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Riverbank protection removal to enhance habitat diversity through bar formation

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Introduction

Over the past centuries natural river banks have been transformed into banks with artificial revetments or sheet piles to protect them from erosion. Important river features for flora and fauna have disappeared and the ecological quality of the river reduced dramatically. Recently, the importance of the ecological function of rivers has been getting more attention. One river restoration measure is the removal of man-made bank protections to increase habitat diversity and biodiversity of riparian areas and the river basin. The river morphology may change due to the freely eroding banks in the restored section. Reference projects show that the removal of bank protection along rivers may lead to the formation of bars (e.g. Schirmer et al., 2014). Bars increase morphological diversity, providing specific habitats for flora and fauna (Kurth and Schirmer, 2014).
There is a lack of knowledge about the formation of bars related to the length and location of the removal of bank protection. The length of river bank protection removal is usually limited, due to human activities along the riversides. Therefore, a guideline is needed for the design of bank protection removal to enhance habitat diversity through bar formation to make this a feasible river restoration method.

Methodology

We carried out mobile-bed flume experiments in the Fluid Mechanics Laboratory of Delft University of Technology. The experiments were focussed on how the length of bank protection removal changed the formation of bars. Furthermore, the experiment was aimed at finding geometrical changes in the setup that led to a difference in bar formation.

Experimental setup

Geometrical and morphodynamic characteristics were selected for the experiment having bar mode = 1 to obtain a system with alternate bars. The bar mode was calculated with the physics-based predictor of Crosato and Mosselman (2009) that estimates the number of bars in a river cross-section:

$$m^2 = 0.17g\frac{(b-3)}{\sqrt{\Delta D_{50}}}\frac{B^3 i}{CQ} \qquad (1)$$

where: m = bar mode, b = degree of nonlinearity of the dependence of sediment transport on depth-averaged flow velocity, B = river width, C = Chézy coefficient, i = longitudinal gradient, D_{50} = median sediment grain size, g = gravitational acceleration, Δ = relative sediment density under water, and Q = water discharge.
The experimental flume consisted of a 6.2 metre long and 0.2 metre wide straight channel with 0.5 metre wide floodplains on the sides. On both sides of the channel, bank protection could be removed over a limited length. The channel bed and floodplain was covered by a layer of sand with a slope of 0.008. The erodible banks had a height of 2 cm above the channel bed. The mean diameter of the sediment was equal to 0.52 mm. The water discharge was kept constant at a value of 0.6 L/s. The mean water level was approximately 1 cm.
A digital camera was installed above the flume that took photos at an interval of 15 minutes during the experiments. At the end of each experiment dye was added to the flow to distinguish deep channel areas from bars. The longitudinal bed profile was measured at three locations in the main channel at the end of each experiment.

Experimental tests

The reference case was a straight channel with fixed banks. The bank protection was removed over a length of three, six and nine times the channel width on either one or both sides. The bank protection was removed at different locations along the channel side. Tests were performed with a symmetrical flow forcing and an asymmetrical flow forcing, i.e. a groyne, upstream of the bank protection removal.

Results

In experiments in which the bank protection was removed, the bank eroded laterally and bars formed in the channel. A scour hole developed downstream of the widened section and the mean bed level rose in the widened section.

Lateral erosion

Fig. 1 shows the evolution of the bank line at one hour intervals. The figures show that the eroded bank line moved downstream. This development was observed in most experiments and complies with downstream meander migration (e.g. Odgaard, 1987).

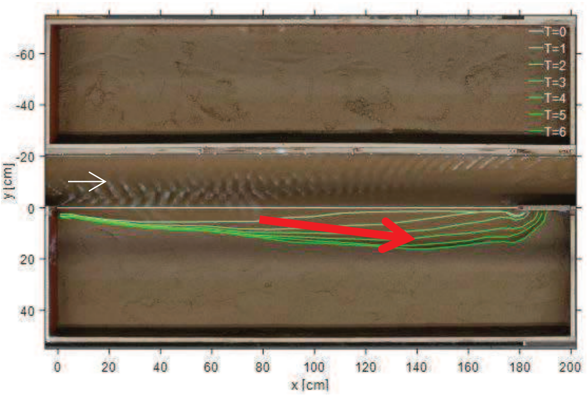

Figure 1. Evolution of bank line with time T in hours in experimental test with bank protection removal length of nine times the channel width on one side of the channel. Red arrow indicates channel widening in downstream direction.

Bar formation

In each experimental test the bar types were indicated with the terminology from Duró et al. (2015) as forced, free or hybrid. In most tests forced bars developed in the widened reach of the channel. The flow decelerated in the widened section, due to an increase in channel width. Consequently, the sediment was deposited in the widened reach, which resulted in bed aggradation and the formation of forced bars. Hybrid bars formed downstream of the forced bar. In areas with higher flow velocities an increased sediment transport deepened the channel.

Bar wavelength and bar height were determined from detrended bed profiles. The bar height was divided in two classes: low and high. The areas of low bars, high bars, floodplains and the deep channel were determined from photos of the final bed topographies. The reference test with fixed banks resulted in a low-bar area of 7% and 12% for a symmetrical flow forcing and an asymmetrical flow forcing, respectively. Fig. 2 shows that the high-bar area increased for a longer bank protection removal up to nine times the channel width on one or two sides of the channel, whereas the low-bar area remained approximately constant. Removing three sections of bank protection with a length of three times the channel width at different locations resulted in a total bar area of 10%. Removing the same bank protection length on one side of the channel with upstream a symmetrical or asymmetrical flow forcing resulted in a total bar area of 16% and 20%, respectively.

Conclusions

Removal of riverbank protection increases the formation of bars and thereby enhances habitat diversity. An increased bank protection removal length up to nine times the channel width or an asymmetrical flow forcing may increase the formation of bars, whereas a bank protection removal at three different locations with a total length of nine times the channel width does not significantly increase bar formation. This research led to results that can be used in future research to upscale the experiment.

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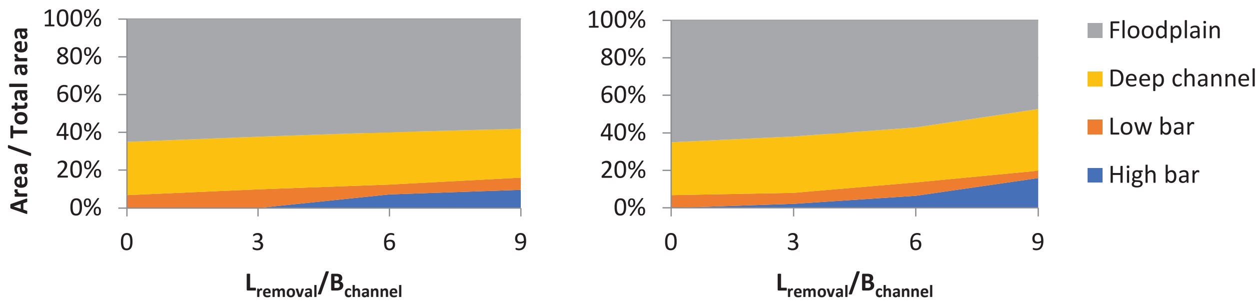

Figure 2. Dimensionless area versus dimensionless length of bank protection removal on one side (left) and two sides (right) of the channel.