

Assessing the Impact of Groundwater on the Vulnerability of a Surface Water Drinking Source : Hydrological Characterization and Integrated Hydrological Modeling



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Drinking Water – Canadian Context

Source

- 70% Surface (urban centres)
- 30% Groundwater (rural areas)

Regulation (Quality, Quantity)

- Provinces (10) and Territories (3)

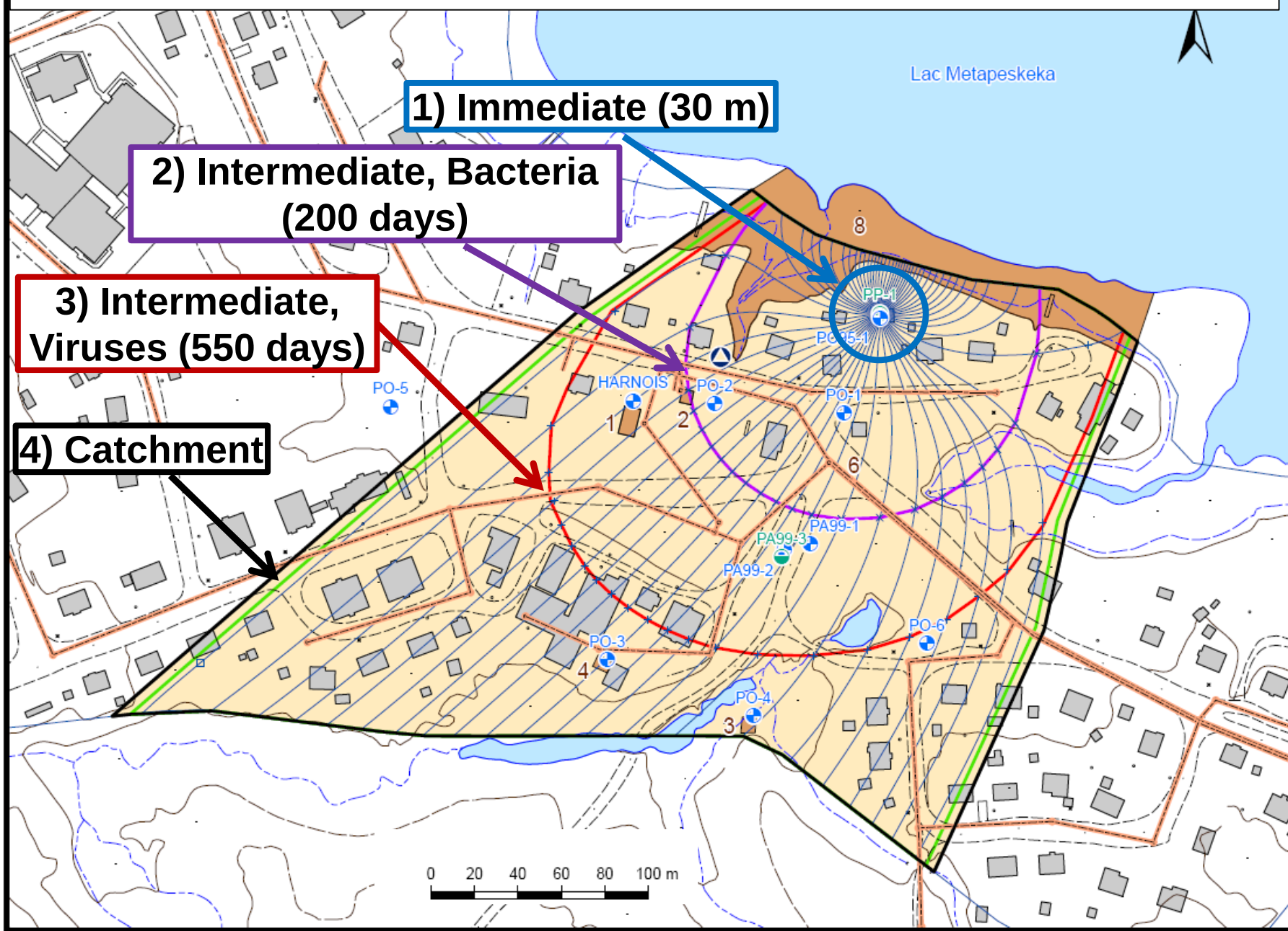
Distribution + Protection

- Public Utilities (municipalities, cities)



Source : Environment Canada

Groundwater Protection – Wellhead Protection Areas (Quebec)



Surface Water – Protection Areas (Quebec)

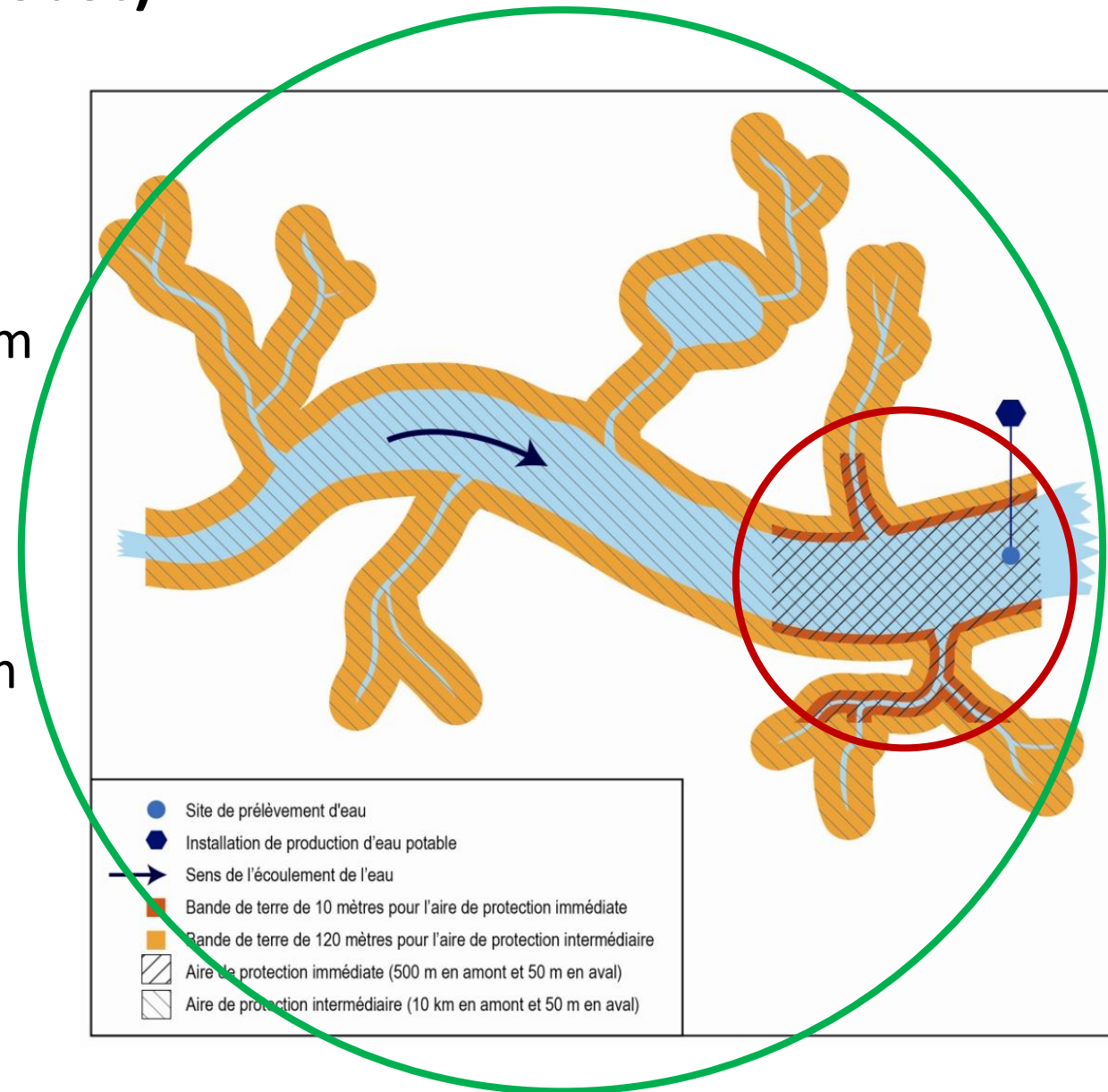
New Regulations

1) Immediate

- 500 m upstream < Intake < 50 m downstream
- 10 m corridor along both sides of stream

2) Intermediate

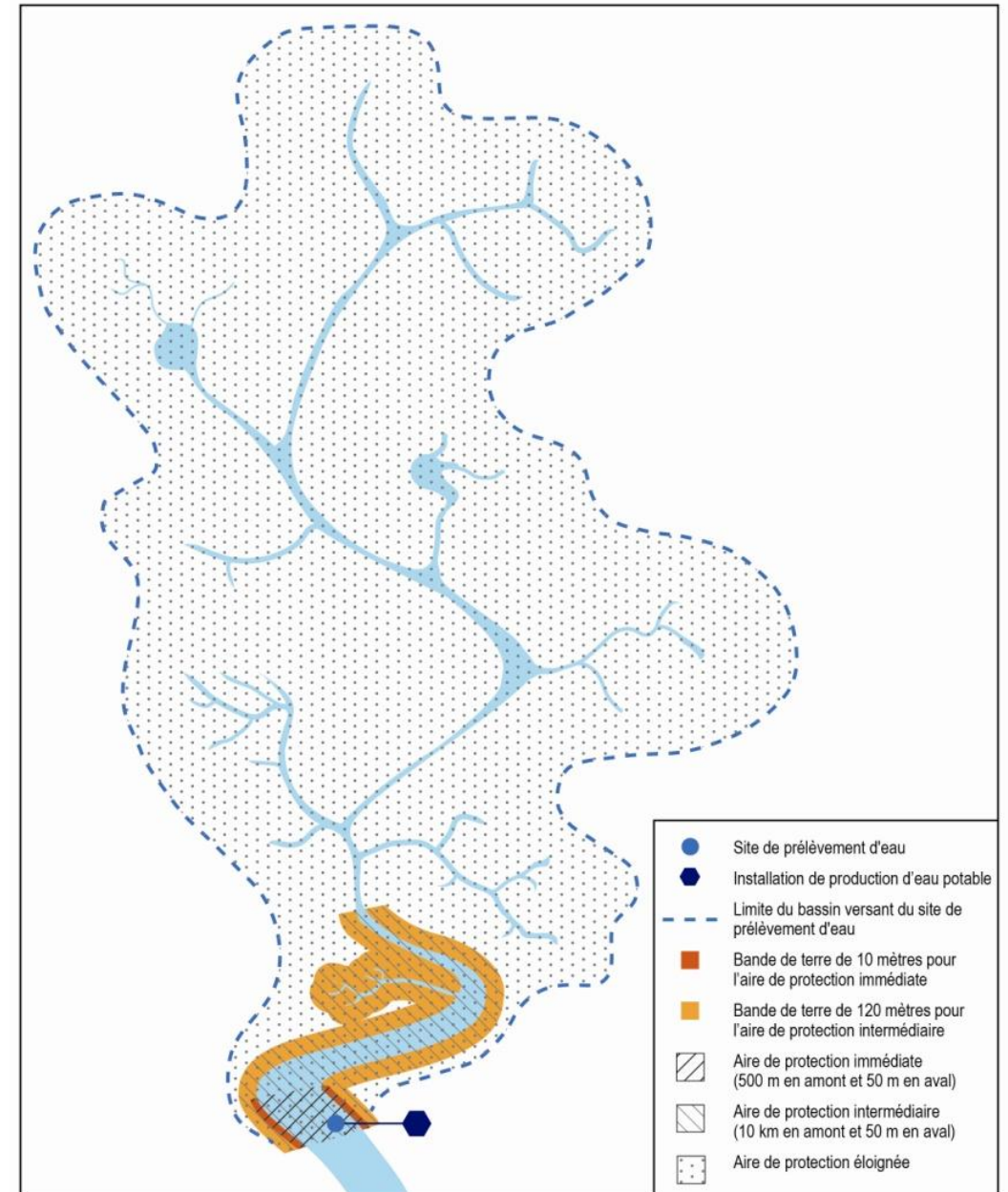
- 10 km upstream < Intake < 50 m downstream
- 120 m corridor along both sides of stream



Surface Water – Protection Areas (Quebec)

3) Entire Catchment

- General hydrological and hydrogeological description
- No detailed characterization required
- Survey of potential sources of contaminant
- Assessment of risk

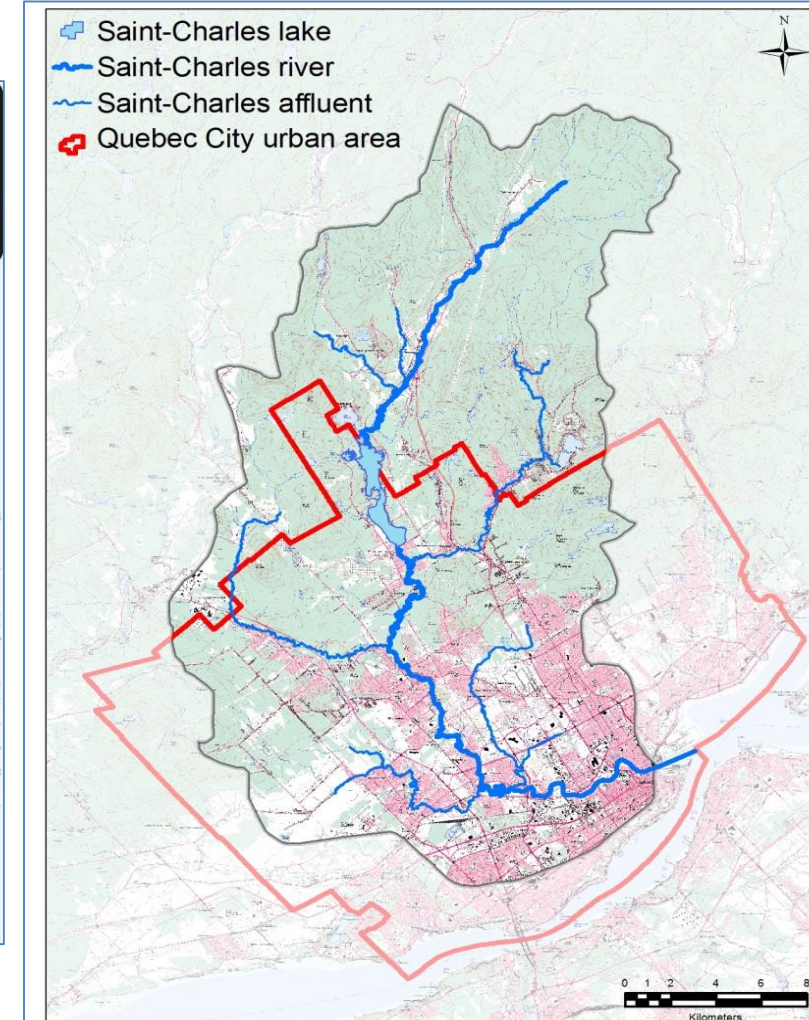


Source Water – Quebec City

- Population : 550 000
- Drinking Water Source : Almost entirely surface water
- Saint-Charles River
 - Drinking water for 300 000 people
- Long-term planning : going beyond the requirements

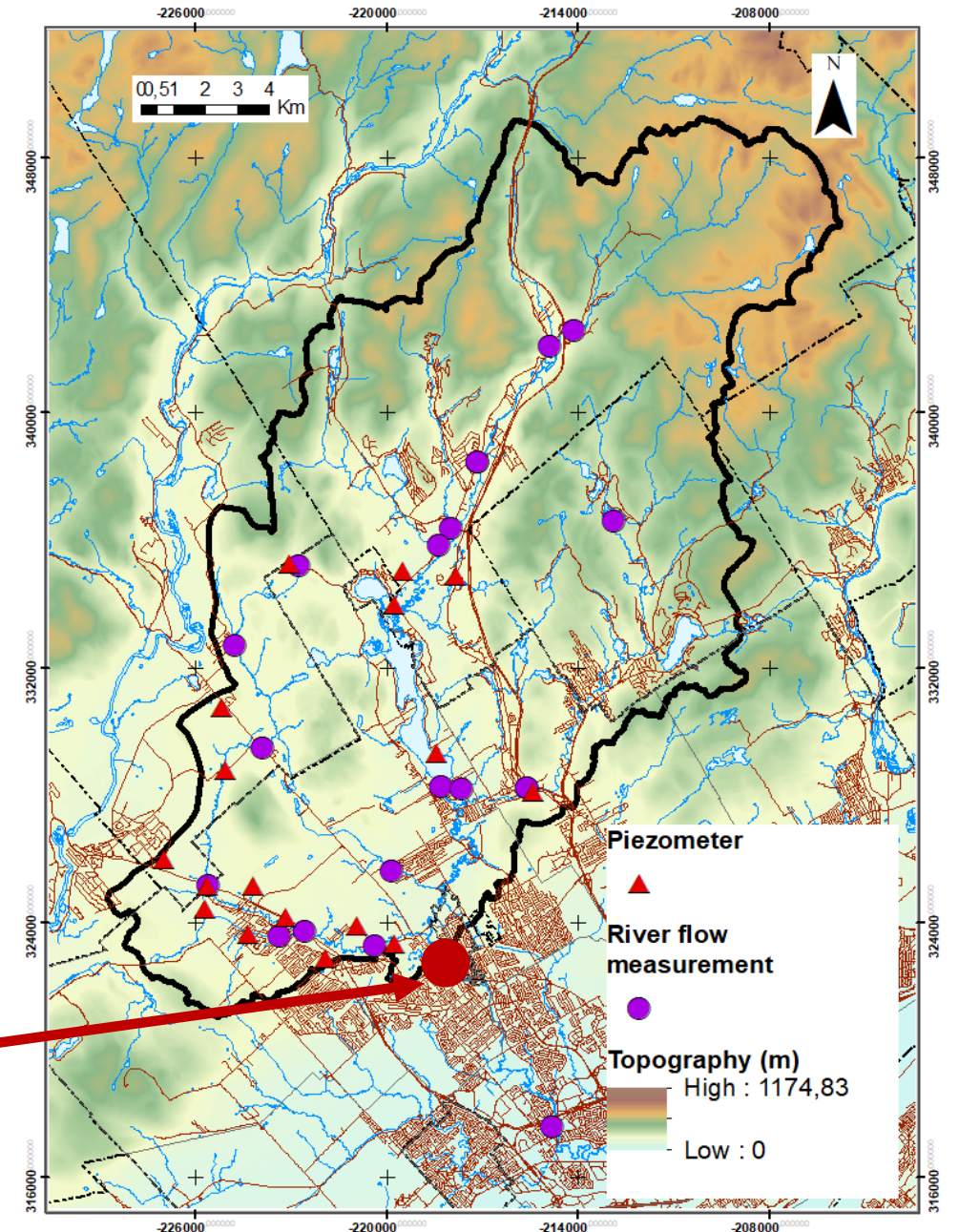


Quebec City Metro Area + Saint-Charles River Catchment



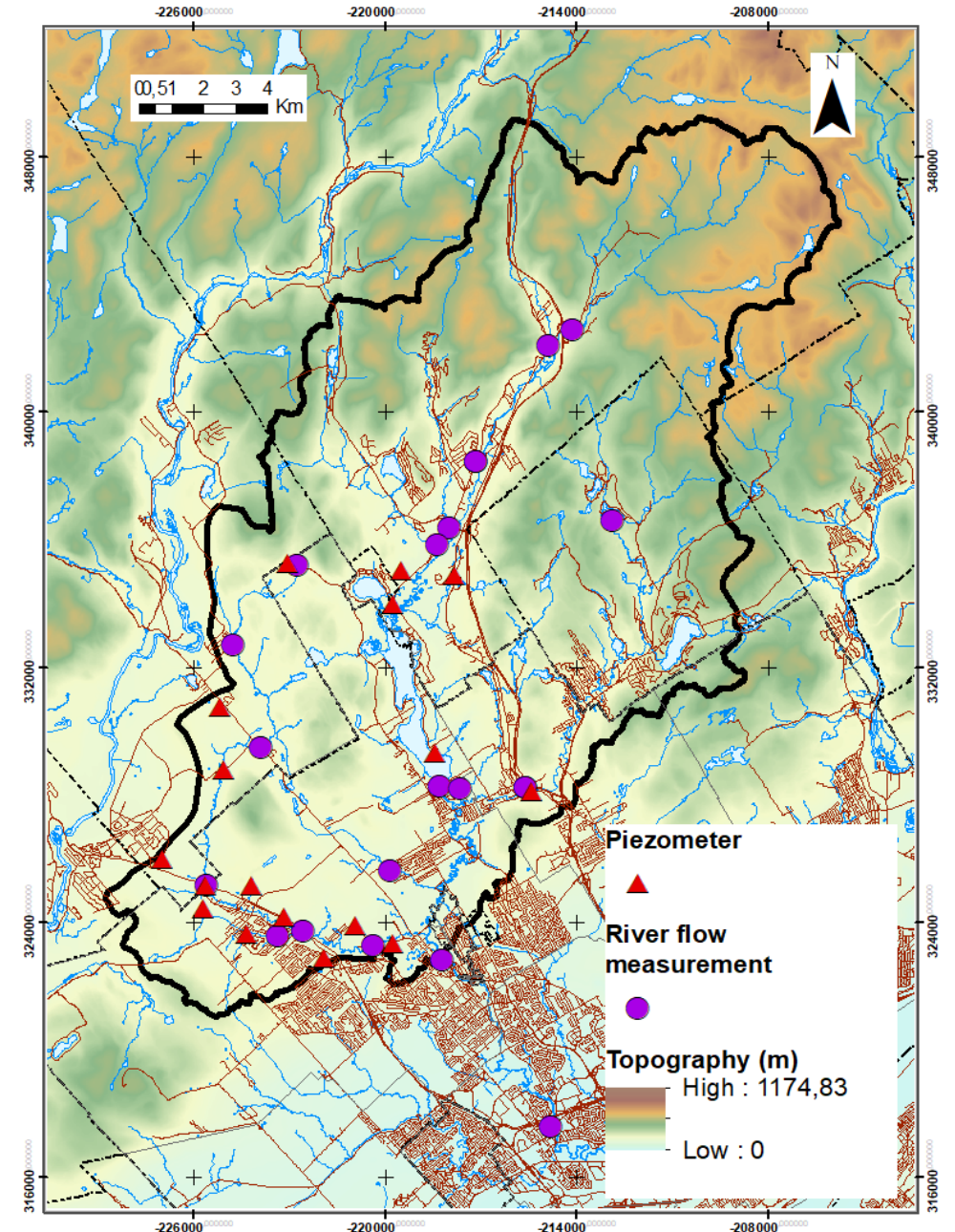
Catchment of the Surface Water Intake

- Area : 350 km²
- Urban growth
- Long-term Concerns
 - Water Quality
 - Water Quantity
 - Climate Variability (seasonal, low flows)
- Catchment overlaps other cities



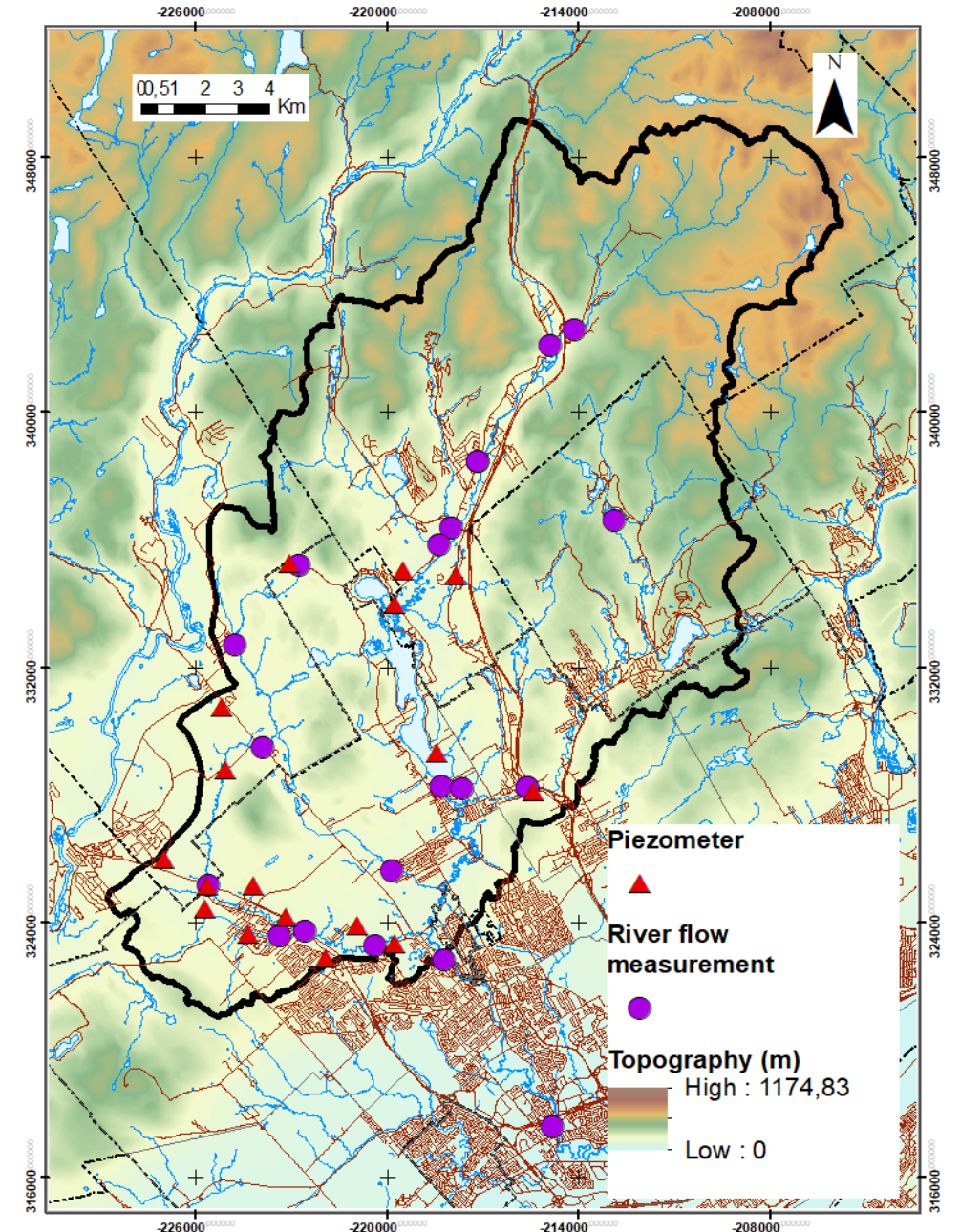
Catchment of the Surface Water Intake

- Existing Data (Variable Spatial Coverage)
 - Bedrock
 - Overburden (glacial deposits)
 - Land use, land cover
 - Weather
 - Surface Water Monitoring
 - Groundwater
 - ~ 5 000 private wells
 - Need for data
 - no long term records for GW levels
 - 3D hydrostratigraphy
 - GW-SW interactions



Short-Term Strategy

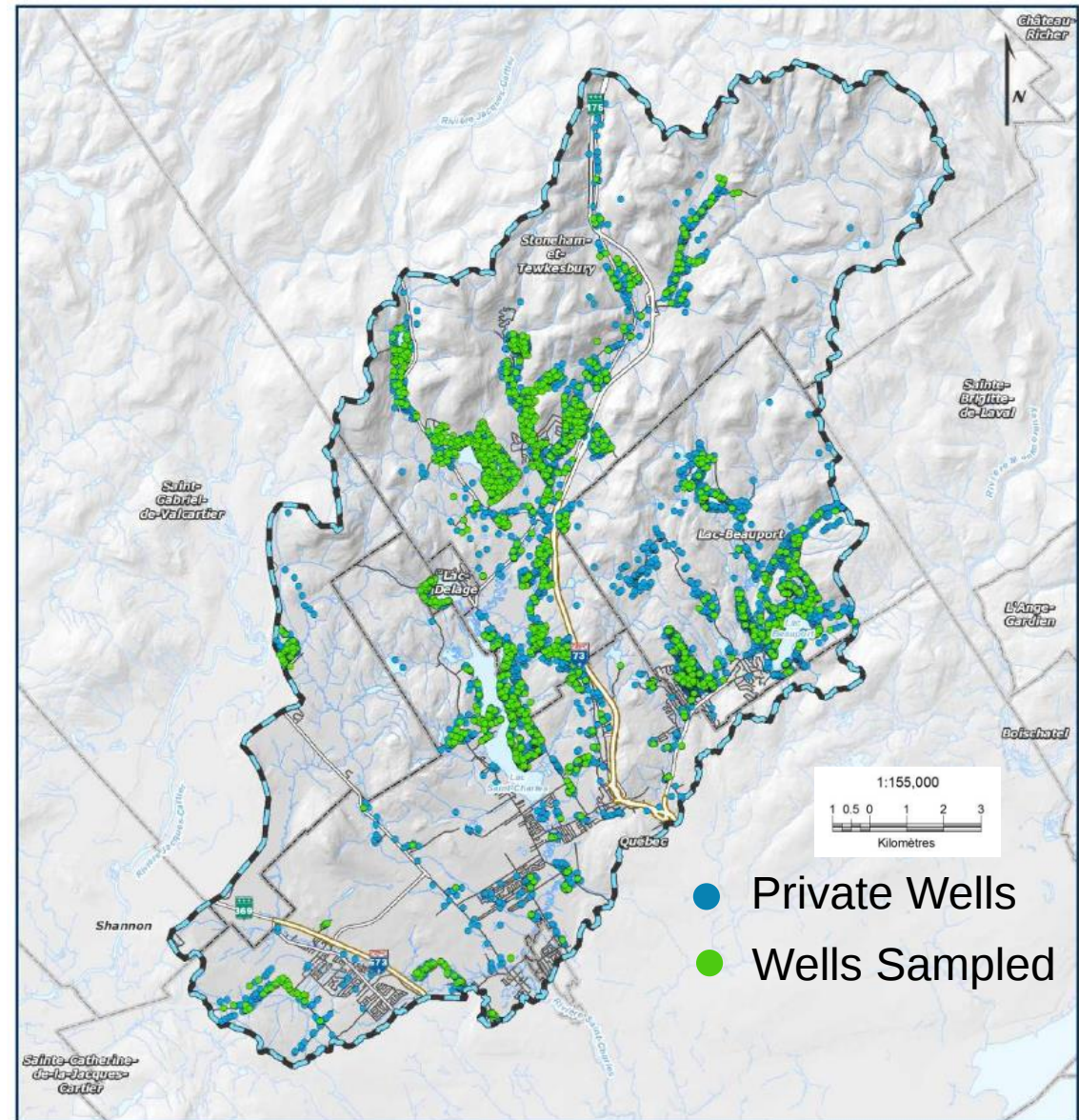
- Network of monitoring wells
- Additional Data
 - Stream Gauging Stations
 - Weather Stations
 - Geochemical signature of groundwater
 - Stable Water Isotopes
 - Age Dating : noble gases, CFCs, tritium



Geochemical Database

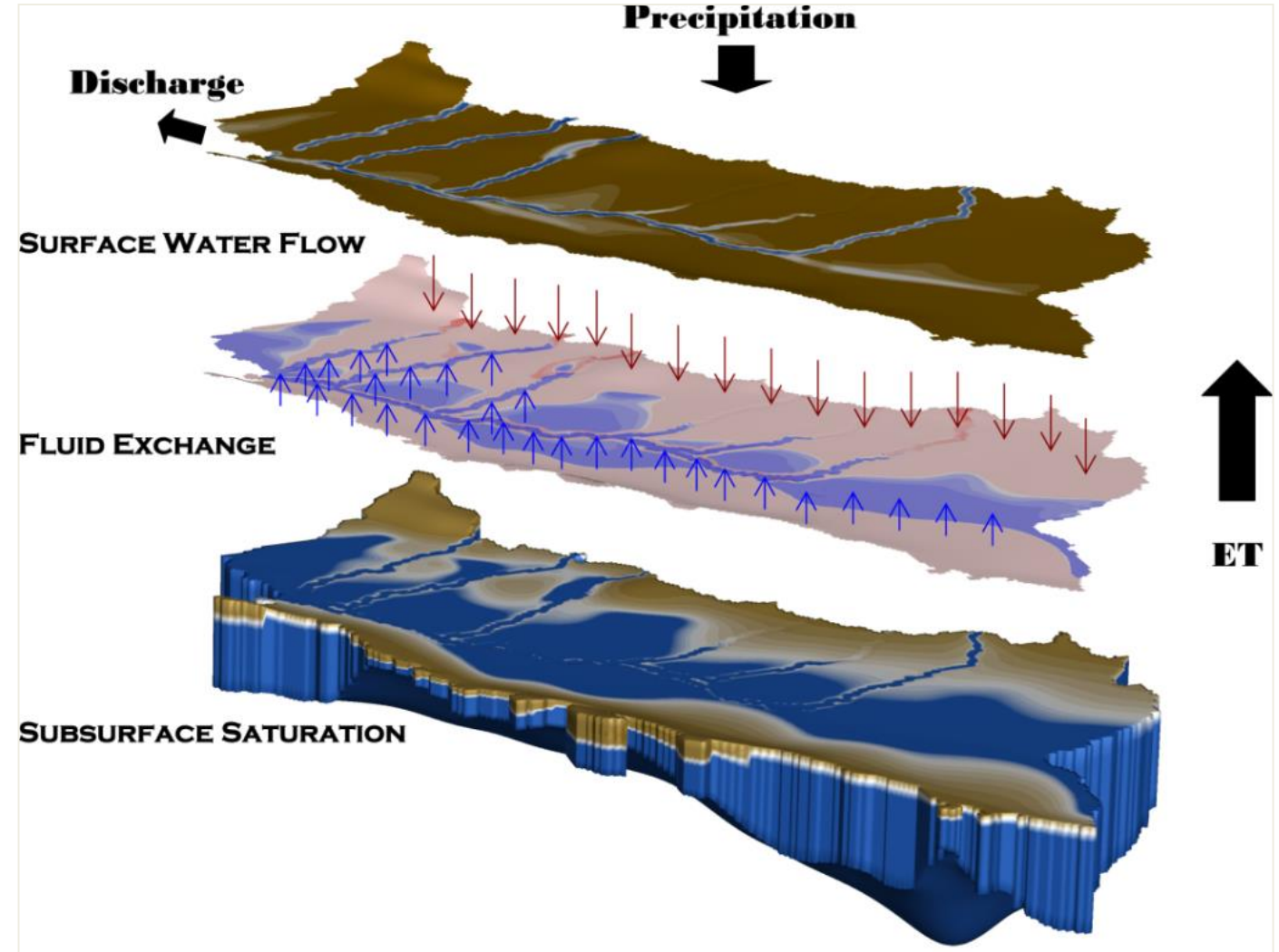
Groundwater Hydrogeochemistry

- 1 600 private wells sampled
- 30 parameters (inorganic, organic, bacteriological)



Long-Term Strategy : Integrated Surface Water and Groundwater Modelling Approach (HydroGeoSphere)

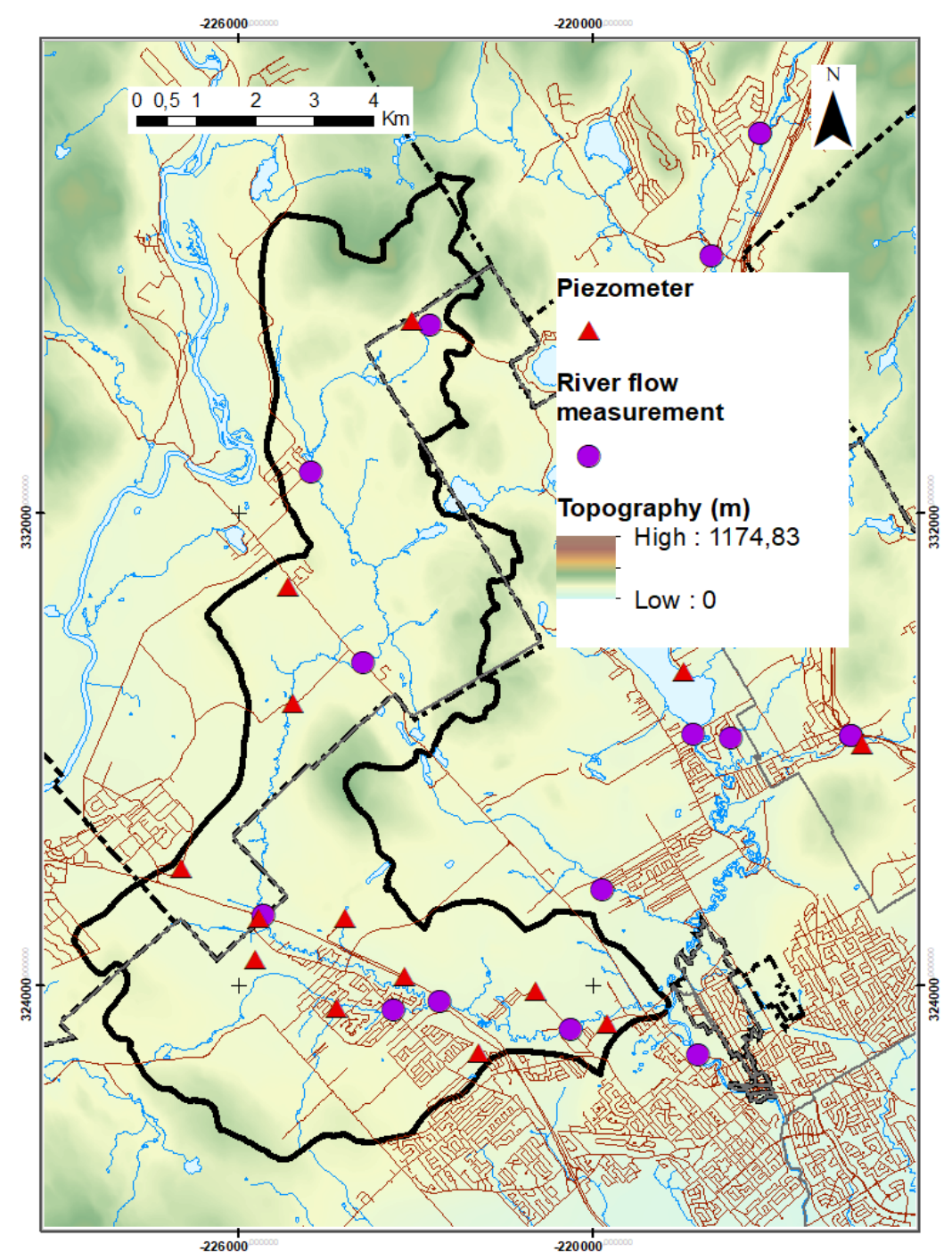
- 2D overland flow
 - Diffusion-wave approximation
- 3D subsurface flow
 - Variably-saturated (Richards' equation)
- Precipitation, Evapotranspiration
- Solute and energy (heat) transport



HydroGeoSphere Simulation Platform , Aquanty (2019)

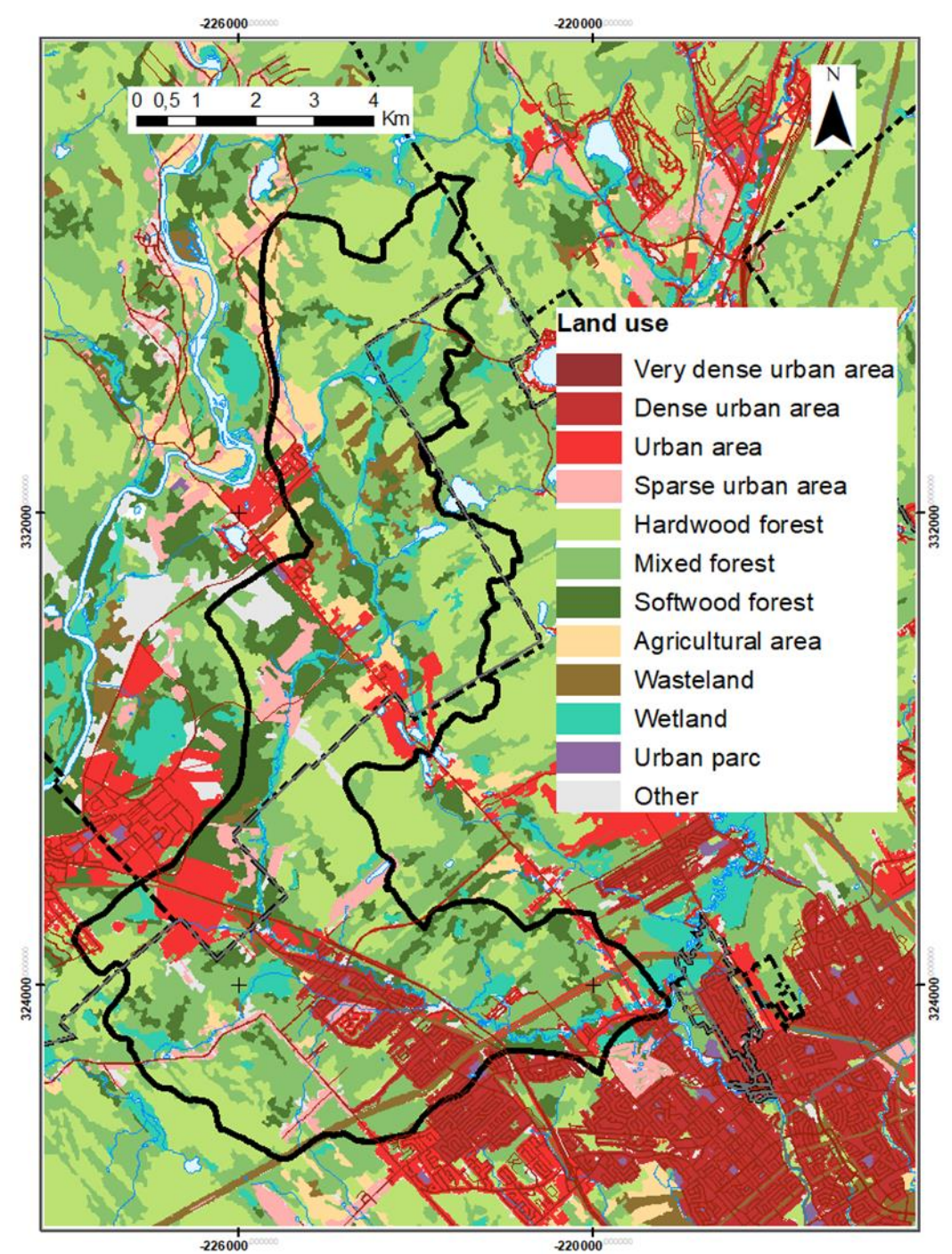
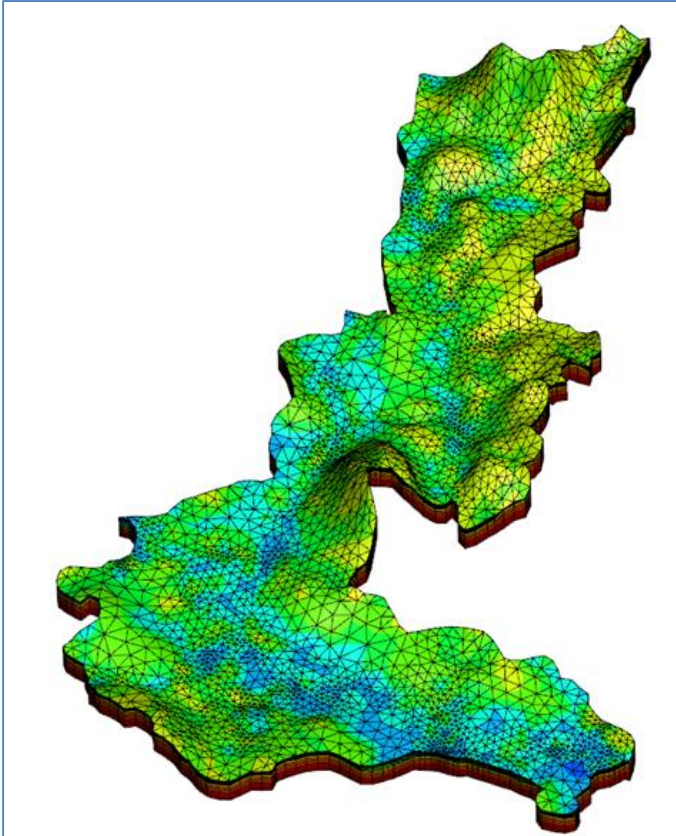
Sub-Catchment (Nelson River)

- Pilot Test
 - Lower South-West part
 - About 70 km²
 - Mostly within city limits
 - Long-term streamflow measurements at 1 station

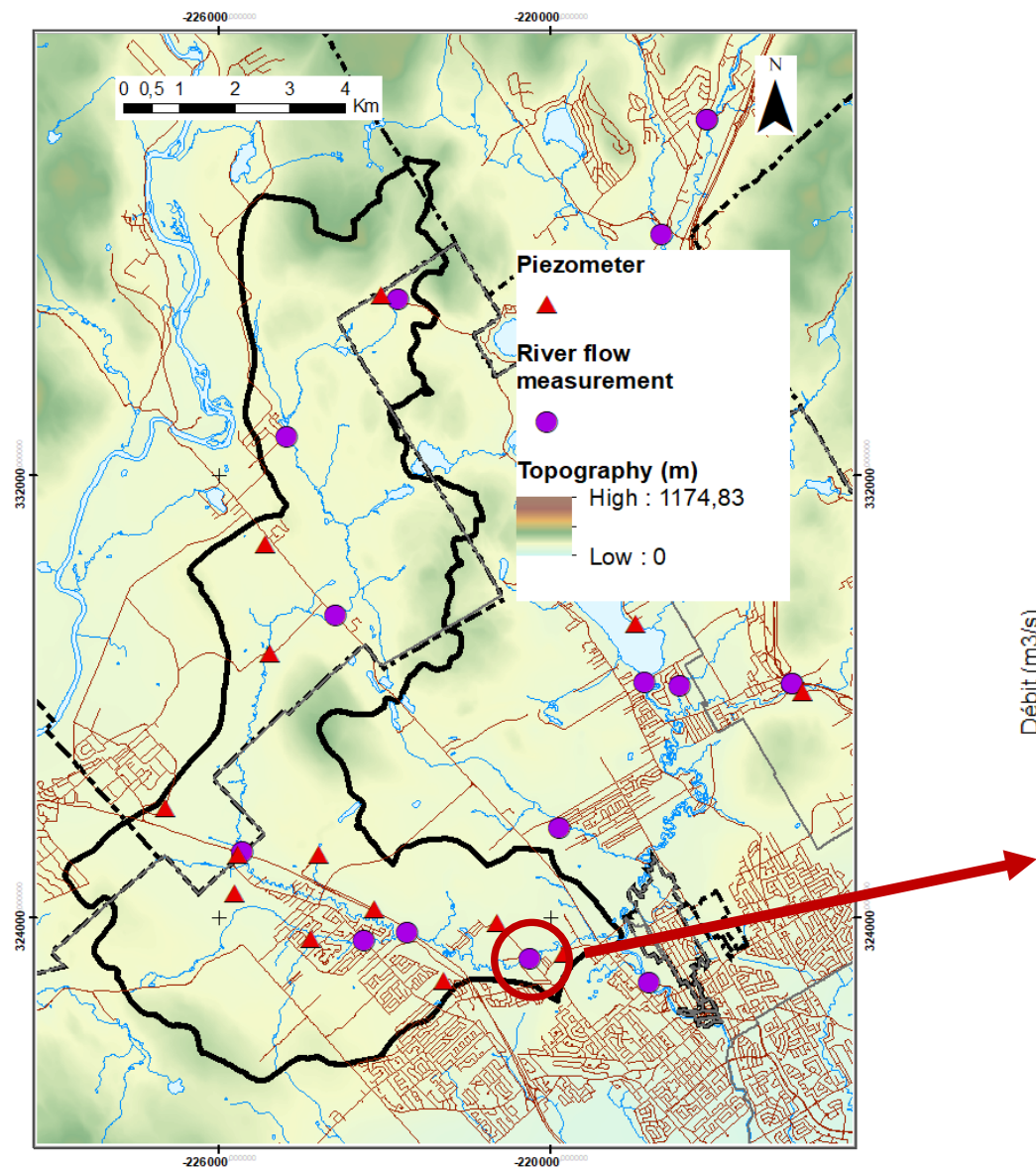


Data required for the model

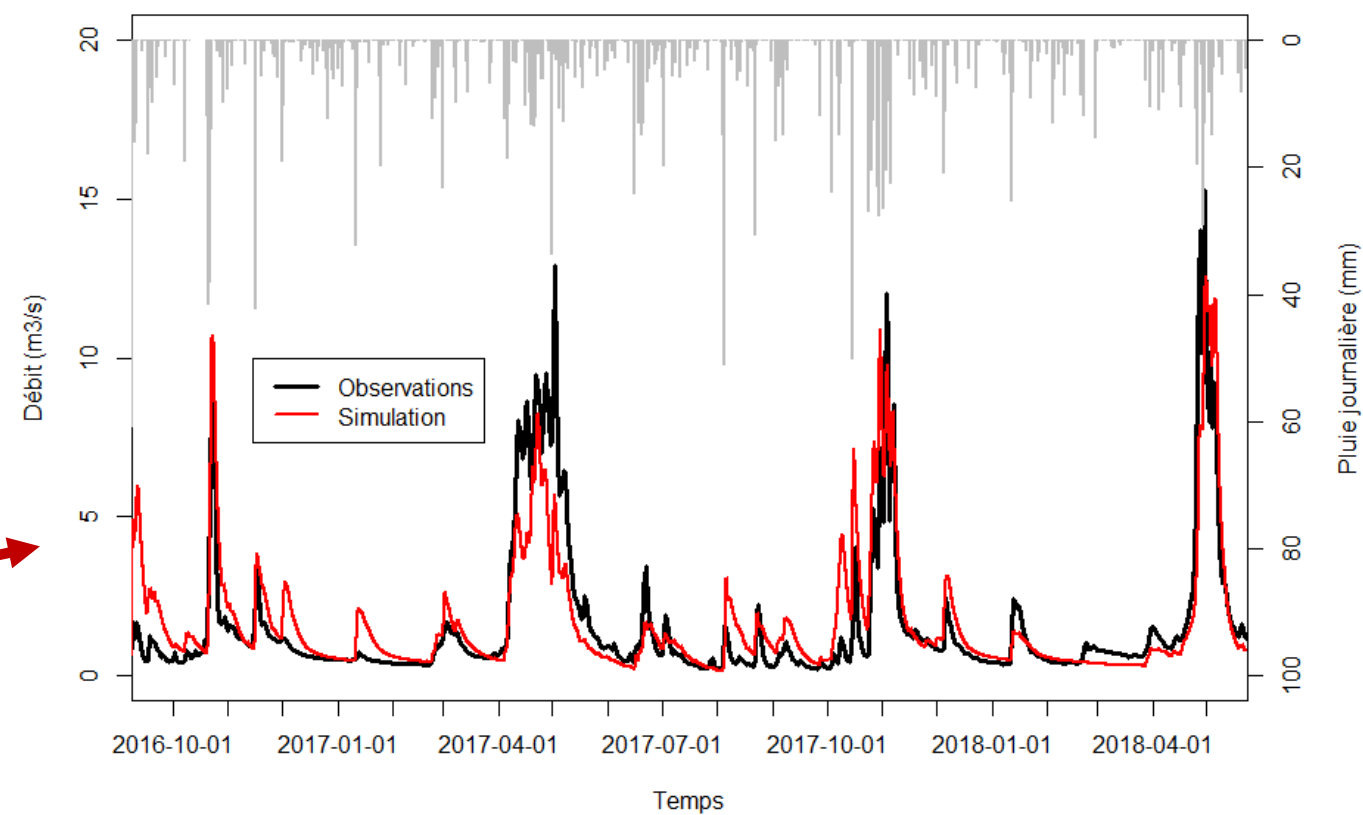
- Land Use (Surface Water, ET)
- Weather (uncertainty)
- Drainage Network
- Geology



Integrated Surface Subsurface Hydrologic Model

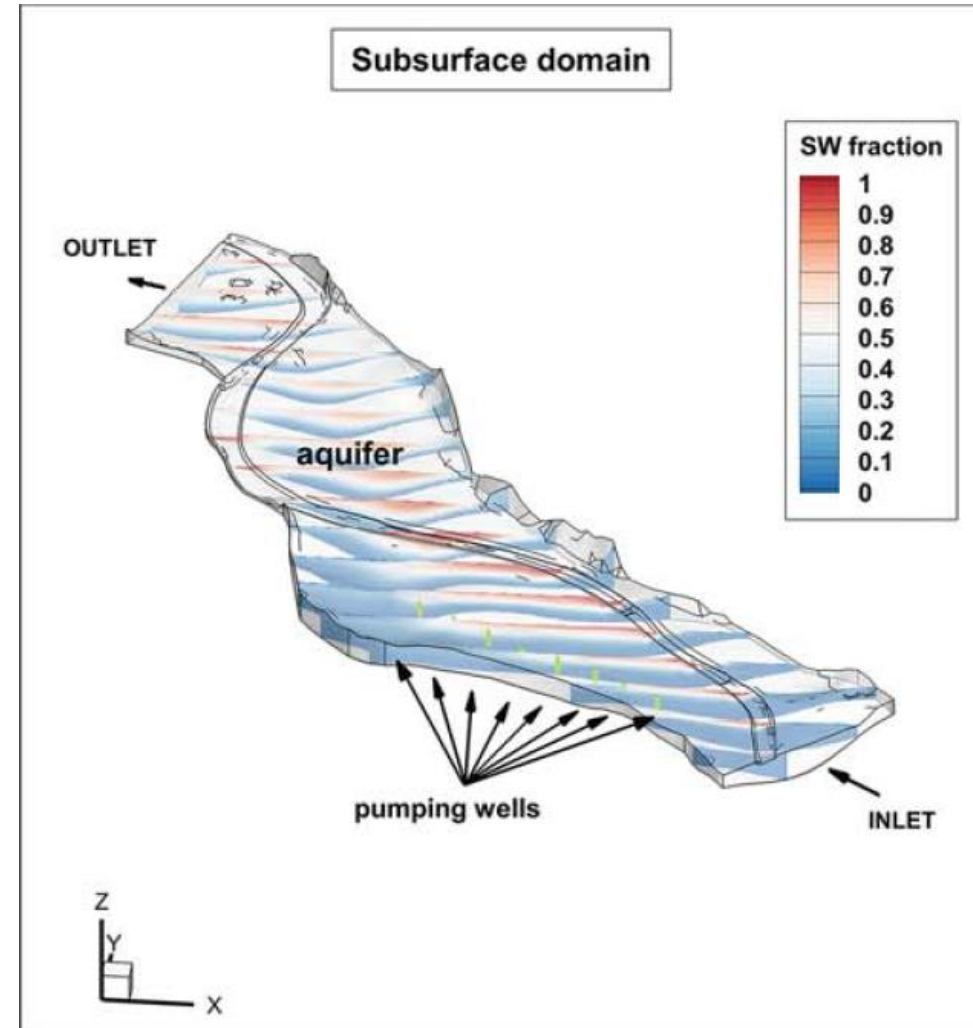
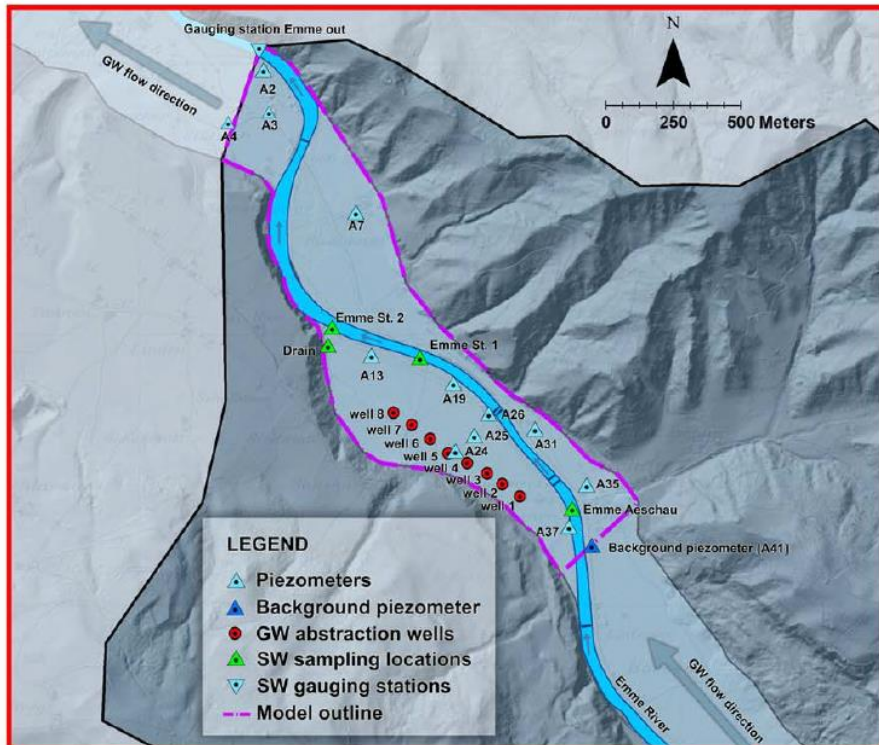


Observed and Simulated Streamflow



Possible Approaches for Simulating Mass Transport

- Advective-Dispersive Transport (Computationally Expensive)
- Particle Tracking (Accuracy Concerns)
- Hydraulic Mixing Cell (Track Origin and Mixing of Water)



Emme Catchment, Schilling et al. WRR (2017)

