Aquifer Thermal Energy Storage in Ontario: Climate-Resilient Energy Solutions for Decarbonization Pathways

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Toronto and Region Conservation Authority

Overview

- Low Temperature Geothermal Energy Principles
- Terminology and Technologies
- Statistics
- Barriers to implementation
- York University Study
- Scale-up potential for the Greater Toronto Area
- Next Steps
- Questions

Geothermal Energy Principles

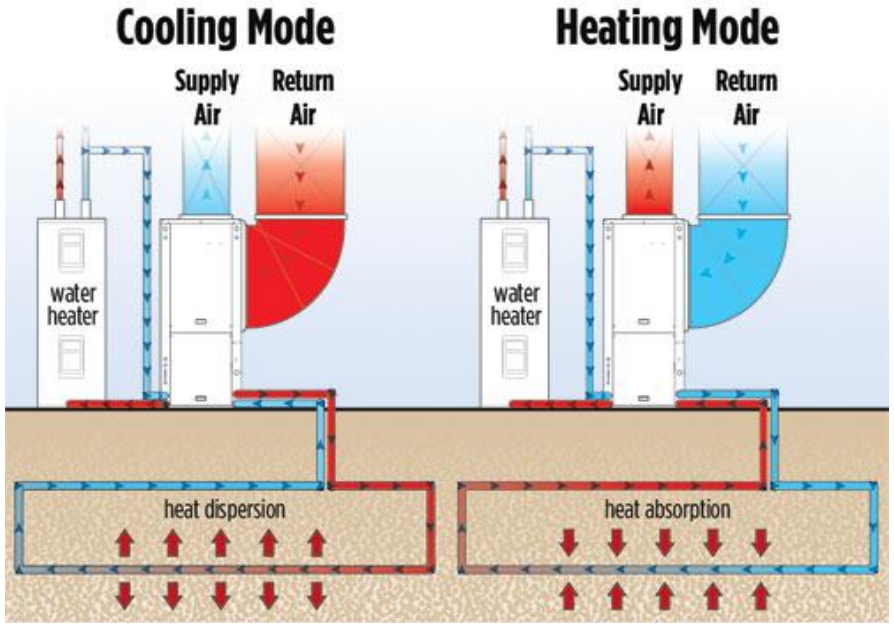
- Heat pumps are based on well-established principles
  - First heat pump built in 1856
  - Shell and tube technology developed in 1920s
- Use electrical energy to transfer energy between a “source” and a “sink”
- Most efficient when the temperature differences between source and sink are small
  - GTA ground temperatures are typically 8-12°C
  - Average monthly GTA air temperatures -3 to 21°C

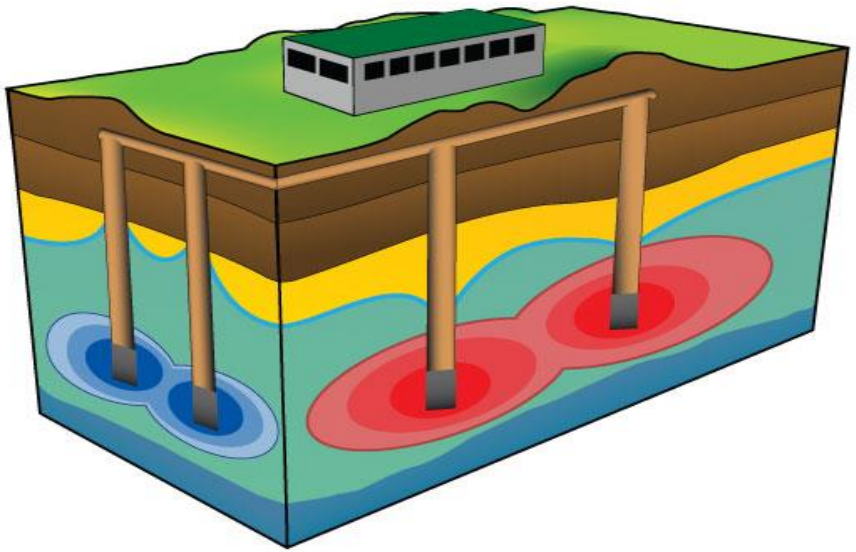
Terminology

- Seasonal Energy Efficiency Ratio (SEER)
  - Seasonal average steady-state cooling efficiency of a heat pump or air conditions
- Coefficient of Performance (COP)
  - Ratio of heat transferred to the energy input for a heat pump
- Closed Loop: Subsurface system that circulates a heat transfer liquid through vertical or horizontal piping
- Open Loop: Subsurface system that extracts water to/from an aquifer
- Thermal storage: Subsurface system that stores energy in soil, rock, or an aquifer

Technologies

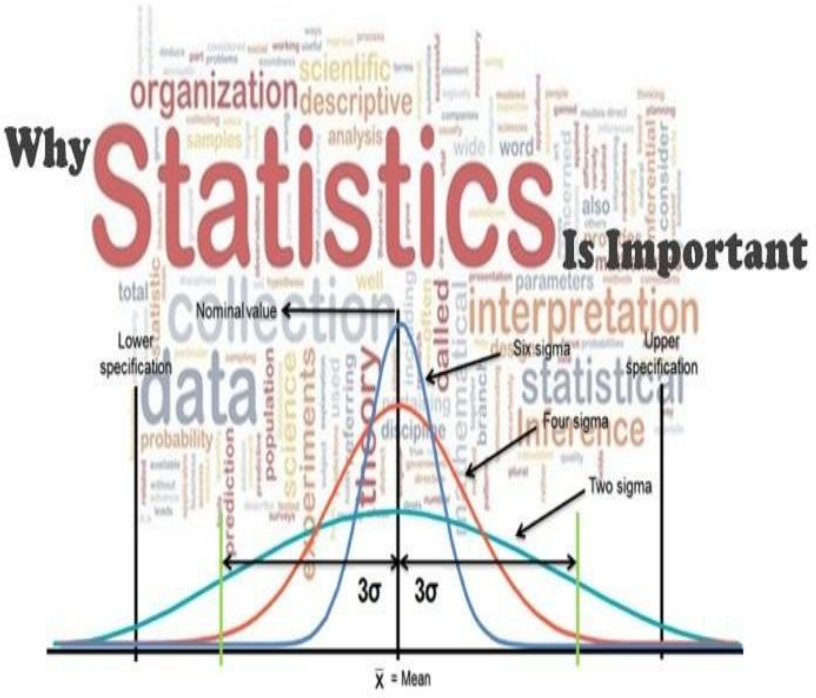
- Closed Loop Systems
  - Horizontal – in a trench
  - Vertical – multiple, deep boreholes
  - Single array or multiple arrays with thermal storage
- Open Loop Systems
  - Minimum of 2 wells
  - Thermal storage requires a pump in each well, with valves to control flow direction





Some Statistics

- Conventional HVAC:
  - Heating: COP: <1
  - Cooling: SEER: 10-14
- Ground Source
  - Heating: COP: 3-4
  - Cooling: SEER: 14-20
- Open Loop/Thermal Storage
  - Heating: COP: 3-4
  - Cooling: SEER: 19-27
- COP at 8°C: 2-5
- COP at -8°C: 1-4



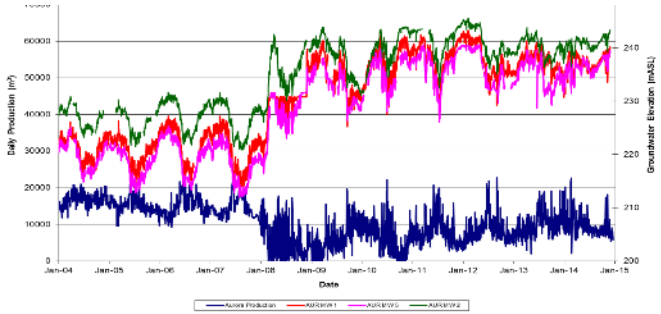
Barriers to Implementation

- Limited land area
- Capital costs
  - Deep boreholes and wells are capital-intensive
  - Thermal storage requires more pumps, valves, controls
  - Interference with existing buried services
- Hydrogeologic uncertainty
  - Groundwater chemistry
  - Example at TRCA's new Head Office:
    - Two wells make more than 500 L/min
    - One well makes less than 225 L/min
- Regulatory approvals
  - Environmental Compliance Approval (ECA)
  - Permit To Take Water (PTTW)

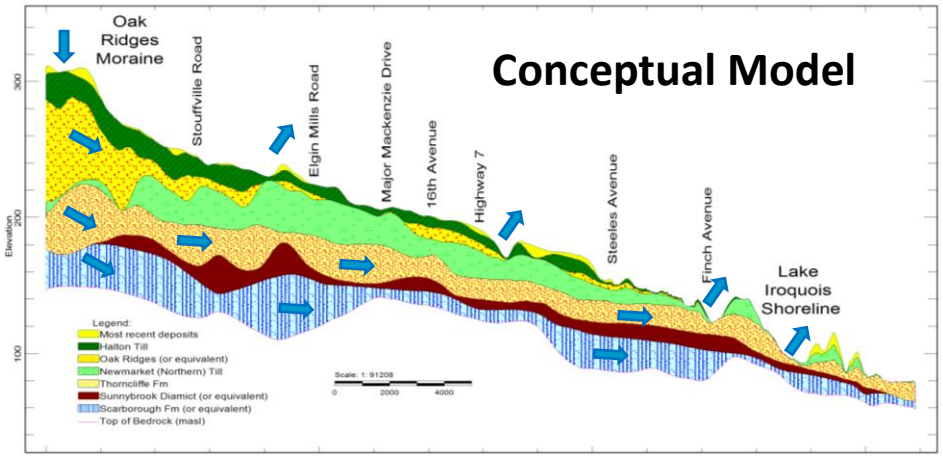
Solutions

- Regional hydrogeologic database(s)
  - Screening maps
    - Reduced uncertainty
- Geophysical screening
- Install systems as part of the development process
- Standardized materials and construction methods
- Contractor certifications

Water Level Data

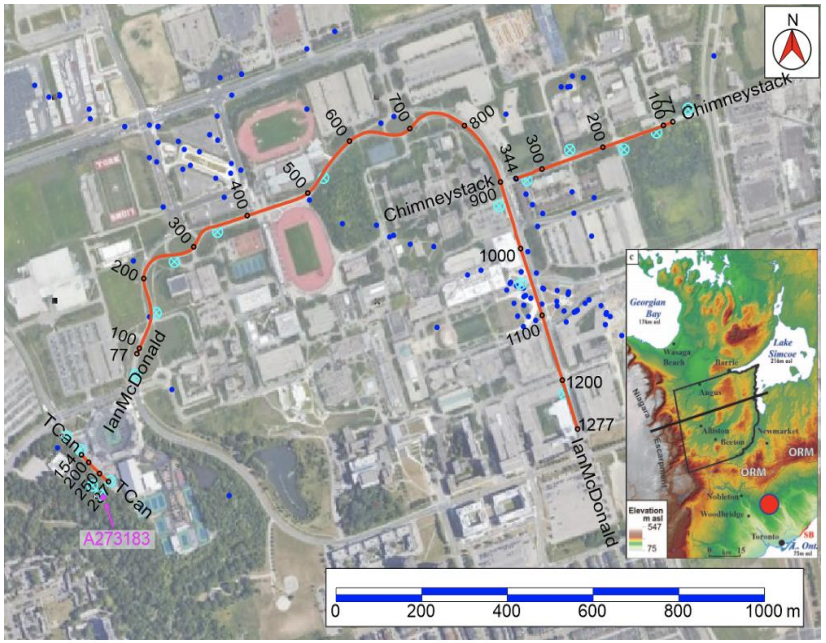


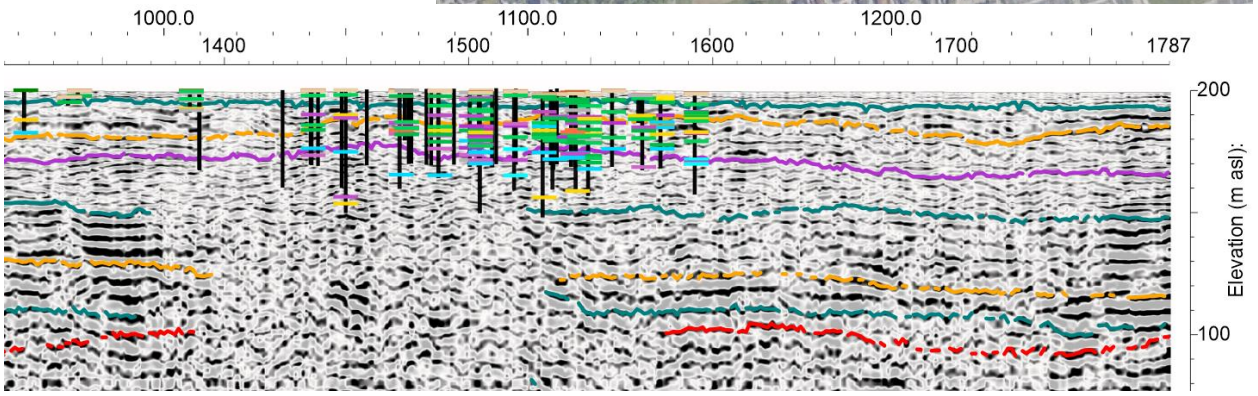
Geologic Data



York University Study – Surface Geophysics

- Possible buried bedrock valley(s)
  - Location?
  - Depth?
  - Geology?
- Non-intrusive



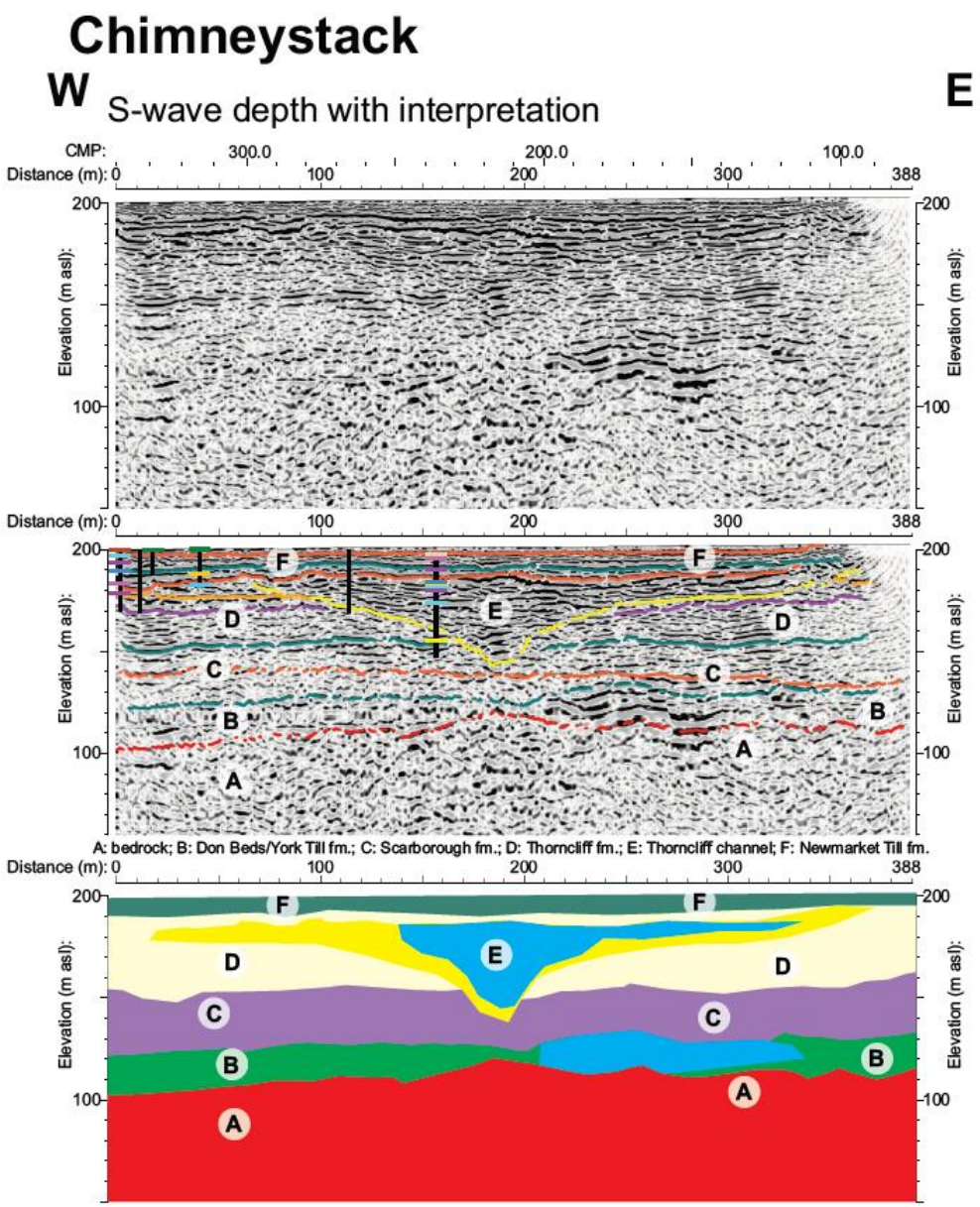


Interpretation of Surface Geophysics – York University

A: shale bedrock

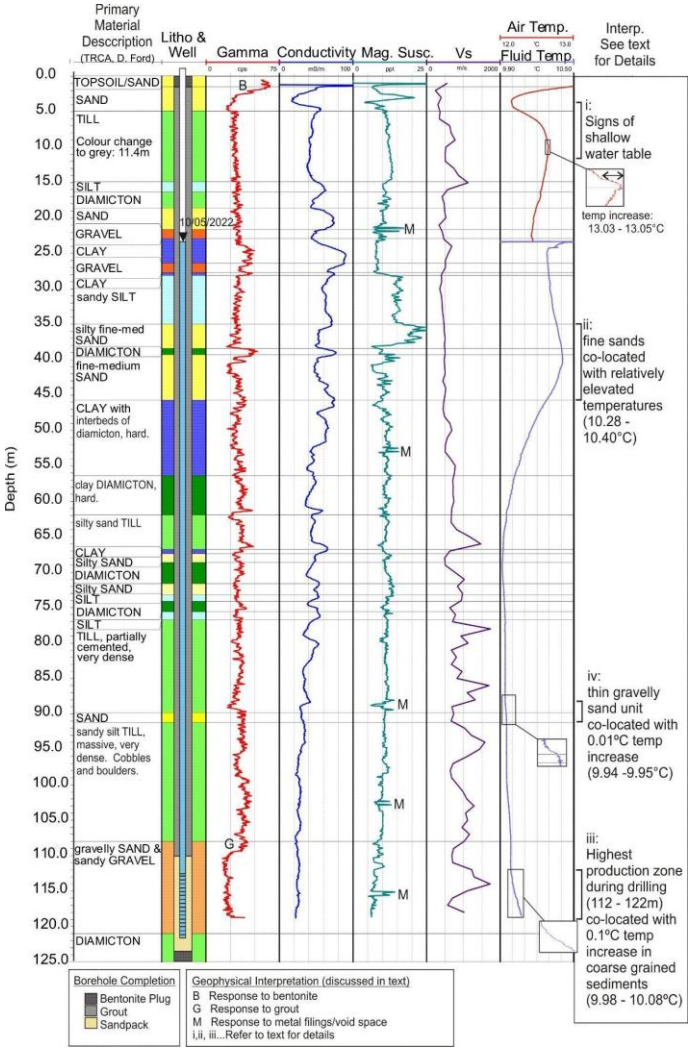
B, C, D, E, F Pleistocene semi-consolidated sediments.

Light blue surfaces: potential aquifer reservoirs that need to be confirmed by borehole data.



TRCA Head Office: Downhole Geophysics

- Bedrock valley interpreted to the west
  - Exact Location?
  - Depth?
  - Geology?
- Initial deep borehole drilled by geothermal consultant
- Test borehole with continuous core – better data
- Installed test well
  - geophysics

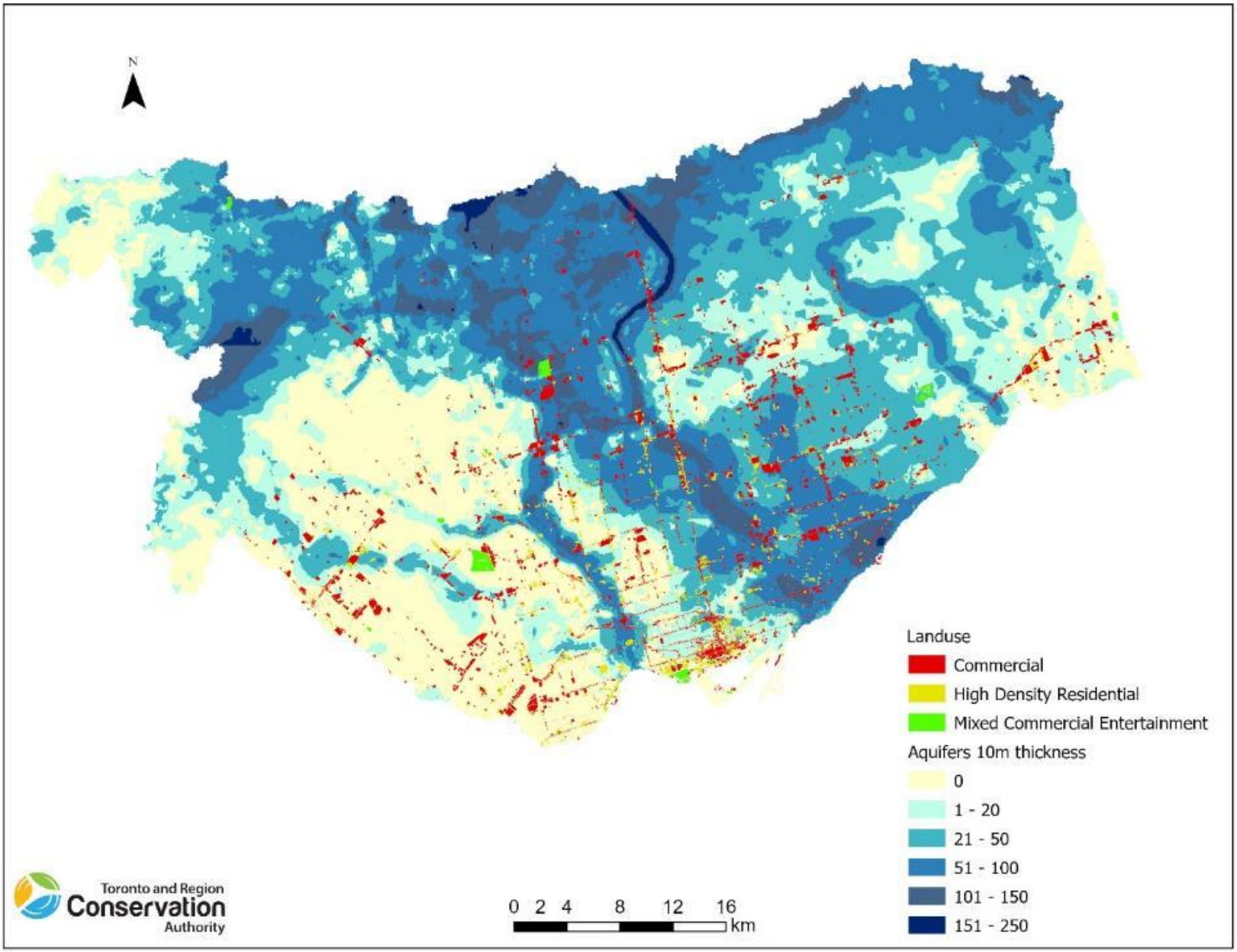


Lessons Learned

- Aquifer thermal storage requires a consistent, productive aquifer
- Borehole thermal energy storage is best in rock or saturated sediments (better thermal conductance)
- Bedrock valleys are still poorly understood in the GTA
  - Locations, depths, geology
- Uncertainty costs time and money
- In the face of uncertainty, property owners will revert to proven technologies

Our Response: Scale-up to the Greater Toronto Area

- Utilize existing hydrogeological data (subways, municipal sewer studies, deep foundation investigations) to improve understanding of GTA hydrogeology
- Overlay geology and areas of anticipated high-density development
- Identify potential opportunities for aquifer thermal energy storage
- Other areas better suited to borehole thermal energy storage or closed loop systems.


N
Landuse
Commercial
High Density Residential
Mixed Commercial Entertainment
Aquifers 10m thickness
0
1 - 20
21 - 50
51 - 100
101 - 150
151 - 250
Toronto and Region
Conservation
Authority
0 2 4 8 12 16
km

Estimated Benefits

- 35-45% reduction in GHG emissions possible
  - 2021 Canada space heating GHG emissions (NRCan):
    - 67.1 Mt CO_2 ⟹ Reduction of 23.5 - 30.2 Mt CO_2
- Zero emissions possible with decarbonized electrical grid
- Heat pumps save money over the long term (20 years)
  - Gas Furnace: ~$70,000
  - Air Source Heat Pump: ~$65,000
  - Ground Source Heat Pump: ~$45,000
- Further reductions possible if geothermal used to pre-heat hot water

Next Steps

- Improve geological and hydrogeological models
- More surface and downhole geophysics
- Monitoring of TRCA's new Head Office geothermal system
- Reviews of other larger-scale geothermal systems in the GTA

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Questions?

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