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Dependence of hydraulic conductivity estimates from slug tests on displacement depth

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Slug tests are generally accepted as an efficient tool for the hydraulic characterisation of aquifers. They can readily be employed without major logistical efforts and allow in particular the characterisation of contaminated aquifers since there is no contaminated water that needs to be disposed of. They are especially suited for assessing low conductive rock formations, where pumping quickly has to be stopped because the wells dry up. In cases where a dense well network is available slug tests can provide detailed information about the spatial variability of hydraulic conductivity.
Limitations are: a) the small volume of integration, b) problems of obtaining representative storage parameters, and c) a large number of effects, the data need to be corrected for, especially in highly conductive aquifers, e.g. inertia, skin effects etc..
During a characterisation study, performed in karstified rocks, it was observed that the hydraulic conductivities obtained from the slug test data depended on the depth of displacement, i.e. an increase in displacement from 2.5 m to 11 m resulted in a change of hydraulic conductivity by a factor of 10.
This feature, which is attributed to the heterogeneous characteristics of the fracture / matrix system, has also been described by Streltsova (1988), who observed that whenever "the formation volume, influenced by the test is smaller than the representative formation volume required for fracture pattern replication". The following conceptual model explains this hydraulic behaviour. If the well is drilled within a compact matrix block, the hydraulic response of an aquifer section is mainly determined by the low matrix conductivity near the well. If however the well is connected to the fracture network, short tests will only excite the highly conductive fractures and the longer the duration of the test, the more the less conductive matrix will contribute to the test result. Therefore a systematic decrease in the hydraulic conductivity with increasing test duration (displacement) can be observed.
The tests were interpreted with analytical solutions as well as with a numerical model. The latter confirmed the above explanation of the flow dynamics.
This observation has large implication for slug test interpretation in heterogeneous aquifers with large contrasts between highly and less conductive parts, e.g. fractured – porous or some porous granular aquifers.

References

Streltsova, T. (1988) Well testing in heterogeneous formations. Exxon monographs, John Wiley & Sons: 413 pp.