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Extended Abstracts

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Data processing in hydrogeology

5.1
Modelling as a tool of groundwater assessment

title: **Stochastic simulation of geological heterogeneity for mapping catchment recharge**

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Quantifying recharge to aquifers that are overlain by glacial sediments presents two problems. First, detailed knowledge of the spatial pattern of the different glacial lithologies is not generally available. Second, recharge in these areas is not solely due to vertical flows from the soil zone to the underlying aquifer: lateral flow can occur within the subsurface above low permeability tills, producing significant recharge at the till edge. Where the low permeability till distribution is patchy, as observed across parts of the UK, it becomes more difficult to map the spatial distribution of lithologies and more important to estimate lateral flows. These two factors contribute to uncertainty in both the spatial and temporal distribution and magnitude of recharge. An approach based on stochastic modelling of the distribution of Quaternary glacial sediments is adopted to investigate uncertainty in recharge due to limited geological knowledge (Thatcher, 2008). This approach is tested for the Tern Catchment in Shropshire, UK for mapping catchment recharge to a till and outwash covered aquifer.

Stochastic simulation has been used to produce alternative maps of the Quaternary geology that overlies the regional sandstone aquifer in the Tern Catchment. In this catchment, the Quaternary geology comprises lodgement till and glacial outwash with limited areas of glaciolacustrine clays and, adjacent to the Tern river and its tributaries, fluvial deposits. Existing borehole and geophysical data that are available over the catchment were used to create a deterministic model of the Quaternary geology by the British Geological Survey. The same data were used to quantify the geostatistical model and condition the generated realisations of the outwash and till. An indicator simulation method was used to model the presence or absence of both till and outwash; catchment maps of both deposits are produced by overlaying an outwash realisation on top of a till realisation (Fig. 1).

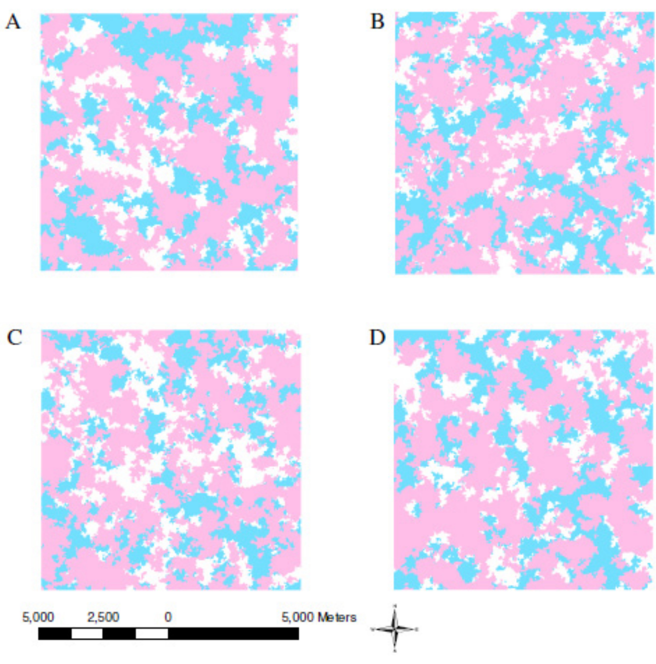


Figure 1. Four geostatistical realisations of till (blue) and outwash (pink) outcrop distribution in the Tern Catchment.

Areas of outwash overlying till are locations where sub-surface lateral flows above the buried till can occur. Lateral flows over buried till will impact aquifer recharge most significantly if the till is discontinuous, allowing lateral flow to become vertical at the till edge and contribute to the recharge of the underlying sandstone (Fig. 2). Such locations are termed "high recharge edges" in this work.

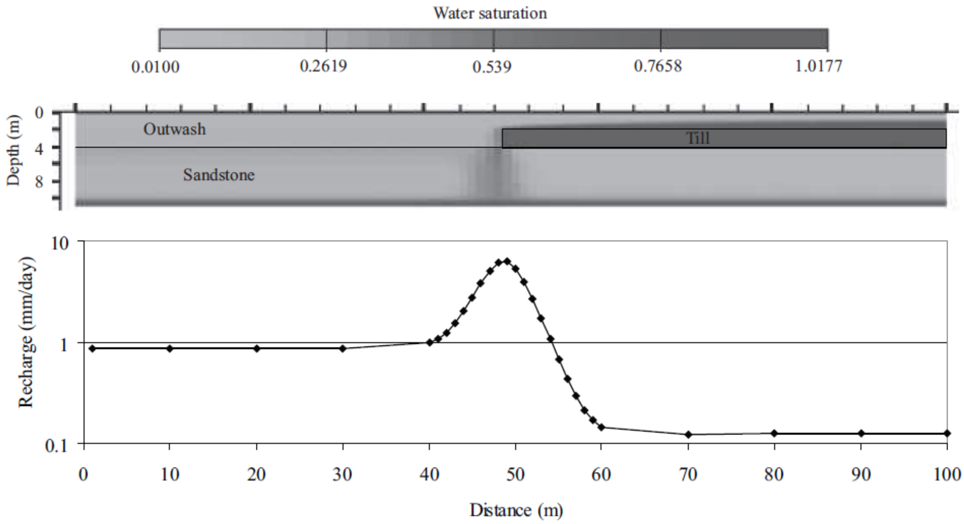
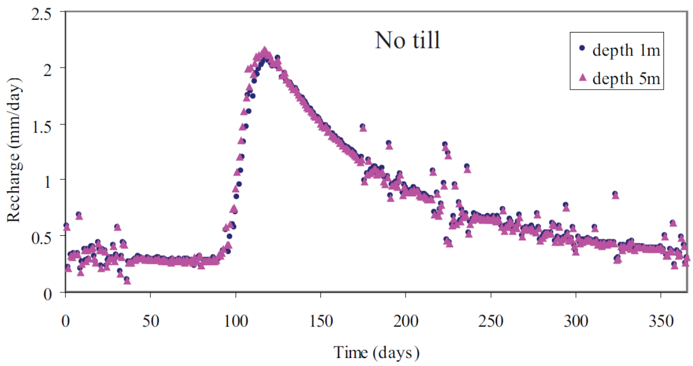


Figure 2. Moisture content for 2D profile orthogonal to the till edge and corresponding recharge to the sandstone aquifer.

The borehole data were also used to produce summary statistics on outwash thickness and the shape of the upper till surface across the catchment. Two-dimensional unsaturated zone flow simulations based on these summary statistics were used to estimate the magnitude of recharge along transects orthogonal to the till edge. Using a simple upscaling rule, these two-dimensional estimates were used to create maps of the spatial distribution of recharge to the aquifer for the distribution of glacial material generated in each realisation.

The resulting map of recharge distribution shows high spatial variability in recharge across the catchment and significant uncertainty in the location of "high recharge edges". "High recharge edges" are narrow zones, less than 20m wide and recharge is an order of magnitude higher than in adjacent areas not covered by till. The amount of recharge at the till edge is strongly dependent on exchanges of water at the soil/vegetation surface and on the thickness of outwash overlying the tills. As moisture content at the till edge is higher than surrounding areas throughout the year, relative permeability is higher in this location and recharge reaches the water table faster (Fig. 3). Around 25% of the recharge to the catchment arises at "high recharge edges", which account for less than 5% of the total catchment area.

The difference in recharge estimates for different geostatistical models is small (mean = 192mm/year, range 170-209mm/year), particularly in comparison with recharge estimated using the deterministic geological model (144 mm/year), which is not within the recharge limits defined by the stochastic models (Fig. 4).



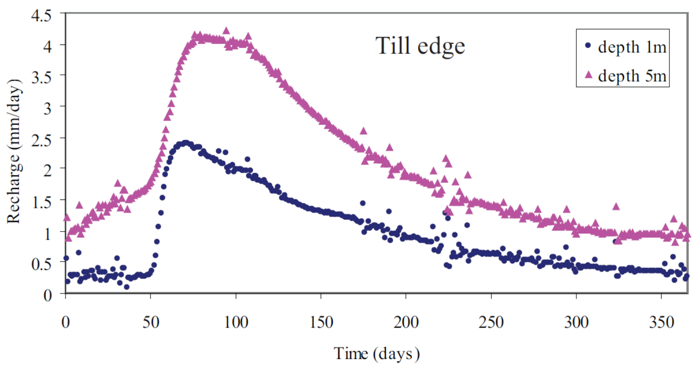


Figure 3. Timing of recharge for 2 till depths showing the early arrival of recharge signal at the recharge edge compared to locations away from till.

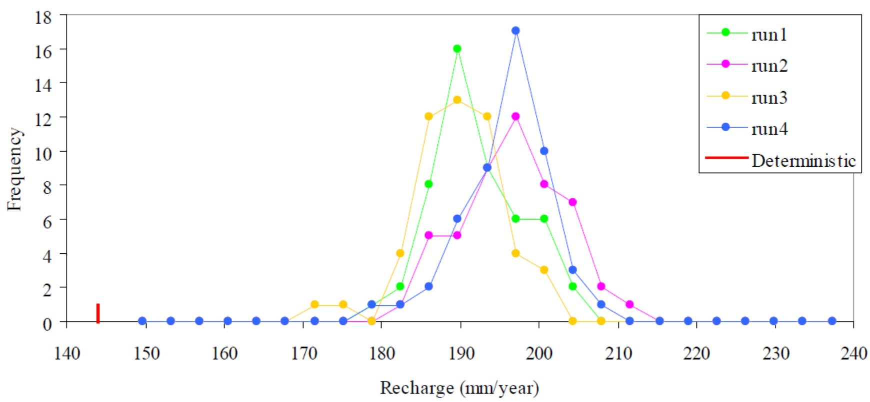


Figure 4. Total catchment recharge from 200 stochastic realisations and the deterministic model. Stochastic realisations are grouped into 4 runs according to slightly different variogram models used for both till and outwash distributions.

The geological realisation produced by deterministic modelling is much smoother than the stochastic realisations with fewer "high recharge edges" and only 5% of catchment recharge occurring in these zones. This implies that there is bias either in the deterministic model or the geostatistical model, but the available data do not allow us to determine which is more correct as both models fit the observations. The uncertainty in the spatial distribution of till and outwash leads to significant uncertainty in the predicted magnitude and spatial distribution of catchment recharge.

The relationship between catchment recharge and atmospheric variables, precipitation and evapotranspiration, is moderated by lateral flows within sediments above the groundwater table. These lateral flows are strongly dependent on the three-dimensional distribution of Quaternary deposits, resulting in a non linear relationship between recharge and atmospheric conditions. This is particularly significant for prediction of future recharge under climate change scenarios, where a simple scaling of catchment recharge with precipitation or evapotranspiration will not be appropriate.

By using stochastic simulation to produce possible conditional realisations of the Quaternary geology in the Tern Catchment, we have been able to build an understanding of the likely spatial distribution of recharge. The results confirm that geological knowledge is limiting accurate prediction of the location of "high recharge edges" but that these zones are crucial to the catchment water balance.

REFERENCES

Thatcher K.E., 2008: *Spatial characterisation and stochastic analysis of unsaturated flows and groundwater recharge through glacial drift*. PhD Thesis, University of Birmingham.

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