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A simple model of variable residence time flow and nutrient transport in groundwater dominated catchments

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A paradox arises when modelling flow and transport in permeable catchments: the response of the water table to major infiltration episodes is rapid (of the order of days), while chemical signals are strongly damped. This suggests that the water is of varying age, with a corresponding mixed history of nutrient loading.

A variety of conceptual models have been proposed to represent this dual response in an integrated way; however these rarely achieve a realistic response while being mechanistically plausible. They are also of limited value for application purposes, due to the high degree of both process and parameter uncertainty. At the other extreme, box models, commonly applied for predictive purposes in catchment modelling, are unable to represent such a history of loading due to the limited frequency response they produce.

However the incoming European legislation, requiring regulation of nutrient loading and predictions of future changes in water quality, places a demand on models that are able to represent the continuous nature of the nutrient loading in a parsimonious way.

This paper presents a pragmatic solution to this problem, with transport of solute and water treated separately through the unsaturated zone, and combined at the water table. However, the effect of varying residence times is included through considering the distance between the water table and the soil surface, and the history of nutrient application at the surface. If an average rate of downwards migration of the nutrients can also be assumed, it is possible to derive a travel time distribution of nitrate transport to the water table using a DTM (digital terrain model) map of elevation and information on groundwater levels (which may change over time, and can be represented within

the model). This distribution can then be implemented through difference equations.

The rationale behind the model and the resulting algorithm are described, and the resulting model applied to a hypothetical case study of nutrient loading located in the ground-water dominated Lambourn catchment in Southern England (sited above the Chalk aquifer). Simulated groundwater concentrations are very similar in magnitude and variability to observed Chalk groundwater series, suggesting that this simple conceptual model may well be able to capture the dominant responses of nutrient transport through permeable catchments.