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Importance of non-Darcy flow on the hydraulics of ageing water wells

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Water well ageing is mainly attributed to biologically- and chemically-induced incrustations as well as suspended particles accumulating around the well. These incrustations can clog the water well components (i.e. pipes, screen slots, gravel pack, adjacent aquifer), which will then increase drawdown (head losses) and therefore lead to a higher energy consumption and pumping costs.

Deviations from Darcy flow are observed in regions of high gradients and flow velocities due to the occurrence of inertial effects. Non-Darcy flow is therefore particularly interesting in near well regions in which flow velocities increase drastically due to a reduction of the available hydraulic area. Hence, this study focuses on the gravel pack, which is where the transition from Darcy to non-Darcy flow occurs.

Gravel pack head losses are calculated using the Forchheimer-Engelund equation, which consists of two terms accounting for linear and non-linear laminar flow, respectively. In this study, the Forchheimer-Engelund equation uses the gravel pack hydraulic conductivity as the main dependent variable since it is directly affected by clogging processes. The gravel pack hydraulic conductivity is estimated using the Kozeny-Carman equation, which takes into account the roughness, pore shape and porosity of the gravel pack. Clogging processes are mimicked by reducing systematically the gravel pack porosity. For simplification purposes, both the roughness and pore shape, which show a linear dependency and do not vary on a wide range, are considered to be negligible. On the other hand, the hydraulic conductivity shows a cubic dependency with the porosity. Furthermore, various equations used in practice of the non-Darcy (Forchheimer) coefficient are investigated.

Preliminary results show that for porosities lower than approximately 15%, the non-linear term of the Forchheimer-Engelund equation starts to show increase with respect to the linear term. For porosities lower than 12%, the non-linear term dominates, showing drastic increases in the head losses. This indicates that calculations of clogged gravel pack head losses considering only the linear term could be underestimated. These findings are relevant for well optimization.