

Borehole dilution experiment in a Karoo aquifer in Bloemfontein

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Abstract

This paper shows that a borehole dilution experiment using common salt is a useful technique for better understanding of some hydrogeological features of a fractured aquifer. A series of such tracer experiments was performed in the campus site aquifer, a hydrogeological experimental site of the Institute for Groundwater Studies at the University of the Orange Free State in Bloemfontein. It is demonstrated that the model for use in homogeneous aquifers may be adapted in fractured aquifers. Results have revealed valuable information on hydraulic parameters of the fracture system at different scales. Profiles of electrical conductivities monitored in several boreholes can be used to locate horizontal fracture zones in the aquifer. These results may provide an important guide to formulate realistic conceptual models for borehole protection zoning. The experiment can also serve as a reference to future experiments of this kind in Karoo aquifers which cover some 50% of the subcontinent of Southern Africa.

Introduction

Tracer experiments have been extensively utilised in hydrogeological studies overseas. According to available information (Peck et al., 1988; Davis et al., 1980), a tracer experiment can be conducted either under a natural gradient or under an induced gradient and its result is scale-related.

In South Africa, Bredenkamp et al. (1995) touched on some dye tracer experiments under the induced gradient conducted mainly in Karoo aquifers of Beaufort West in 1977. To date, very few tracer experiments have been performed locally. One of the reasons would be that flow regimes in our aquifers are often complicated by unpredictable fracture systems.

Generally speaking, tracer tests are more established for primary aquifers. For instance, tracer tests using common salt are often performed in porous media. Even so its applications are not very popular on the ground that the tracer does not flow far along the natural flow paths due to its denser solution and tends to sink to the bottom of the aquifer. This problem may be overcome if a fast-flow fracture zone could be separated from the matrix. To do so, straddle packers may be used to separate a fracture zone from the matrix in a borehole. We selected a Karoo aquifer at the campus site of the University of the Orange Free State (UOFS) for a series of borehole dilution experiments. The experiment, part of a project entitled "Utilization of tracer experiments for the development of rural water supply management strategies for secondary aquifers" sponsored by the Water Research Commission, is aimed at establishing appropriate methodology for tracer application in secondary aquifers.

Experiment

The selected aquifer is a hydrogeological experimental site for the Institute of Groundwater Studies at the UOFS in Bloemfontein (Fig. 1). The site consists of the Beaufort Group of Karoo sedimentary rocks. The ground surface is fairly flat with a slight dip toward the North-East direction. The depth to piezometric

Borehole Location At Test Site at UOFS in Bloemfontein

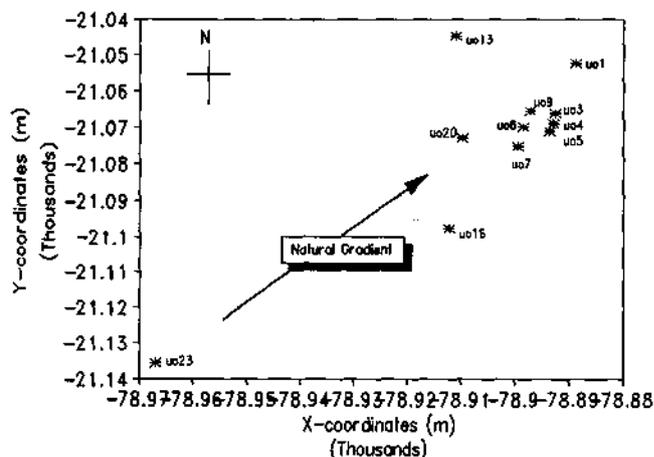


Figure 1
Borehole location map

surface is about 11 m. In this campus aquifer, a horizontal fracture zone has been identified occurring at depths of 21 to 25 m below ground surface. The fracture zone was selected for this experiment.

The in-hole common salt dilution test using electrical conductivity (EC) as tracer indicator was conducted in a borehole termed UO20 on the campus site at the UOFS on 13 February 1996. According to measurements in borehole UO20 and borehole UO1, natural gradient was determined at 0.6% along UO20 to UO1.

The experimental procedure was:

- to establish the background chemistry of the groundwater, measuring EC in boreholes of interest (average of 85 mS/m at a temperature of 18.5°C in this case);
- to prepare salt solution with EC of 1 130 mS/m by dissolving 70 g NaCl in 10 l of tap water of 20 mS/m EC;
- to seal off 1 m fracture zone with centre at depth of around 21 m in borehole UO20 using straddle packers with screen diameter of 160 mm (Fig. 2);

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Received 11 April 1996; accepted in revised form 7 November 1996.