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Mean transit times in contrasting headwater catchments from southeast Australia determined using Tritium

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Headwater streams contribute a significant proportion of the total discharge of many river systems. However, despite their importance, the time taken for rainfall to pass through the catchment into the streams (the transit time) in headwater catchments is largely unknown as are the catchment characteristics (such as drainage density, topography, landuse, or geology) that determine variations in transit times.

Because the peak in Tritium activities in rainfall produced by atmospheric nuclear tests in the1950's and 1960's (the "bomb-pulse") was several orders of magnitude lower in the southern hemisphere than in the northern hemisphere, Tritium activities of remnant bomb pulse water in the southern hemisphere have decayed below those of modern rainfall. This allows mean transit times to be estimated from single Tritium measurements. Here we use Tritium to estimate transit times of water contributing to perennial streams in the adjacent upper catchments of the Yarra and Latrobe Rivers (southeast Australia). Samples were collected at varying flow from six headwater tributary sites in the Latrobe catchment, which is largely forested and four tributaries in the Yarra catchment which has been extensively cleared for dryland agriculture.

The lowest Tritium activities were recorded during summer baseflow conditions and are between 1.25 and 1.75 TU, these are significantly below the Tritium activity of local rainfall ($\sim$2.8 TU). Mean transit times calculated using an exponential-piston flow lumped parameter model are 21 to 47 years. Tritium activities during the recession periods following winter high flows are higher (1.54 to 2.1 TU), which may reflect either the dilution of a baseflow component with recent surface runoff or mobilisation of different stores of water with different residence times (e.g., from the soils or the regolith) from within the catchment. The variation of major ion concentrations with discharge suggests it is more likely that that different stores of water from within the catchment are being mobilised rather than there being simple dilution of a baseflow component by rainfall. If a single store of water is assumed, mean transit times are 8 to 31 years for these winter flows. Despite the major differences in landuse, there is no significant difference in mean transit times between the two catchments; however, mean transit times do correlate with a combination of drainage density and the runoff coefficient. The observation that the water contributing to these upper catchment streams has mean transit times of years to decades implies that these streams are buffered against rainfall variations on timescales of a few years.

Numerical model simulations were performed to assess the reliability of the lumped parameter models when the assumptions are violated. Parameters assessed include variations in recharge, aquifer dimensions, as well as the influence of fractures and aquifer heterogeneity. Results of these simulations show that while mean transit time estimates differ from those made using the lumped parameter models, the overall conclusion that the mean transit times are in the range of years to decades remains.