Evapotranspiration vs. Pumping Control of Groundwater in a Reclaimed Legacy Mine Pit under Uncertainty

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Since excavation, a mine pit acts as a hydraulic sink via evapotranspiration of groundwater from a mineralized sandstone (unit A). The reclamation plan preserves the evaporative sink, but unknown future water supply pumping may cause pit groundwater to migrate from the reclaimed pit. To assess closure risks to groundwater from future offsite pumping, we implemented a scripting-based uncertainty analysis (UA) workflow to estimate the probability of poor-quality groundwater being retained within the pit. The UA workflow quantifies the predictive uncertainty in pit groundwater retention, determined through particle tracking and water fluxes, given uncertainties in future pumping, hydraulic properties, and boundary conditions, including poorly known historical pumping.

The UA workflow adopted a high-dimensional approach to represent uncertain model inputs, estimated posterior parameters from random prior parameter samples by assimilating head observations through history-matching, and predicted post-reclamation groundwater heads using posterior parameters. The fully reproducible UA workflow used pestpp-ies, FloPy, PyEMU, MODFLOW 6, MODPATH, and Python scripts in a parallel computing environment.

Model input uncertainty included spatially varying hydraulic properties of unit A and boundary conditions, with a high-dimensional representation of historical and future pumping. Offsite pumping wells intercepted unit A and other sandstones, making water pumped from unit A uncertain. Unit A historical pumping rates were derived from estimated effective transmissivity and randomly sampled multipliers for spatial and temporal patterns to capture this important source of uncertainty. Three predictive scenarios span the plausible range of future pumping over 200 years.

Particle tracking and water flux results from 600 posterior realizations reveal a high probability that evapotranspiration will retain groundwater within the reclaimed pit for 200 years despite constant offsite pumping. Unit A cannot sustain higher future pumping rates over the long term. The estimated predictive uncertainty in pit groundwater retention provides important and conservative information about risks from unknown future pumping.