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Impact of the saprolite/bedrock interface geometry on artificial recharge dynamics in crystalline rock aquifers

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In semi-arid Southern India, perennial water resources consist mainly of shallow weathered and fractured crystalline aquifers, where groundwater flows are mainly controlled by preferential flow pathways. The most transmissive pathway at the kilometer scale is the interface between the upper weathered layer and the fissured bedrock. It is sometimes considered to be sub-horizontal, which neglects the possible effects this pathway's topography may have on aquifer connectivity and flow, including recharge dynamics. This study aims to investigate the effect the bedrock interface topography may have on artificial recharge dynamics, particularly how the bedrock interface topography may control the borehole water level response to artificial recharge. In this context, an artificial recharge basin was implemented at the Experimental Hydrogeological Park in Telangana (South India), a well-equipped and continuously monitored site situated in Archean granitic terrain. The basin is periodically supplied with surface water deviated from the nearby Musi river, downstream of Hyderabad. The topography of the bedrock interface and its hydraulic properties are well known from previous Electrical Resistivity Tomography surveys and hydraulic tests.

Monitoring of water levels in the basin and collection of rainfall and evaporation data allowed us to estimate infiltration through a water budget equation. We thus quantified the inputs from the MAR structure into the groundwater system. To better characterize recharge dynamics and consider interactions with the aquifer, groundwater data from 9 onsite boreholes was used to calibrate analytical and numerical simulations of recharge processes. Analytical modelling was aimed at obtaining a first order estimation of hydraulic parameters at the initial stage of infiltration, when the recharge basin was not yet hydraulically connected to groundwater. Numerical modelling accounted for structure and was used to test the effect of aquifer geometry on water level drawup dynamics posteriorly to hydraulic connection.

Hydraulic parameters obtained through analytical modelling calibration during the initial stages of infiltration pointed towards a dominant role of preferential flow paths, with high permeability and storativity. Numerical modelling highlighted our inability to reproduce the observed long term water level response assuming a sub-horizontal geometry of the basement. On the other hand, a model with a heterogeneous basement elevation simulated by a depression at the center was able to much better honor the water level data. The lateral extension of the depression controls the response dynamic, the smaller being the lateral extension, the faster the increase of the drawup. The vertical extension of the depression controls the amplitude of water level variations but only slightly the speed of water level increase. In this way, we were able not only to better understand the phenomena driving the water level response to recharge in crystalline rock, but to loosely constrain the dimensions of the topographic depression describing the geometry of the bedrock interface, which was supported by the ERT imaging of the depth of the saprolite. Thus, our study shows promising results regarding improved simulations and understanding of the effect of basement topography on flow and recharge processes, and even possible quantification of aquifer geometry through monitoring of groundwater levels only.