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Theoretical and practical limits to the use of storage cell codes for flood inundation modelling

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Since 1962 storage cell codes have been developed to simulate flow on fluvial and coastal floodplains. These models treat the floodplain as a series of discrete storage cells, with the flow between cells calculated explicitly using some analytical flow formulae such as the Manning equation. Recently these codes have been reconfigured to use regular Cartesian grids to make full use of widely available high resolution data captured from remote sensing platforms and stored in a raster GIS format. Such raster-based storage cell codes have many of the advantages of full two-dimensional de St Venant schemes but without the computational cost, and have been used successfully in a number of flood inundation modelling studies. These studies are reviewed and the nature of the model validation evidence assessed. For each modelled event this is shown to consist, at best, of hydrometric data and single images of flood extent derived from air photo data, and airborne and satellite Synthetic Aperture Radars.

Despite their ability to successfully replicate this data, the simplifying assumptions made in the development of storage cell codes do lead to a number of theoretical constraints to their usage. These include an inability to develop solutions that are independent of time step or grid size, and an unrealistic lack of sensitivity to floodplain friction. In this paper, we (i) illustrate these problems through a number of hypothetical test cases and (ii) propose a novel solution to these problems based on an optimal adaptive time step determined using the CFL condition for model stability. Comparison of this new unconditionally stable scheme to analytical solutions of wave propagation on flat and sloping planar surfaces shows considerable improvement over

a standard explicit raster storage cell model. Moreover, the new scheme is shown to yield results that are independent of grid size or choice of initial time step and which show an intuitively correct sensitivity to floodplain friction over spatially-complex topography.

Given these pervious problems, the question arises as to why storage cell codes have thus far been able to replicate available validation data as well or better than alternative hydraulic models? In this paper we show this is because of the inability of the validation evidence to discriminate conclusively between the dynamic performance of competing model structures or parameterizations. Hence, hydrometric data are 1D in time but 0D in space and cannot therefore test the spatial ability of a model and single synoptic images of inundation extent are 2D in space but 0D in time and therefore do not test model performance through time. As the above problems with storage cell codes relate to dynamic changes in spatial patterns, they require data that has dimensions of both space and time in order to identify their impact. At present, known problems with existing storage cell codes can largely be compensated for in the model calibration and they do not prevent the model being able to match the available data to within the observation error. Rigorous validation will therefore only be achieved with data consisting of sequences of high spatial resolution inundation extent maps through a flood hydrograph. Whilst other hydraulic model structures will not suffer from the same theoretical constraints as storage cell codes, the practical limits to model validation imposed by the quality of available data will still apply. Until better data become available, the further development of our ability to model flood inundation with all classes of code will therefore be fundamentally limited.