Numerical simulations of regional groundwater flow and residence time distributions in the Chaudière-Appalaches region, Québec

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ABSTRACT
Regional groundwater flow and advective-dispersive residence time distributions have been simulated within the Chaudière-Appalaches region, south of Quebec City, Canada. Demands on water supply are growing within the basin, including increasing agricultural, municipal and industrial use, while shallow groundwater is also at risk from potential resource development (ex. shale gas). The study falls in part within the framework of the Quebec provincial PACES program of regional aquifer and groundwater characterization. Specific objectives include estimating the maximum depth of active groundwater flow, investigating the influence of normal faults on regional flow, and understanding the links between the scale-dependent flow systems and the aqueous geochemistry.
A three-dimensional groundwater flow model of the entire Chaudière River watershed was first developed using the WATFLOW finite element model to gain insight into the active flow systems at the basin and sub-watershed scales, including the primary water supply aquifers within the fractured sedimentary rock and Quaternary sediments. The watershed model covers an area of 6,700 km^2 and extends to a depth of 500 m. Groundwater flow and mean residence times within a representative 2D vertical section extending 65 km from the upper basin to the St. Lawrence River, and to a depth of 8 km, were then simulated using the FLONET/TR2 simulators.
The simulations show dominant sub-regional scale flow systems on maximum scales of 10-20 km, including significant flow through the upper 50-100 m of the fractured rock aquifer. Deeper regional flow systems extend to depths of a few kilometers but have very slow flow rates with groundwater ages reaching several millions of years. Regional groundwater discharge zones near the St. Lawrence River are perturbed by low-permeability faults that can help explain some of the geochemical signatures observed in the shallow flow systems, which suggest mixing of young and older water.