**the role of geophysics for hydrogeological assessment of a contaminated site in quebec, canada**

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We developed a 5-step hydrogeological assessment workflow to guide the planning of the upgrade of a groundwater treatment plant at a contaminated site in the Province of Quebec, Canada. The geology of the area is mostly made of clay and glacial tills, with sandy to gravelly channels (eskers) formed during the last glaciation in discordance on a quartzite bedrock. The objective of this paper is to outline the role of geophysics during each step of the workflow.

 The first step of the workflow consists of leveraging existing data and planning the acquisition of new geological, hydrogeological, or geophysical data to improve our understanding of the site. Geological well markers from multiple drilling campaigns were provided from our partner, along with existing conceptual models of hydrostratigraphic units, and 2D vintage seismic lines. This information was integrated to build an initial version of the conceptual model of hydrostratigraphic units to locate regions of increased uncertainty where additional geophysical data were suggested to acquire.

The second step of the workflow consists of building an initial version of the conceptual model of hydrostratigraphic units, by leveraging all data gathered in Step 1. We use this initial model to locate regions of high uncertainty to plan an acquisition campaign of 2D seismic reflection data. A total of 40 km of 2D seismic reflection profiles were recorded in winters 2019 and 2021. The seismic profiles were recorded with a landstreamer with an accelerated weight-drop impact source. The data were recorded with 48 vertical-component geophones with 28Hz nominal frequency. A separation of 1.5m between geophones and a spacing of 4.5m between the shot points and the first geophone were used during the acquisition. The profiles aimed at addressing the uncertainty about the lateral extensions of the esker channels, and to characterize the heterogeneity of the hydrofacies distribution. These two aspects are essential to understand the propagation of the contaminants at site. Horizons picked in time domain on the 2D seismic lines are integrated with geological markers using a sequence of kriging with external drift approach. The seismic profiles gave us the possibility to map the esker in 3D, identify the different hydrofacies existing within the esker, and help better define the unconsolidated sediment-rock interface. It also permits to discover new branches of esker on both sides of the known esker and allows re-estimating the extent of the esker by at least 10 km. This is of major importance when conducting groundwater flow simulations in Step 3 the since the esker is by far the most hydraulically conductive material in the area. The interpretation of the recorded seismic data was also used to plan a drilling campaign (multi-level slug tests, geophysical well logs, and groundwater observation wells) to better characterize the hydrogeological properties of the esker and the fractured bedrock.

Geophysical and multi-level slug tests well data acquired during the drilling campaign were used together with existing data to build an ensemble of stochastic numerical models of groundwater flow (Step 3), which are populated with geostatistical distribution of hydraulic conductivity to consider the known spatial heterogeneity and the uncertainty between data points. Well data are crucial to represent the vertical resolution of hydraulic conductivity in the area.

The stochastic models of groundwater flow are calibrated using an iterative ensemble smoother approach (Step 4). The 2D seismic profiles, the geophysical logs, and the multi-level slug tests acquired during the project were essential in reducing the uncertainty during the calibration, by limiting the possible outcomes of the calibration, thus allowing the calibration process to converge toward an ensemble of realistic hydrogeological models. The final ensemble of hydrogeological models is finally used (Step 5) to test different remediation scenarios of the pump and treat plant, using a probabilistic approach for risk analysis.