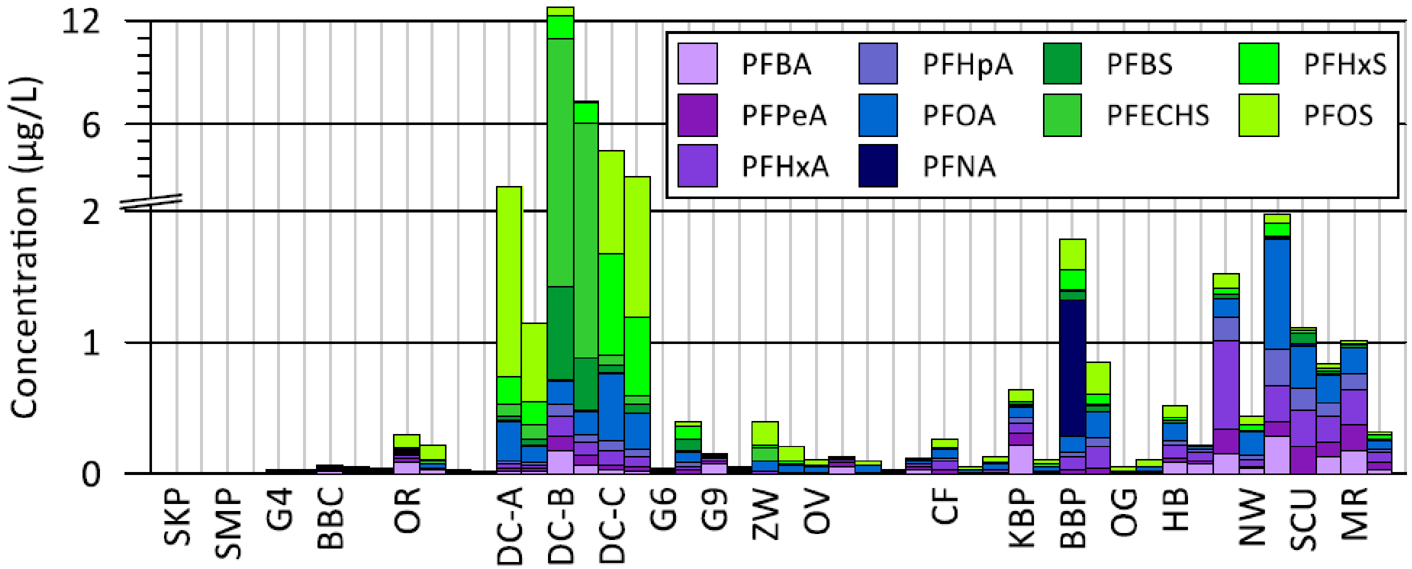
9. Evaluation of Landfills as a Source of Contaminants to Great Lakes Waters (Findings)

Roy, et all. 2020. **Emerging contaminants in leachate of old closed landfills.** *Geoconvention 2020.*



PFAS Results

Landfills ordered by age with older ones (closed 1920s-50s) on left, younger one (closed early 1990s) on right

Findings:

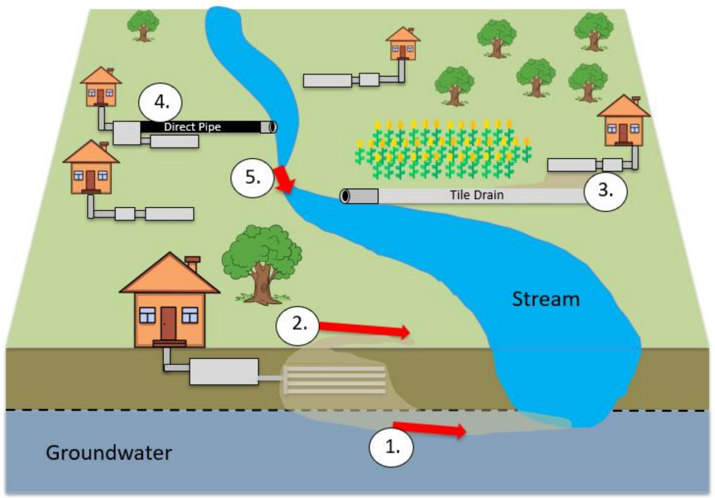
- Closed municipal landfills can be long-term sources of elevated concentrations of CECs.
- Potential threat for contamination of nearby wells and surface water bodies.
- OPE, bisphenols A and S, artificial sweeteners, sulfamic acid, and cotinine also detected in leachate-impacted groundwater.

Ontario

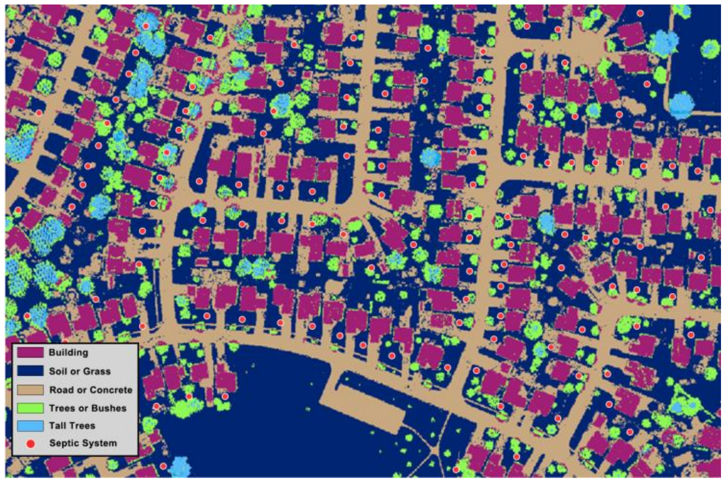
10. Contribution of Septic System to Contaminant Loadings in Lake Erie Tributaries (Methods)

C.J. Jobity, J.W. Roy, E.A. Angus, T.A. Edge, C.E. Robinson,
Determining Pathways Via Which Septic System Wastewater Effluent Reaches Tributaries, IAGLR Presentation 2023

Pathways – wastewater from septic system to streams



1. Groundwater transport
2. Overland transport
3. Interception of septic plume by tile drains/utility trenches etc.
4. Direct pipe "misconnection"
5. Temporary storage in disconnected compartments of watershed (e.g. disconnected stream reaches)



Remote sensing and machine learning used to spatially locate septic systems (a total of 141,000) across Ontario Lake Erie Basin.

Stream water analyzed for multiple tracers (chemical and microbial):

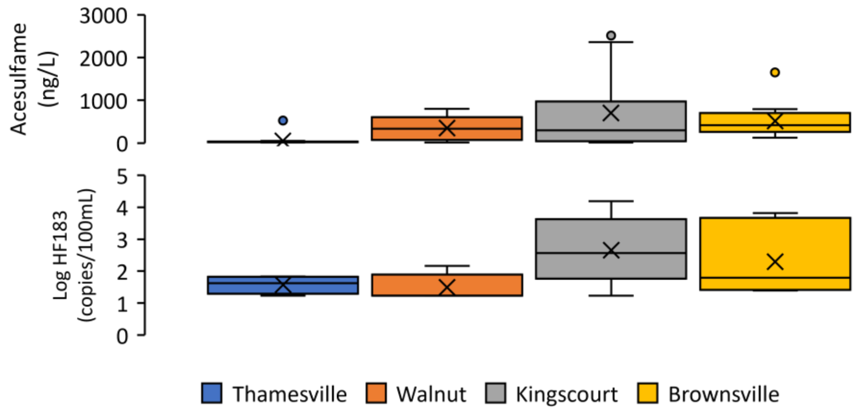
Constituents	Human Wastewater Tracer	Alternative Sources	Conservative	Subsurface Transport	Overland/ Direct pipes
Acesulfame	✓		✓	✓	✓
Saccharin	✓	✓		✓	✓
Cyclamate	✓			✓	✓
Sucralose	✓		✓	✓	✓
HF183	✓				✓
Mitochondrial marker	✓				✓
E. coli	✓	✓			✓

Ontario

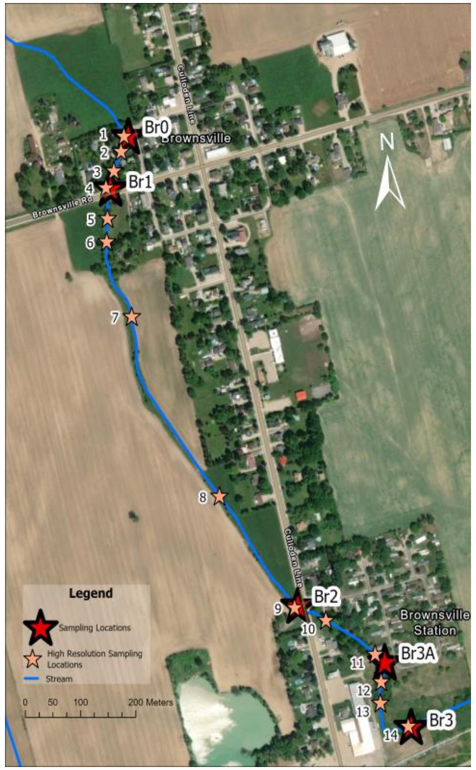
10. Contribution of Septic System to Contaminant Loadings in Lake Erie Tributaries (Findings)

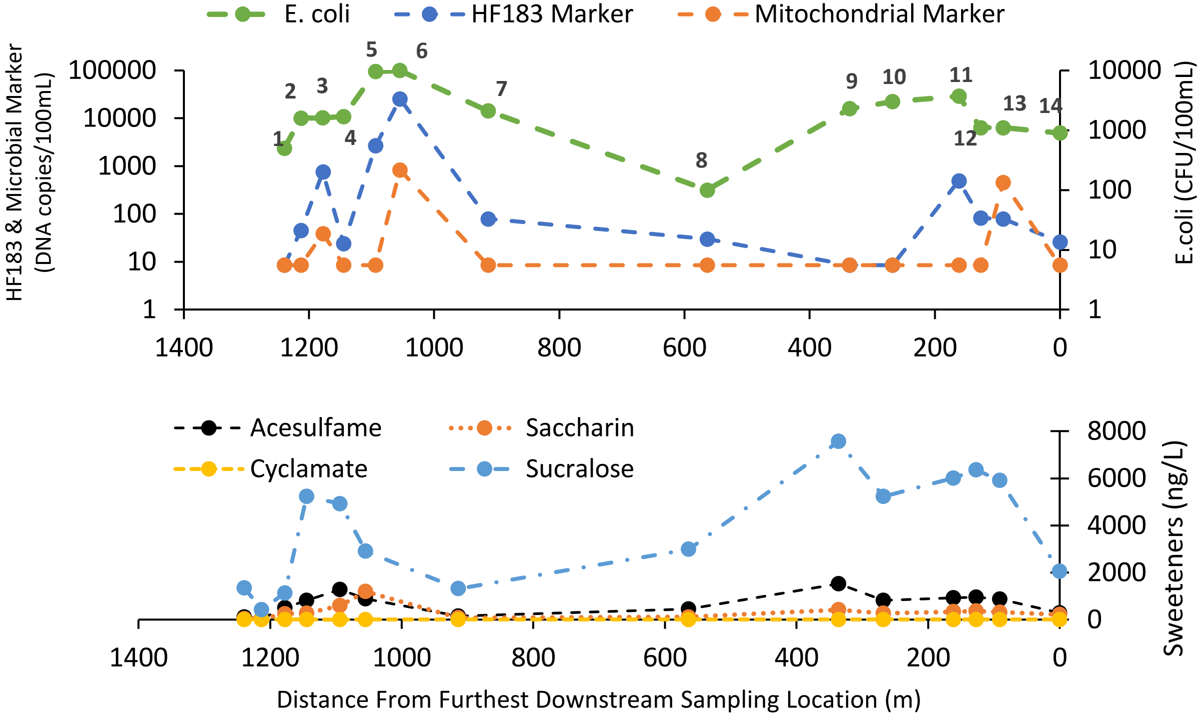
C.J. Jobity, J.W. Roy, E.A. Angus, T.A. Edge, C.E. Robinson, **Determining Pathways Via Which Septic System Wastewater Effluent Reaches Tributaries,** IAGLR Presentation 2023

Septic system wastewater tracer (acesulfame and human HF183 bacterial marker) concentrations at subwatershed outlets used to determine amount of septic wastewater reaching streams



High resolution longitudinal surveys during baseflow conditions used to identify pathways via which septic system wastewater entering stream (Brownsville, ON)





Findings:

- Use of multiple human wastewater tracers provides insight into pathways via which septic wastewater enters streams.
- Evidence of septic wastewater effluent reaching streams via rapid pathways (tile drains, overland flow) in addition to groundwater pathway.
- Rapid pathways mostly identified in small subwatersheds /streams with low permeability.

Questions?

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