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Numerical upscaling of the hydraulic properties of fractured rock using hydro-mechanical property data

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A methodology for upscaling of hydraulic properties based on an analysis of coupled hydro-mechanical (HM) processes in fractured rock is presented that examines the impact of multiple uncertainties in the HM parameter estimation. Two-dimensional HM modelling is conducted on fracture networks generated from fracture length and density statistics, which are described by a power-law. A critical analysis has been performed of the uncertainties in the interpretation of the geometrical and HM properties of the geological formations obtained from site investigations and their mathematical representation in the HM models. The modelling of the coupled HM processes is achieved using both discrete fracture network (DFN) and discrete element (DEM) models. The mechanical modelling is carried out with the empirical Barton-Bandis model (UDEC-BB). Stochastic realisations of the fractured rock mass coupled with stochastic realisations of the joint roughness coefficient (JRC) and the joint compressive strength (JCS) are entered to the model to derive stochastic models for upscaled hydraulic conductivity and effective porosity. The upscaling results have then be used in a Monte-Carlo simulation with a site scale continuum model of groundwater flow and transport to determine the particle travelling times from a hypothetical deep nuclear waste repository to ground surface. The results indicate that statistical inference of the stochastic models for fracture length, fracture density and JRC/JCS data can all have a significant effect on the travel time results. The stochastic HM and the continuum modelling at the field scale indicates that, of the controls investigated, mechanical properties of the rock have the greatest influence on solute travel times followed by the uncertainty of the fracture density and the spatial distribution of the fracture density.