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Detailed hydraulic model of weathered-fractured hard rock aquifer: implications for groundwater flow at watershed scale

Nicolas Guihéneuf (1,2), Alexandre Boisson (1), Olivier Bour (2), Jean-Christophe Maréchal (3), Benoit Dewandel (3), Tanguy Le Borgne (2), Jérôme Perrin (4), Shakeel Ahmed (5), Mathieu Viossanges (1), Amélie Dausse (1), Subash Chandra (5), and Mohammed Wajiddudin (1)

(1) BRGM, IFCGR, Uppal Road, 500606 Hyderabad, India (nicolas.guiheneuf@univ-rennes1.fr), (2) Géosciences Rennes - OSUR, UMR6118 CNRS, Université de Rennes 1, 35042 Rennes cedex, France, (3) BRGM, Water Department, NRE, 1039, rue de Pinville, 34000 Montpellier, France, (4) BRGM, Water Department, GDR, 3, Av Claude Guillemin, 45060 Orléans, France, (5) NGRI, IFCGR, Uppal Road, 500606 Hyderabad, India

In Southern India, groundwater constitute the main water resource for rural communities and since Green revolution of the seventies, the overexploitation of groundwater for irrigation land induces quantity and quality problems. Understanding groundwater functioning in term of flow and transport processes in this area is a prime importance in order to improve aquifer management. Here we propose a detailed study on fracture properties at different scale to analyse fracture connectivity and groundwater flow. Our analysis takes advantage of the Experimental Hydrogeological Park (Andhra Pradesh state) where a large network of observation boreholes is available.

Due to large abstractions and to an insufficient recharge in the last years, most of the saprolite horizon is no longer saturated during most of the hydrological cycle. As a consequence, fracture network connectivity of the underlying granitic body appears as a crucial parameter for ensuring groundwater flow. Temperature logging, flowmeter measurements and packer tests show few mains conductive fractured zones below saprolite horizon. The first zone is found in the upper part of the granite and consists in a well-connected fracture network a few meters thick that can be observed in all boreholes. The other deeper zones consist in general in single sub-horizontal fractures of limited extension, which can be found at different depths and that are in general not connected together. The overall fracture connectivity seems to strongly and rapidly decrease with depth.

Slug tests and pumping tests carried out before and after recharge show a transmissivity decrease with depth of one order of magnitude from 10^{-4} to 10^{-5} $m^2.s^{-1}$. Derivative analysis of the pumping tests indicates highly channelized flow in a groundwater system that is hydraulically partitioned. Transport experiments (cross-hole tracer tests and push pulls) were performed in one of the deeper fractures zone of lower permeability. These experiments reveal the presence of few rapid flow paths within isolated single fractures over relatively but limited large scale (20 – 200 meters).

This consistent dataset allows us to propose a detailed conceptual functioning model of the aquifer. It highlights the hydraulic partitioning of the aquifer in function of piezometric level due to decreasing fracture connectivity with depth. These results have great implications for groundwater flow at the watershed scale. In particular, we show that groundwater flow may be much more limited and restricted in sub-compartments due to the fracture connectivity decreases with depth. We also demonstrate that in this low permeability medium, solute transport can be nevertheless fast due to some local sub-horizontal fractures. These results are of prime importance for groundwater exploitation and management in Southern India.