# Morphodynamic styles: a novel index of gravel-bed river behaviour

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**Abstract**

The interaction between form and process within a river produces the variety of morphodynamics we observe in channels. This poster presents a method using a simple index of channel behaviour that quantitatively represents the style of deformation a river reach undergoes. We term this index the throughput ratio (ζ), and it is calculated by comparing the volume of morphologic change recorded during an event to the volume of sediment transported during the event. The ratio of these two volumes represents a change in behaviour from exchange-based deformation of the channel ($\zeta < 1$) to a more resilient throughput channel state where material is sourced from upstream, does not interact with the reach in question and is transmitted through ($\zeta > 1$). A pair of experiments that developed different morphodynamics whilst sharing the same initial width, slope, discharge and grain size were used to demonstrate this methodology and interpretation of the results. The difference in morphodynamics between the channels was due to the presence of inerodible banks in one experiment, and a freedom to widen in the other. The inclusion of fixed banks prevented the system from being able to adjust its channel cross-section as freely, and maintained a high but variable sediment throughput over the experiment. In the system with mobile banks, the channel widened and exhibited a greater capacity to store sediment inside and outside of the active channel, causing the sediment transport rate to decline to zero during the experiment. In both, the rate of morphologic change tended to zero despite their marked differences in sediment transport over time. As a result, the throughput ratios depict two contrasting evolutions of channel behaviour. The differences in trajectory are due to the processes available to each system and their feedback with channel form. This approach provides a new method of representing channel character that may act to supplement existing analyses of river behaviour.

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## Introduction

Fluvial classification systems predominantly rely on form-based metrics to delineate channel type[1]. Although process is implicit in some indices used in classification such as channel sinuosity or Shields number[2,3] there are opportunities to improve channel characterisation with the inclusion of process. One such aspect of channels is the relationship between morphology and sediment transport (Figure 1).

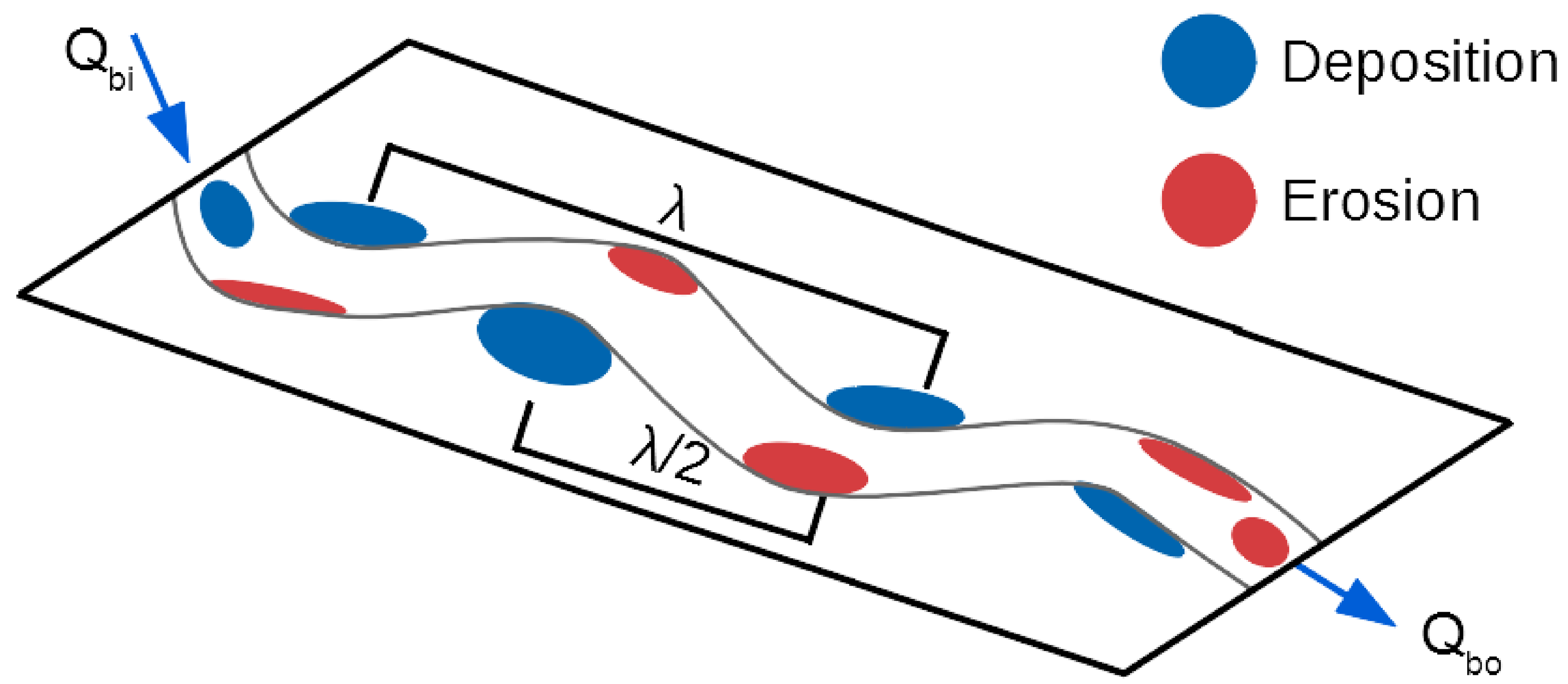



Figure 1. λ is the wavelength between two sequential zones of deposition or erosion, assumed to reflect the characteristic transport length of bed load. It is thought to scale with width[4] or more commonly wavelength of bed forms[5]. This distance varies in response to bed state and flow condition[6] and may extend past λ, causing reaches to throughput material downstream.

The style of deformation- in other words, character- exhibited by a river reach is reflected in the interaction between the volumes of sediment transport and morphologic change. We present an index here to quantify this behaviour.

## Methodology

We conducted paired experiments using Froude scaled, recirculating models with the same grain mixture and discharge. The fixed bank experiment used inerodible lateral boundaries and the mobile bank experiment used bed material as its boundary.

The 'throughput ratio' (ζ) represents the relative dominance of transport or bed deformation:

$$\zeta = \frac{Q_b \Delta t}{M}$$

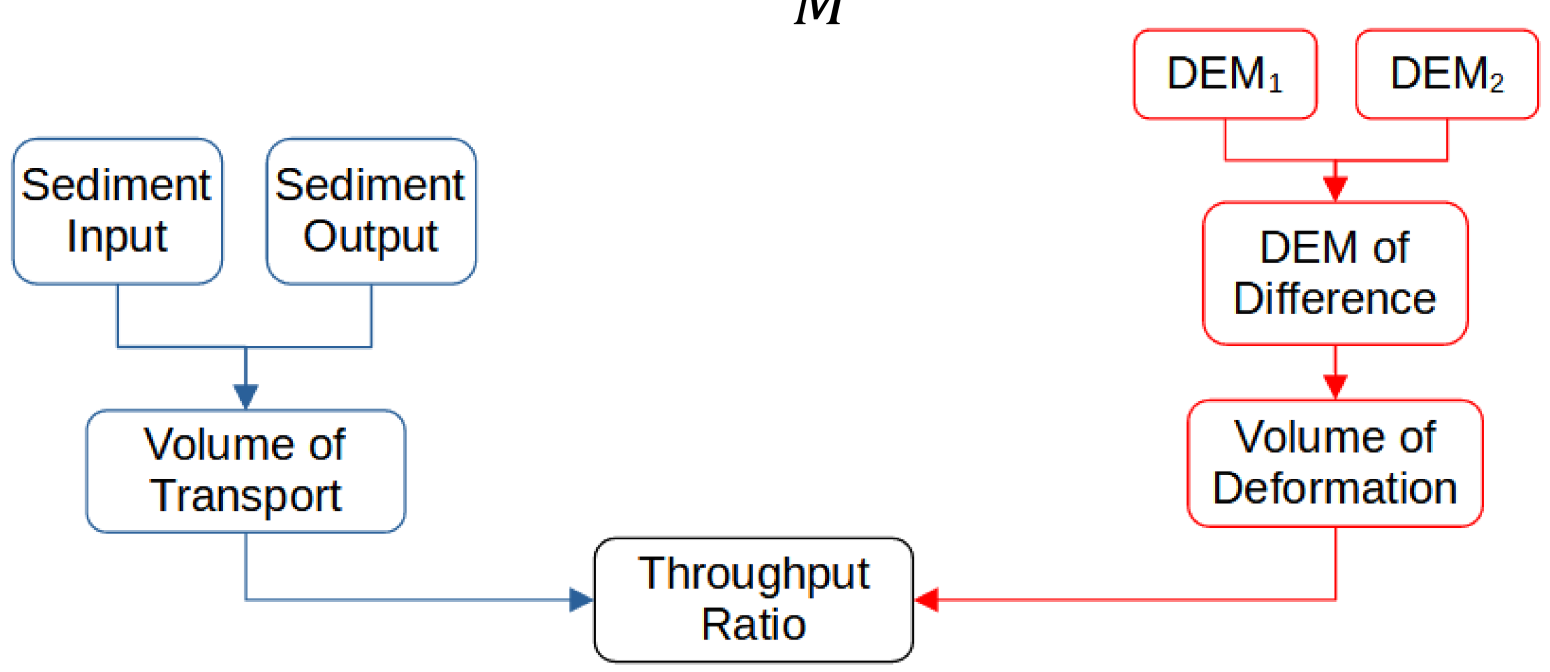



Figure 2. The throughput ratio is calculated as the ratio of the total volume of sediment transport, given by sediment output, to the volume of bed deformation, given by the difference in surface elevations, between two timesteps.

$Q_b$ is the volumetric transport rate, $\Delta t$ is the timestep and $M$ is the total volume of deformation between successive DEMs.

## Results

The presence of fixed banks caused the channel to evolve from an initial period of bed reorganization to establish a **throughput dominated system** as there was a limited ability to decrease transport capacity. In contrast, the mobile banks widened and stabilised the bed and banks resulting in a system that was primarily **exchange oriented** through small scale internal reorganisation of sediment.

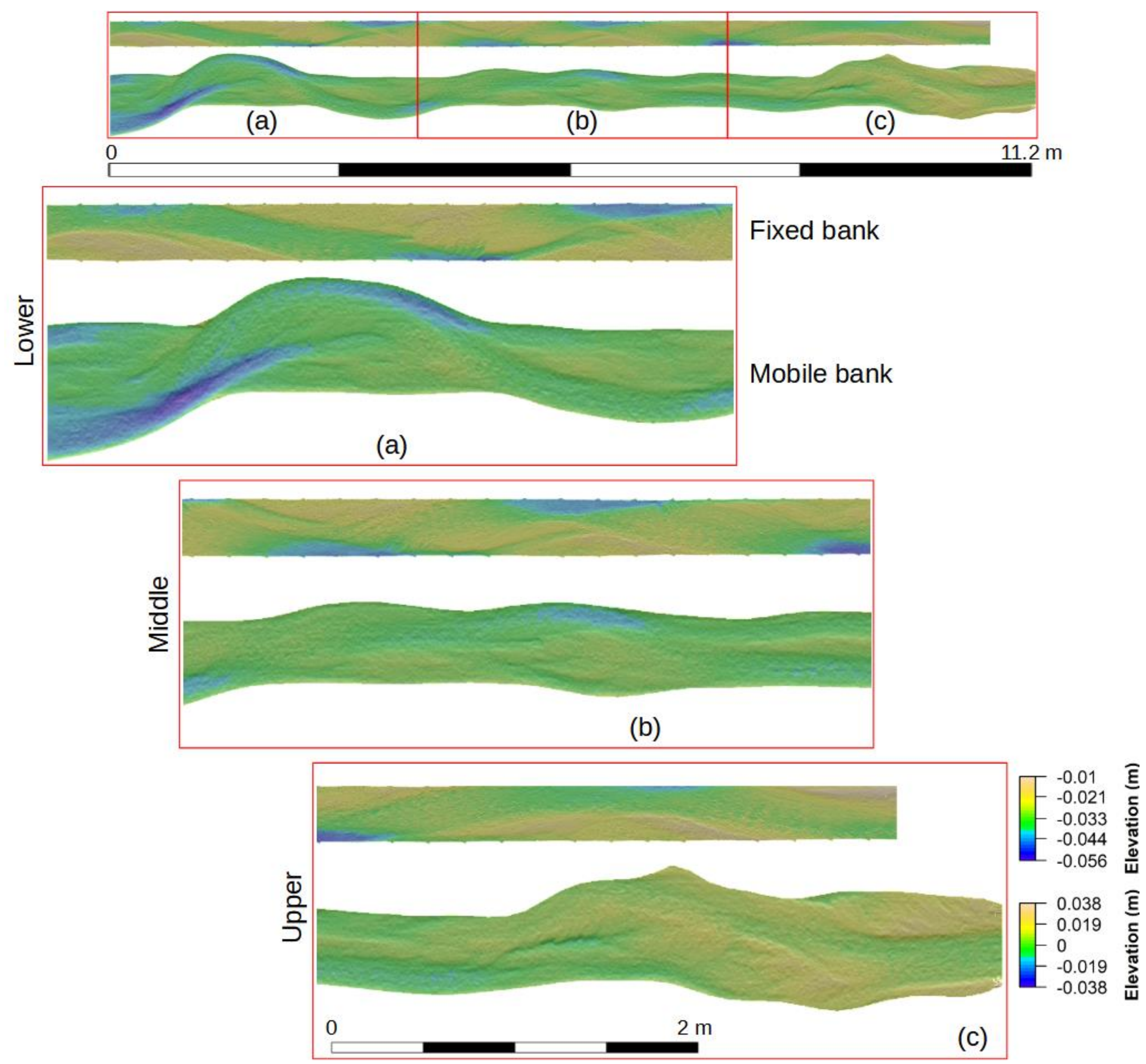



Figure 3. DEMs showing difference in morphologies from the final scan of the fixed bank (upper) and mobile bank (lower) experiments, (a-c) downstream, middle and upstream sections, in greater detail.

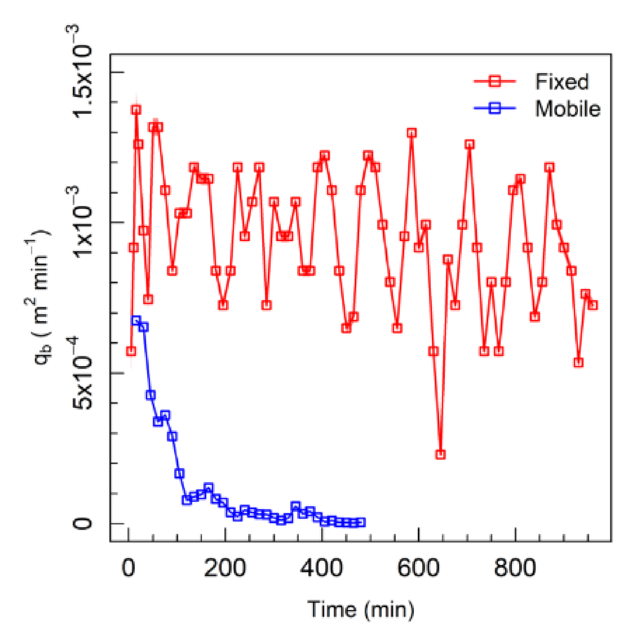



Figure 4a. Unit volumetric rates of sediment transport show a clear distinction between the maintained output with fixed banks and the decreased output with mobile banks.

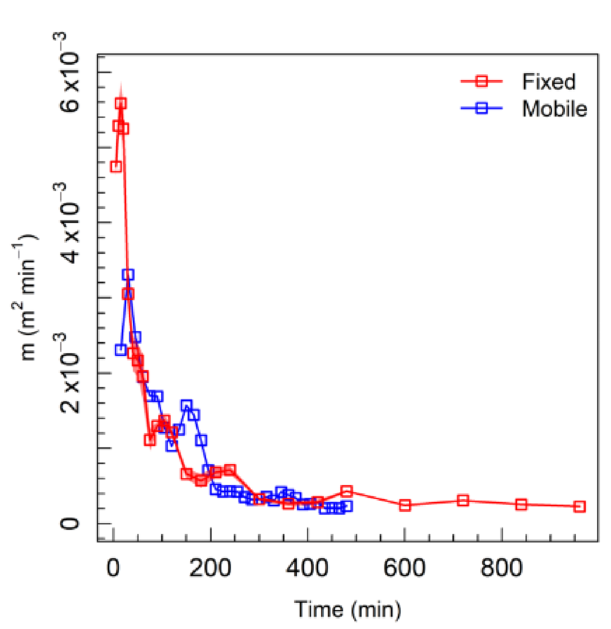



Figure 4b. Unit volumetric rates of bed deformation both follow an exponential decrease over the course of each experiment, stabilising at roughly the same value.

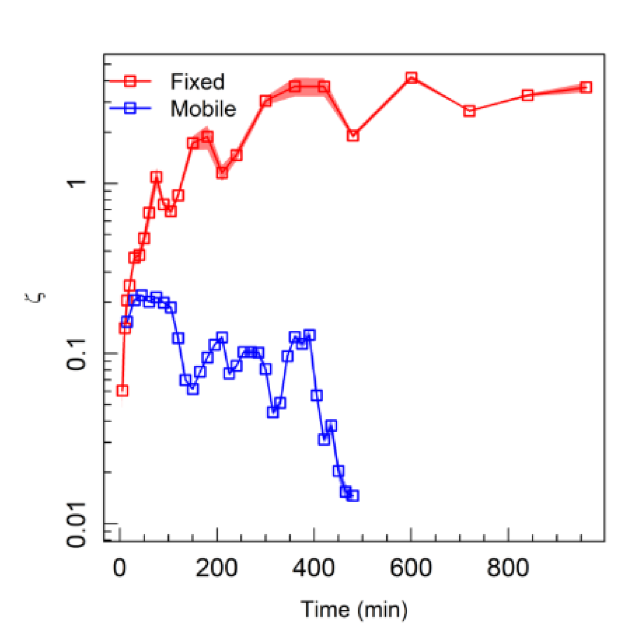



Figure 4c. Resulting throughput ratio calculation of the volumes of transport and bed deformation show a strong divergence in character from an initial similar position.

## Summary

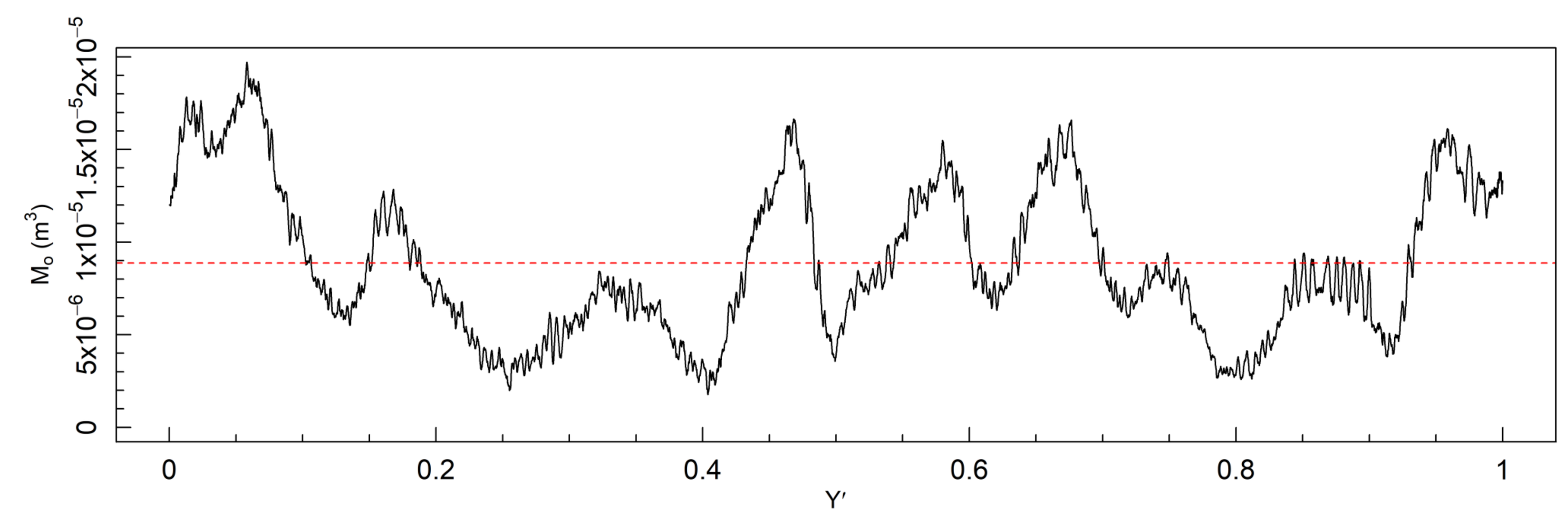
The style of deformation exhibited by each channel was controlled by the availability of processes in each experiment. Through channel widening and decreased sediment connectivity through upstream deposition (Figure 3c) the character of the channels followed two distinct trajectories.

Metrics such as Shields number or changes to shear stress distribution would also demonstrate similar results to these findings but require further data for calculation (i.e., bed surface texture) or validation (i.e., flow modelling). The throughput ratio provides an index to supplement well established systems of channel classification using data typically collected in laboratory and field settings.

Using high resolution data also provides the opportunity to generate information on the spatial nature of channel character by using the longitudinal pattern of deformation to adjust the reach average throughput ratio (Figure 5).


$$M_r = \frac{\overline{M_o}}{M_o}$$

$M_r$ is the ratio of the mean ($\overline{M_o}$) to the observed ($M_o$) volume of deformation at each cross-section




$$\zeta_{adj} = \zeta \frac{M_r}{\overline{M_r}}$$

$\zeta_{adj}$ is the adjusted, spatialised value of ζ according to the ratio of $M_r$ to $\overline{M_r}$

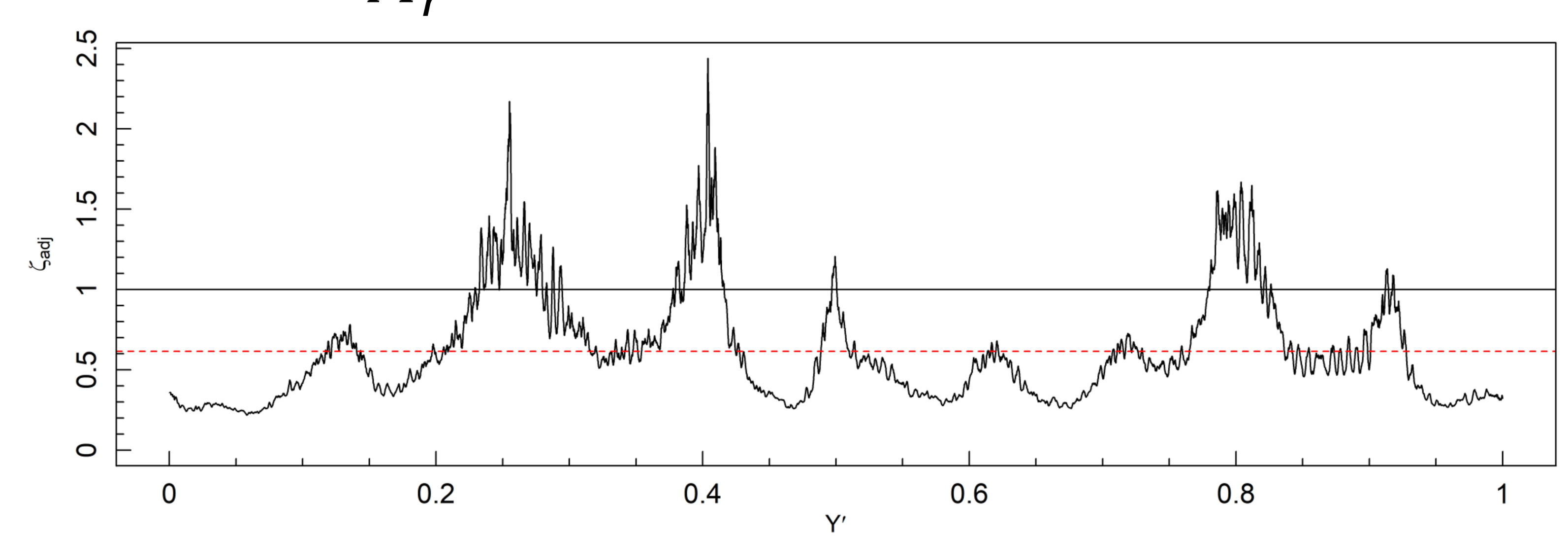



Figure 5. Spatialisation of an example timestep in the mobile bank experiment. (a) DEM of Difference, (b) distribution of total bed deformation per cross-section downstream- red dashed line shows the value of $\overline{M_o}$ and (c) resulting throughput ratio at each cross-section- red dashed line shows the reach average value ζ, black line is equal to unity.

## References

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