# Implementation of runoff attenuation features into a landscape evolution model for the assessment of the impact on catchment sediment dynamics

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## 1. INTRODUCTION

- **Natural flood management** (NFM) has been **increasingly implemented** throughout the UK (Dadson et al., 2017).
- **Run-off attenuation features** (RAFs) are among the NFM measures being implemented (Nicholson et al., 2019).
- They seek to **temporarily store flood water** through the use of **man-made structures** to **lengthen flow pathways** (Wilkinson et al., 2013).
- RAFs include a number of designs such as **leaky barriers**, **storage ponds** and **bunds**, with measures being chosen depending on **cost**, **location** and **material availability**.
- Current **knowledge** of their benefits is **primarily hydraulic.**
- **Geomorphological impact** is also **important - scour** and **sedimentation** being potential issues for their **management**.
- *Therefore this study looked to* ***implement RAFs*** *into a* ***landscape evolution model*** *to assess their* ***geomorphological impact***.

## 2. METHODOLOGY

- Eastburn Beck is a **40.8 km² catchment** within the larger Aire catchment in West Yorkshire, UK.
- The catchment has **known sediment issues:**
  - A sediment trap at the outlet fills regularly.
  - SCIMAP showed the highest mean channel sediment accumulated risk for any of the Aire sub-catchments.

## 2. METHODOLOGY

- A **CAESAR-Lisflood** model was set up using a **4 m resolution** DEM, with model parameters optimised based on a wider sensitivity analysis.
- The model was **spun up** using a repeated rainfall time series spanning 20 months.
- Rainfall data implemented into the model was for the **Boxing Day 2015** event.
- **274 RAF locations** were identified by using the **WWnP 1 in 100 year RAF opportunity maps** (Burgess-Gamble et al., 2017).
- RAFs were implemented into the model by **editing the DEM** to create features of **increased elevation (2m)**, in a similar fashion to building **earth bunds**.
- RAF **designs** were implemented based on **shape**, **size** and **quantity** (Fig. #).

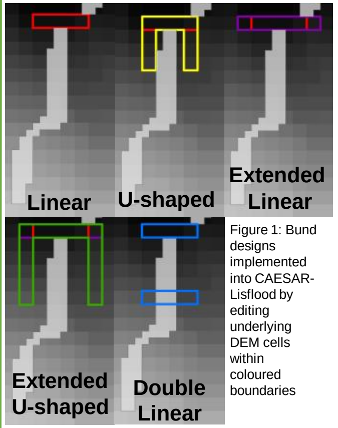


Figure 1: Bund designs implemented into CAESAR-Lisflood by editing underlying DEM cells within coloured boundaries

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## 3. RESULTS

**Catchment outlet (Fig. 2):**

- **Little change** in **water discharge** (Fig. 2a).
- **Sediment volume increase** (Fig. 2b):
  - **Linear** (4.37% from baseline)
  - **U-shaped** (7.28%)
  - **Extended Linear** (2.83%)
- **Sediment volume decrease** (Fig. 2b):
  - **Extended U-shaped** (1.53%)
  - **Double Linear** (6.27%)
- 8.4% **increase** in **suspended sediment** for **Double Linear** bunds.
- 21% **decrease** in **largest grain size fraction** for **Extended U-shaped** bunds.

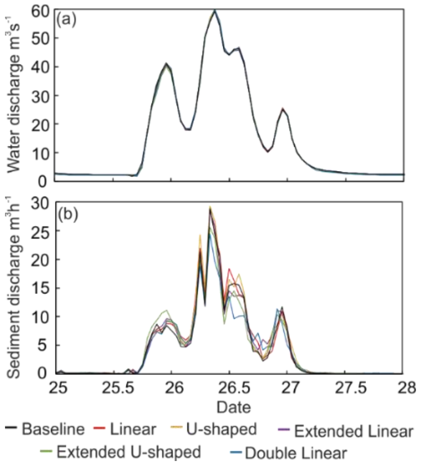


Figure 2: Discharge at the catchment outlet (a) water and (b) sediment

**Water volume held upstream (Fig .3):**

- Number of features:
  - **Least – Linear**
  - **Most – Extended U-shaped**
- Volume at event peak:
  - **Least – Linear** (Med.=12.6m³)
  - **Most – Extended U-shaped** (Med.=150m³)

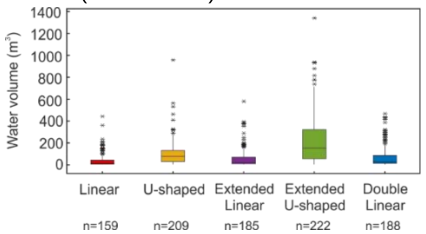


Figure 3: Water volume held upstream of different bund designs

**Whole catchment net elevation change** (Fig. 4)**:**

- **Little difference** between the **bund designs**
- **Less than 1% change** in area for any given magnitude.

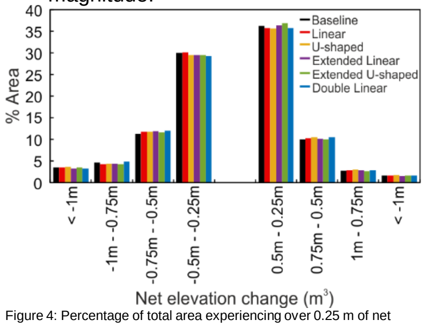


Figure 4: Percentage of total area experiencing over 0.25 m of net elevation change

**Negative volumetric elevation change upstream of features** (Fig. 5)**:**

- Number of features:
  - **Least – U-shaped**
  - **Most – Extended Linear**
- Volume lost between Day 24 and 28:
  - **Median** volume between **2 m³ and 4 m³** for **all bund designs**.
  - **Maximum** volume:
    - **Smallest – U-shaped** (11.5 m³)
    - **Largest – Extended Linear** (149.8 m³)

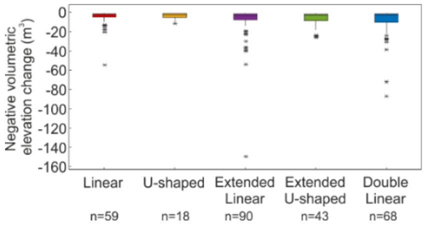


Figure 5: Negative volumetric elevation change for different bund designs

***Many of the features themselves experienced erosion (Table 1).***

Table 1: Number of bunds experiencing erosion

| Linear | U-shaped | Extended Linear | Extended U-shaped | Double Linear |
|---|---|---|---|---|
| 93 | 106 | 117 | 131 | 117 |

***A greater number of bunds exhibited positive volumetric change (deposition) than negative volumetric change (erosion).***

**Positive volumetric elevation change upstream of features (Fig. 6):**

- Number of features:
  - **Least – U-shaped**
  - **Most – Extended Linear**
- Volume gained between Day 24 and Day 28:
  - **Median** volume between **3 m³ and 5 m³** for **all bund designs**.
  - **Maximum** volume:
    - **Smallest – U-shaped** (29.7 m³)
    - **Largest – Extended U-shaped** (138.1 m³)

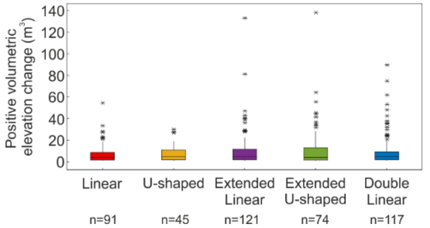


Figure 6: Positive volumetric elevation change for different bund designs

Burgess-Gamble, L., Ngai, R., Wilkinson, M., Nisbet, T., Pontee, N., Harvey, R., Kipling, K., Addy, S., Rose, S., Maslen, S. and Jay, H. 2017. *Report No. SC150005.* Environmental Agency.

Dadson, S.J., Hall, J.W., Murgatroyd, A., Acreman, M., Bates, P., Beven, K., Heathwaite, L., Holden, J., Holman, I.P., Lane, S.N. and O'Connell, E. 2017. *P. ROY. SOC. A-MATH. PHY.* ***473***(2199), pp. 1-18.

Nicholson, A.R., O'Donnell, G.M., Wilkinson, M.E. & Quinn, P.F. 2019. *J. Flood Risk Manag.* **13**(S1), pp. 1-14.

Wilkinson, M.E., Quinn, P.F. & Welton, P. 2010. *J. Flood Risk Manag.* **3**(4), pp. 285-295

## 4. DISCUSSION

- **Greater differences** occurred **locally** compared to the **catchment as a whole**.
  - The **features** are **relatively small**, their **impact** on hydrology and geomorphology are **lost**, particularly as many are **located** on the **smallest, upstream channels**.
- **Adds to literature** evidence that there is **little hydrological effect** of such features **at larger scales** (Dadson et al., 2017). Importantly, our study suggests this is **also the case for geomorphological impact**.
- **Deposition** was **more prevalent upstream** - bunds **inhibit the water flow**, **increasing depth and decreasing velocity** of water behind features, **increasing the likelihood of deposition.**
- A large proportion of the **features themselves experienced erosion** – due to **overtopping** of features

Our study has highlighted the **need to understand the geomorphological impact of RAFs** as they will require **future management** for likely **scour** and **sedimentation**, **reducing efficiency** and **cost effectiveness**.