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Modelling under environmental uncertainties to assess favourable Coal Combustion Residue backfill scenarios

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Abstract: Large volumes of Coal Combustion Residues (CCR's) are produced via coal-fired power stations. A proposed high disposal solution is to backfill opencast coal mines with CCR monoliths. Limited South African studies have focused on the hydraulic behaviour of CCR's in this application, leading to uncertainty in understanding environmental impacts. This study aims to address this environmental uncertainty by using a modelling approach to assess flow and transport properties under various CCR backfill scenarios. Generic flow and transport models were constructed to represent a typical coal mine in Mpumalanga, South Africa. A three-dimensional MODFLOW USG control volume finite-difference grid was set up, consisting of 8 layers, 100 x 100 cells in each, with a 10m cell size. All layers are flat, whereby the upper second and third layers (20 – 30 meters below ground level) attain a north and south general head boundary which introduces a 10m flow gradient. Transient drain boundary conditions were set up to dewater the mine during its operational phase as well as act as a mining decant point. Transient models were constructed to simulate a period of 100 years post-closure for the following CCR backfill scenarios: (1) No CCR, (2) CCR above the water table, (3) CCR below the water table, (4) CCR in middle of pit, (5) CCR wall to surface, and (6) CCR wall to below weathered zone. Simulated model results indicate that CCR backfill scenarios which intercept the water table experience a 20% rise in water levels with a faster recovery. Furthermore, solutes in these scenarios tend to induce lateral and downstream plume migration. CCR backfill scenarios which do not intercept the water table have no significant effect on the flow regime and limit plume migration to an extent. Salt loads indicate that backfilling with no CCRs is highly unfavourable as it produces significantly (>50%) higher salt loads. Concluding that backfilling with CCR's under all scenarios will have a positive effect on groundwater, however needs to be examined under site-specific conditions. Thus, generic numerical flow and transport models are successful tools in predicting the environmental impact of CCR backfill applications by providing insight into the changes in: the flow regime, flow directions, water table recovery rates, concentrations and plume migrations.

Key words: conceptual scenarios; environmental impact; feasibility; generic modelling approach