# Estimation of water content distribution using time-lapse electrical resistivity tomography and ensemble Kalman filter

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Several strategies can be used to mitigate the risk of acid mine drainage associated with mine wastes. One of these methods is to build a cover with capillary barrier effects (CCBE) over the tailings to prevent the migration of oxygen to the reactive wastes. The performance of such cover relies on precise control of the degree of saturation in the moisture-retaining layer, which should remain above 85%. Current methods for evaluating the water content use point measurements (capacitance or TDR sensors) and their representativity is limited since the waste storage facilities often cover several hectares. Time-lapse electrical resistivity tomography (ERT) shows promise as it can monitor changes in the electrical conductivity (EC) of soil on a large scale. EC is directly related to saturation, but it is also affected by other factors such as temperature, porosity, and electrical conductivity of pore water. ERT should be combined with other information to obtain a quantitative and accurate estimation of the degree of saturation.

We propose to use ensemble Kalman filters (EnKF) to combine point moisture measurements, ERT and hydrogeological modeling to obtain a near-real-time estimate of water content distribution within the control layers of the covers. The ensemble Kalman filter (EnKF) is a probabilistic data assimilation approach used for nonlinear problems that has been used successfully in many hydrogeological and geophysical applications, although not widely used in mining engineering. A major strength of EnKFs is their ability to provide the posterior state distribution (i.e. water saturation here) through the ensemble covariance, thus leading not only to an estimate of the most likely state but also its uncertainty.

Our study focuses on a column water infiltration test reproducing the structure of a large-scale experimental CCBE (geometry and materials) under investigation at Canadian Malartic, a gold mine located in Quebec, Canada. We model the 1D flow of groundwater through the retention layer to predict variations in water saturation over time and space as well as the measurements of six probes placed within the column. Geoelectrical forward modeling calculates the resistance measurements of the array of 32 electrodes located on two opposite sides of the column wall. We generate independent realizations of hydrogeophysical parameters (porosity, hydraulic conductivity, water retention curves, EC relation of water saturation, …) which are constrained by laboratory measurements on waste samples. EnKF is then used to condition each realization to the probe and ERT measurements throughout the experiment.

The stability and accuracy of the EnKF algorithm are tested with synthetic experiments. We discuss the effect of different parameters: the size of the ensemble, the data co-variances and the adequacy of 1D flow modeling to reproduce the CCBE conditions. Using ERT in conjunction with probe measurements seems promising to predict spatiotemporal variations in water saturation. We finally test our approach on the drying cycle of the column infiltration experiment and discuss the performance of the EnKF to reproduce the observed water saturation variations.