A GEOMORPHOLOGICAL COMPARISON BETWEEN A CAESAR-LISFLOOD LANDSCAPE EVOLUTION MODEL'S NET ELEVATION CHANGE OUTPUT AND A HEC-RAS 2D HYDRAULIC MODEL'S SHEAR STRESS OUTPUT

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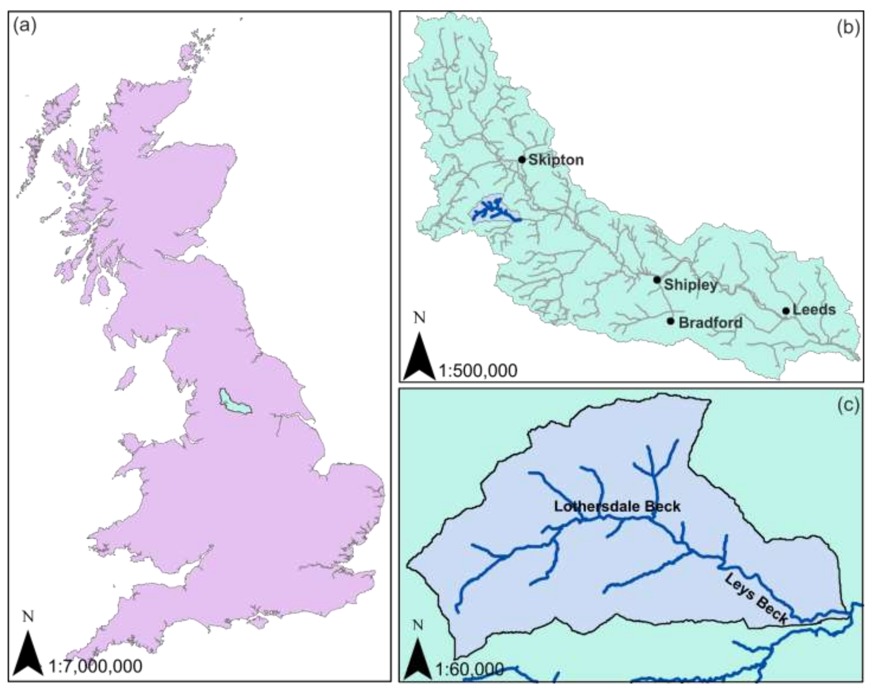
1. INTRODUCTION

- Hydraulic models have been built for areas across the country containing a wealth of information, often not exploited during flood risk assessments.
- Such information includes calculations of shear stresses in which information regarding the potential for sediment transport can be sought.
- If these shear stress data sets can be shown to match well with observed and modelled results, they would provide a valuable resource for those interested in the effects of sediment dynamics without the need for expensive monitoring campaigns or extensive morphodynamic modelling efforts.
- In this study, a comparison between maximum shear stress data from a hydraulic HEC-RAS 2D model was compared to the net elevation change from a landscape evolution CAESAR-Lisflood model.

2. METHODOLOGY



- Lothersdale is a small upland catchment (12.9 km^2) contributing to the larger Aire catchment that runs through Leeds. The land use consists primarily of pasture and heath.

Figure 1: Catchment location (a) the Aire catchment located nationally, (b) the Lothersdale catchment located within the larger Aire catchment and (c) the drainage network located within the Lothersdale catchment

- A CAESAR-Lisflood model was set up using a 2m resolution composite LiDAR DEM and model parameters optimised based on a wider sensitivity analysis and knowledge following site visits to the catchment. The model was spun up to create a more realistic catchment wide sediment distribution and DEM.
- A HEC-RAS 2D model was set up using the DEM from the spun up CAESAR-Lisflood model. Parameter values were as closely matched with those of the CAESAR-Lisflood model as possible.
- A ReFH model rainfall time series was run through both models, which had a 47 hour duration and a 120 year return period, this was a similar size to the Boxing Day 2015 event which caused properties further downstream to flood.
- The CAESAR-Lisflood elevation data from the end and the beginning of the model simulation were subtracted to create net elevation change. All positive change was reclassified as deposition (1) and negative change as erosion (-1).
- The HEC-RAS 2D maximum depth and velocity data was taken and maximum shear stress was calculated using a single value for Manning's n (0.032) and spatially distributed values that were used in the model (0.024 – 0.07) (Eqn.1) (Lane and Ferguson, 2005).

$$\tau = \frac{\rho g n^2 U^2}{d^{1/3}} \quad (1)$$

U = depth-averaged velocity, d = depth, and n = Manning's roughness

- A value for critical shear stress was calculated (Eqn.2), this critical shear stress was used to define areas of erosion (areas with a shear stress above the critical value) and deposition (shear stresses below the critical value).

$$\tau_{ci} = \tau^*_{c_{50}} \rho_s g D_{50} \quad (2)$$

τ_{ci} = Critical shear stress; $\tau^*_{c_{50}}$ = Shields parameter (-); ρ_s = Rock density; g = Gravity; D_{50} = median grain size (m)

- The effect of the Shield's parameter value chosen was tested based on various values stated in the literature (Table 1).

Table 1: Values of the Shield's parameter tested

Value	Reason for choice	Reference
0.06	Original value	Shield (1936)
0.045	More recent common value	Yalin and Karahan (1979)
0.03	Lowest value found	Lavelle and Mofjeld (1987)
0.086	Highest value found	Buffington and Montgomery (1997)

- The D_{50} was taken as the catchment mean D_{50} from the spun up CL model (0.031m).
- Visual comparisons were made in combination with assessment of aerial imagery taken in April 2015 and June 2018.
- The F co-efficient (Horritt and Bates, 2001), a metric to compare binary patterns of modelled and observed data, was altered to compare patterns of erosion or deposition between the two models.

$$F = \frac{CL1HEC1}{(CL1HEC1 + CL1HEC0 + CL0HEC1)}$$

CL1HEC1 = # erosion/deposition cells in both models; *CL1HEC0* = # erosion/deposition cells in CAESAR-Lisflood but not HEC-RAS; *CL0HEC1* = # erosion/deposition cells in HEC-RAS but not CAESAR-Lisflood

- Values range from 0 for no correct predictions to 1 for perfect prediction
- F was used to assess the effect of spatially distributing Manning's n in Equation 1 and the effect of values of the Shields parameter in Equation 2.

3. RESULTS

- The hydrological response from the CAESAR-Lisflood model and HEC-RAS 2D model to the ReFH model rainfall time series showed a similar magnitude of discharge at the catchment outlet and both model responses were similar to the ReFH model direct runoff (Figure 2).

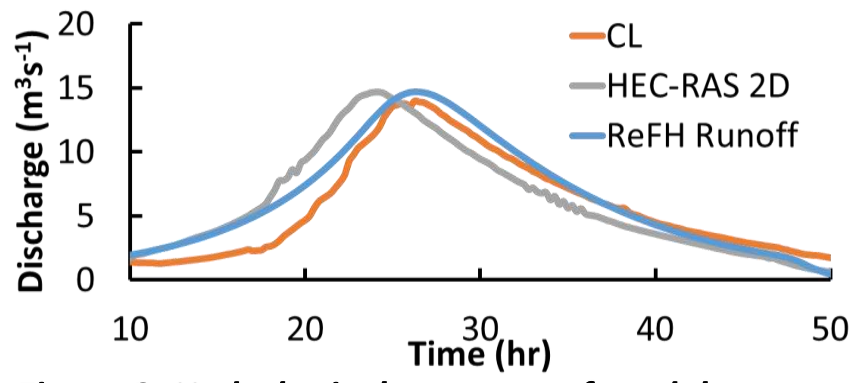


Figure 2: Hydrological response of models compared to ReFH runoff

Table 2: F co-efficient for sensitivity to Manning's n and Shields parameter

	Lumped Manning's n		Spatial Manning's n	
Shields	Erosion	Deposition	Erosion	Deposition
0.086	0.056	0.145	0.126	0.140
0.06	0.111	0.126	0.169	0.128
0.045	0.156	0.102	0.186	0.109
0.03	0.183	0.070	0.199	0.078

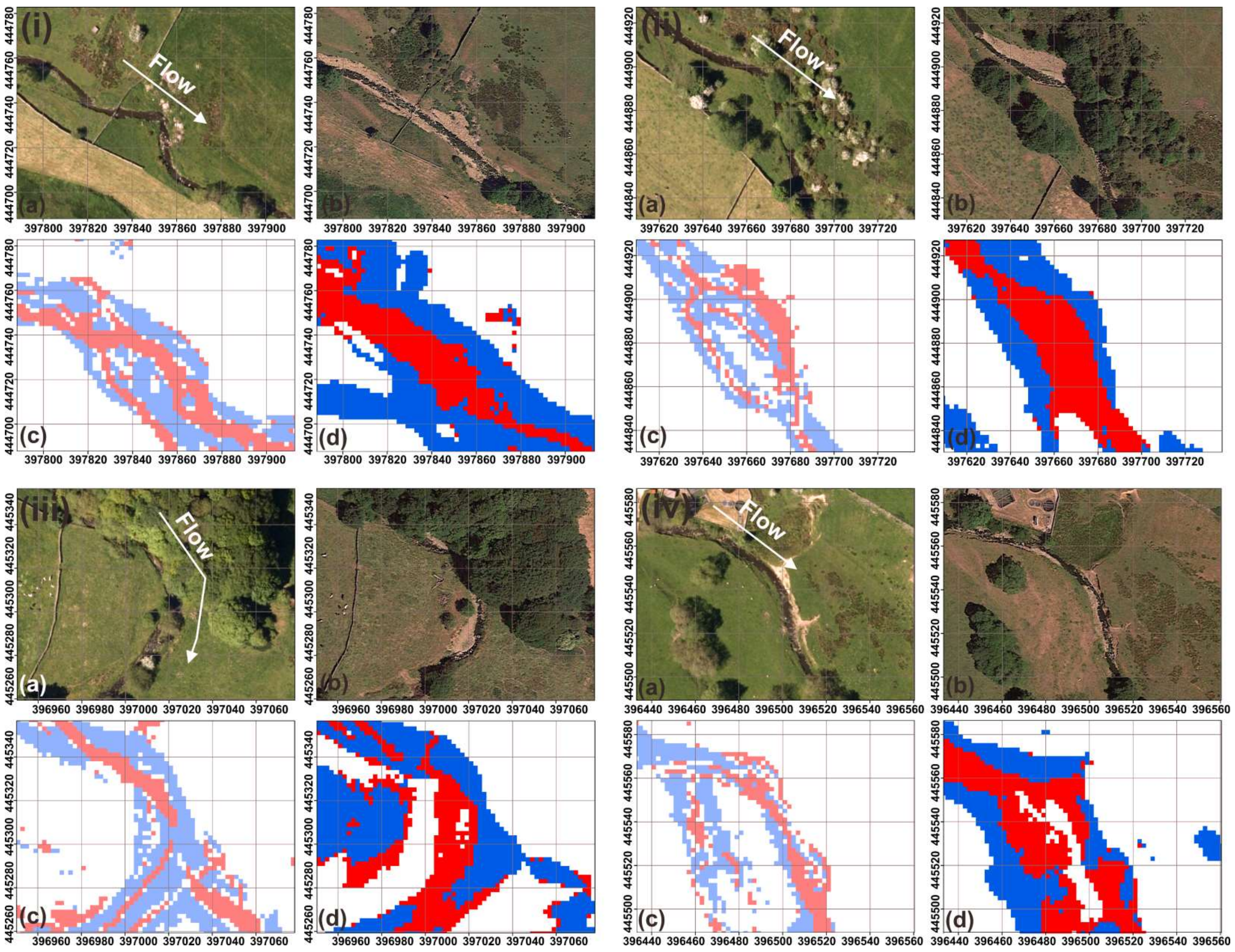


Figure 3: Examples of model outputs with aerial imagery with (a) 2015 aerial imagery; (b) 2018 aerial imagery; (c) CAESAR-Lisflood output; (d) HEC-RAS 2D output, both whereby blue is deposition and red is erosion.

- Shear stress calculated using spatially distributed Manning's n increased F particularly for erosion due to the addition of a separate Manning's n value for the channel (Table 2).
- Decreasing the value of the Shield's parameter increased F for erosion cells, as the shear stress threshold for erosion was lower for a lower Shield's parameter value (Table 2).
- Figure 3(i) shows that both models suggested a straightening of the channel and deposition either side with a band of erosion through the centre of the plot.
- Figure 3(ii) highlights added complexity within the CAESAR-Lisflood model that is not apparent in the HEC-RAS output, although both suggest deposition where the bar is visible in the 2018 aerial imagery.
- Figure 3(iii) shows deposition on outer arc of meander in both models, however the inner bank shows deposition in CAESAR-Lisflood, but erosion in the HEC-RAS model.
- Figure 3(iv) shows similarity between the models upstream in terms of deposition and on the right hand side of the figure in terms of erosion.

4. DISCUSSION

- Slight differences in the methodology for the two models may factor into the low F scores.
  - HEC-RAS cannot account for change occurring from the change in elevation through time.
  - HEC-RAS output is derived from the event peak, whilst the CAESAR-Lisflood output is derived from the event as a whole.
- The models appear to exaggerate the extent of geomorphological activity.
  - Modelled outputs are reclassified into binary maps, thus all magnitude of change is shown as a single value much of which would not be observable from aerial imagery.
  - Only large differences are visible in the imagery e.g. bar formation and channel migration.
- With careful consideration alongside aerial imagery or site walk overs, hydraulic models can be used to evaluate geomorphological dynamics in areas of a catchment.
  - HEC-RAS produces general patterns, though CAESAR-Lisflood appeared far more realistic, particularly for variability across the channel and within a reach.
  - Thus an understanding may also be achievable for hydraulic structures, which are often too complex to be implemented into morphodynamic models, allowing for structure design to be aided through an acknowledgement of its geomorphological impact.

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