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Towards predicting mean residence times in ungauged basins using conservative tracers and soil distributions

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In recent years, the Mean Residence Time (MRT) of water in catchments has been shown to be a very useful descriptor of hydrological function; as well as a valuable tool for inter-catchment comparison which is now also being used as a basis for model rejection. Intensive tracer-based studies and improved modelling techniques have been applied to increasingly constrain MRT estimates in experimental catchments. However, there has been little progress in producing MRT estimates for ungauged basins. This paper is based on well-constrained MRT estimates (from isotope tracers) from 15 experimental sites (0.9 to 230km2 in area) in the Scottish Highlands which were found to be strongly correlated with catchment soil distributions mapped using the UK Hydrology Of Soil Type (HOST) digital data base. These relationships are used to predict the MRT of 22 further Scottish catchments (ranging from 0.9 - 251km2 in area), which were treated as "ungauged" basins, even though tracer data were available. Catchment soils were classified into "responsive" soils (i.e. those likely to generate significant storm runoff) and "freely draining" soils (which mainly facilitate groundwater recharge) on the basis of hydrologic properties used in the HOST scheme. The percentage cover of soils classified as "responsive" was used to predict the MRT of the 22 "ungauged" basins. This compared reasonably well ($r2 = 0.602$, $p<0.001$) with MRTs independently estimated from the tracer data available for the 22 catchments. These predictions were improved ($r2 = 0.706$, $p<0.0001$) when only the percentage distribution of "responsive" soils in the riparian zone was used, presumably as this better captures the connectivity of runoff source areas to the channel network. The tracer data were also used to demonstrate that simple metrics of conservative tracer damping in input - output relationships can be used as a MRT proxy that compares well (r2

= 0.804, p>0.0001) with those estimated from more complex modelling approaches. These analyses show that soil maps have considerable potential for scale-independent estimates of MRTs in ungauged basins. Moreover, minimal tracer data requirements for estimating MRTs in sparsely instrumented basins can be defined. The implications for modelling and catchment management will be discussed.