Application of the STIR model to a small river at different river flow rates

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ABSTRACT

The STIR (Solute Transport in Rivers) model describes solute transport along a river in terms of advection-dispersion occurring in the main channel together with a two-way transient exchange of solute between the main channel and surrounding storage zones. Although the STIR model has a multiple storage zone capability, here we used its single storage zone form, assumed an exponential residence time distribution and focused on short time-scale transient storage. The STIR model was applied to three reaches of a small river, namely the Murray Burn in Edinburgh. By fitting the model output to temporal solute concentration profiles observed during nine tracer experiments, four model parameters were estimated at flow rates between about 15 and 400 L/s. Hence it was possible to examine the nature of the variation of the parameters with river flow rate.

In all three reaches: the cross-sectional area of the main channel and the dispersion coefficient in the main channel increased with increasing river flow rate; the exchange rate between the main channel and the storage zones was approximately constant over the range of river flow rate; the mean storage zone residence time reduced with increasing river flow rate (see Fig. 1). One further (derived) parameter, namely the ratio of the cross-section occupied by storage zones to that occupied by the main channel reduced with increasing river flow rate (see Fig. 1). These trends are broadly consistent with the few previously published studies in which the flow rate dependence of transient storage model parameters has been considered.

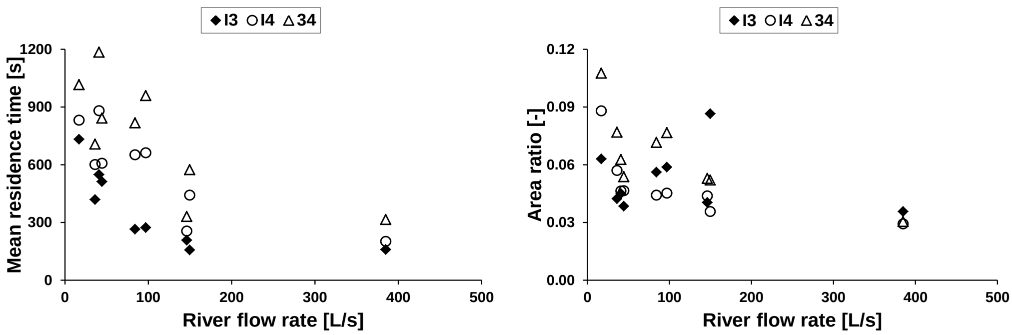

Fig. 1. River flow rate dependence of mean residence time and ratio of storage zone area to main channel area for three reaches on the Murray Burn: I3 indicates reach between tracer injection site and observation site 3; I4 indicates reach between tracer injection site and observation site 4; 34 indicates reach between observation sites 3 and 4.

The cross-sectional area and dispersion coefficient results were consistent with an independent analysis of the same tracer data that estimated the parameters of the Advection-Dispersion model. In particular the cross-sectional areas and dispersion coefficients from the latter analysis were larger by about 1% - 2% and by about 22% - 25%, respectively, than those from the STIR model, reflecting that the latter analysis yielded results for the whole river cross-section not just the main channel. This is illustrated in Fig. 2, which also shows the increasing trend with increasing river flow rate of these two parameters.

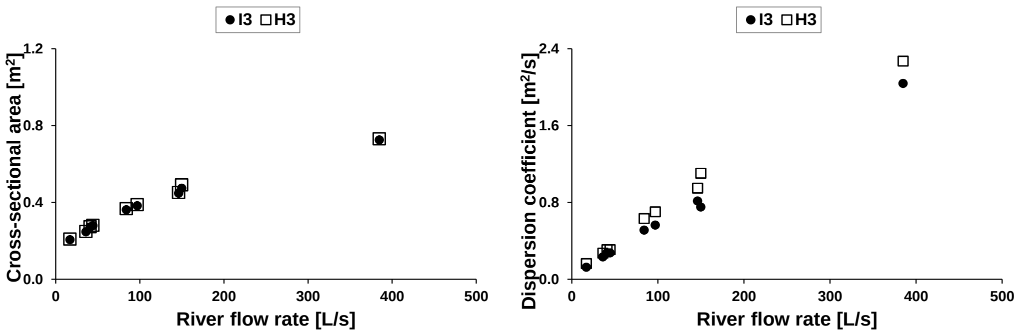

Fig. 2. River flow rate dependence of cross-sectional area and dispersion coefficient for reach I3 on the Murray Burn: I3 indicates STIR model results; H3 indicates Advection-Dispersion model results.

A comparison of the dispersion and transient storage results from reaches I3 and 34 suggested that these reaches have different longitudinal mixing characteristics. This is consistent with observed differences in geomorphology along the channel. In particular, the upper part of reach I3 is a natural, meandering, non-uniform channel with relatively large roughness elements which contrasts with the lower part of reach I3 and the whole of reach 34 which are straighter, more uniform channels with smaller roughness elements.