National scale quantification and evaluation of travel times using a numerical groundwater flow model and observed proxy residence time indicators

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Coupled models of water resource, quality and ecological status at the national scale are being increasingly used to evaluate the impacts of climate and land use change on freshwater ecosystems. These models often have a highly simplified representation of the physics of groundwater flow and solute transport. The development of numerical groundwater flow models at the national scale affords significant potential to improve the representation of groundwater within coupled models. Here we develop a methodology to quantify and validate groundwater travel times (TTs) using a national-scale groundwater model, with the resulting TTs to be used in a coupled model. TTs in the saturated zone are derived from a distributed, steady state, groundwater flow model for the UK mainland using forward particle tracking. Saturated TTs are then combined with unsaturated zone TTs from previous published research. A novel rule-based methodology based on backward particle tracking simulations for over 2000 boreholes and proxy residence times indicators (CFC, SF6, and nitrate concentrations and trends) is used to validate the combined TTs. Results show that the combined simulated TTs are within observed ranges for > 76% of boreholes. TTs are greatest on the Chalk aquifer associated with thick unsaturated zones. The methodology developed can be applied to evaluate simulated travel times wherever there is a body of proxy residence time indicator data.

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