NUMERICALLY SIMULATED GROUNDWATER AGE DISTRIBUTIONS WITHIN COMPLEX FLOW SYSTEMS AND DISCRETE FRACTURE NETWORKS

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Context

Age simulations can be applied in a variety of contexts including defining capture zones for pumping wells, characterizing fractured rock aquifers, and for improved understanding of flow systems and geochemical evolution.

Methodology

We apply the finite element models FLONET/TR2 (in the 2D vertical plane; Molson & Frind, 2020) and HEATFLOW (in 3D systems), using the standard advection-dispersion equation with an age source term. The governing equations for mean age (A) or residence time, including advective-dispersive age mixing within a porous medium can be written as:

$$\frac{\partial}{\partial x_i}\left[D_{ij}\frac{\partial A}{\partial x_j}\right]-v_i\frac{\partial A}{\partial x_i}+1=0$$

where x_i are the spatial coordinates (x,y) (L), v_i is the average linear flow velocity (L/T), D_{ij} is the hydrodynamic dispersion tensor (L^2/T), A is the mean age (T), and the +1 source term expresses the growth of the age mass at the rate of 1 day/day as it moves along its flowpath in the forward (downgradient) direction. A Type-1 boundary condition where A=0 is applied along recharge zones. Life expectancy uses a similar equation in a reversed flow field. The codes are available without charge for research use; please contact authors..

Numerical Simulations

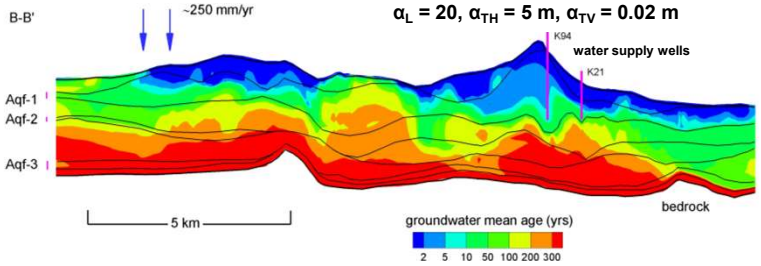

Fig. 1 3D model of groundwater age in a multi-aquifer system

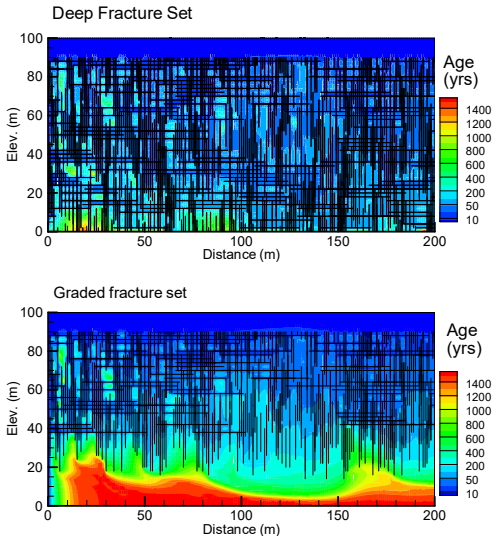

Fig. 2 Groundwater age in a discrete fracture network

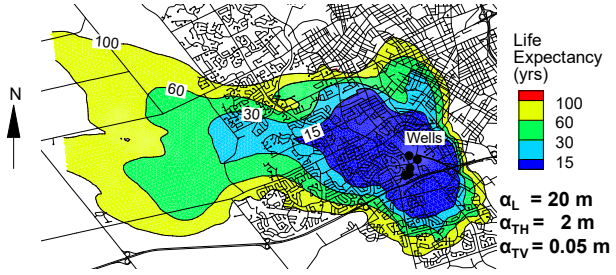

Fig. 3 Application to well-head protection zones

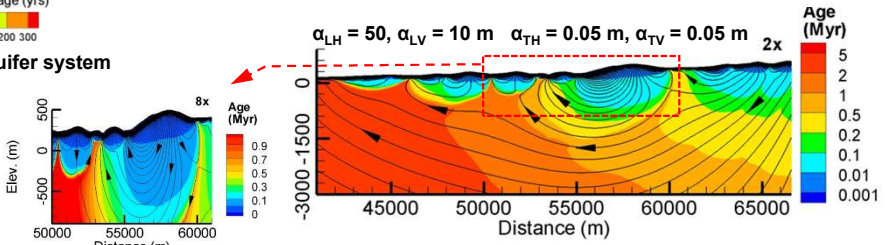

Fig. 4 Simulated age distribution in a regional groundwater flow system (Flonet/TR2 model).

Discussion:

- Age simulations provide insight into complex flow systems
- Dispersivities control age mixing, the Lichtner (2002) formulation is preferred

References:

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