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Calibrating binary lumped parameter models

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Groundwater at its discharge point is a mixture of water from short and long flowlines, and therefore has a distribution of ages rather than a single age. Various transfer functions describe the distribution of ages within the water sample. Lumped parameter models (LPMs), which are mathematical models of water transport based on simplified aquifer geometry and flow configuration can account for such mixing of groundwater of different age, usually representing the age distribution with two parameters, the mean residence time, and the mixing parameter.

Simple lumped parameter models can often match well the measured time varying age tracer concentrations, and therefore are a good representation of the groundwater mixing at these sites. Usually a few tracer data (time series and/or multi-tracer) can constrain both parameters.

With the building of larger data sets of age tracer data throughout New Zealand, including tritium, SF6, CFCs, and recently Halon-1301, and time series of these tracers, we realised that for a number of wells the groundwater ages using a simple lumped parameter model were inconsistent between the different tracer methods. Contamination or degradation of individual tracers is unlikely because the different tracers show consistent trends over years and decades. This points toward a more complex mixing of groundwaters with different ages for such wells than represented by the simple lumped parameter models.

Binary (or compound) mixing models are able to represent a more complex mixing, with mixing of water of two different age distributions. The problem related to these models is that they usually have 5 parameters which makes them data-hungry and therefore difficult to constrain all parameters. Two or more age tracers with different input functions, with multiple measurements over time, can provide the required information to constrain the parameters of the binary mixing model. We obtained excellent results using tritium time series encompassing the passage of the bomb-tritium through the aquifer, and SF6 with its steep gradient currently in the input. We will show age tracer data from drinking water wells that enabled identification of young water ingression into wells, which poses the risk of bacteriological contamination from the surface into the drinking water.