Arresting Bed Degradation in the Waal River: Intervention strategies

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Introduction

The upper Dutch Rhine branches show continuous bed degradation (1-2 cm/year) threatening multiple river functions. The bed degradation is a response to past sand mining, channel narrowing and straightening, which increased sediment transport capacity and created a sediment transport gradient that drives ongoing erosion (Figure 1). Room for the River 2.0 (RftR 2.0) aims to create a climate-resilient river system, supporting river functions. Arresting bed degradation is essential to prevent further deterioration of river functions. For the Waal River, two principal intervention strategies were investigated: (1) continuous sediment management and (2) a large-scale implementation of the multi-channel approach. While sediment nourishment counteracts ongoing erosion by supplying the deficit in the sediment balance, the multi-channel approach reduces sediment transport by diverting discharge from the main channel to a parallel side channel.

The objective of this abstract is to determine the effectiveness of both interventions in arresting bed degradation. We present the results of the intervention strategies evaluated with a quasi-3D morphodynamic model (Delft3D) in which the multi-channel approach is schematised as longitudinal training walls separating a side channel from the main channel.

Method

For RftR2.0, the existing DVR Delft3D model of the Rhine branches was updated with a more recent geometry and mixed-sediment in all model domains (Sloff et al. 2024). This model was calibrated such that the gradient in sediment transport and thereby the erosion rates reproduce observations. We use the model to evaluate three strategies to arrest the bed degradation in the Waal River: Do nothing, nourishment and the multi-channel approach.

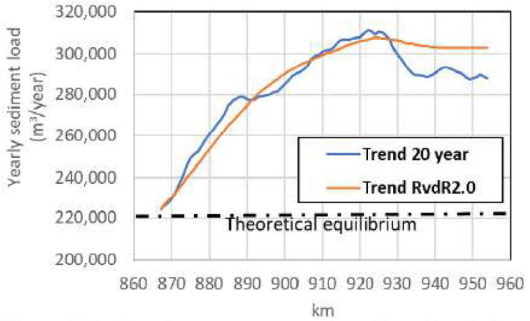

Figure 1 The long-term average yearly sediment load along the Waal River.

Nourishments

The annual repeating nourishment schemes are applied in the outer bend of eroding river sections. The nourishment material is similar to the local bed material preventing additional erosion (Czapiga et al. 2022), but the immobile (coarse) grain sizes are excluded to prevent armouring. Each year, the nourishment volume is limited to the amount eroded during that year, maintaining a constant bed level at the nourishment locations.

Multi-channel approach

A multi-channel approach divides the river into two separate channels: the main channel and a parallel side channel. The side channels widen the effective channel width during intermediate and high flows, reducing flow velocities and sediment transport rates. The goal is to create a gradual downstream reduction in flow velocity, eliminating the gradient in sediment transport. This requires progressive downstream enlargement of the side channels relative to the main channel: from 10% upstream to 50% downstream.

In addition, the main channel is narrowed to increase water levels increase during low-flow conditions by constructing the dam in the main channel about 40 m from the bank. This

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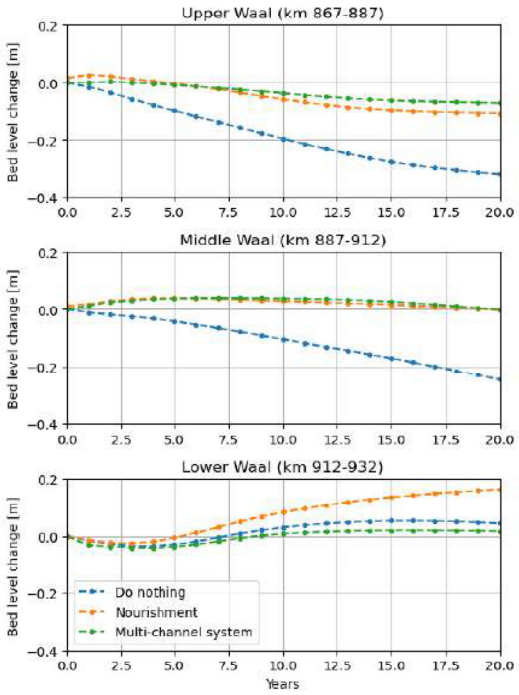

Figure 2 The computed bed-change for three strategies and averaged over the three domains.

achieves two objectives: maintaining adequate navigable depth and diverting additional discharge to the Pannerdensch Canal, stabilizing the low-flow discharge distribution between the Waal and Pannerdensch Canal.

Results

Figure 2 shows the average bed level change in three reaches of the Waal River. The interventions reduce erosion rates in the Upper Waal from 2 cm/year to 0.5 cm/year, approaching a constant bed-level after 10-15 years. The nourishment volume is variable and is similar to the sediment deficit of 150,000 m^3/yr. However, initially, the nourishment volume is much larger because the river needs to adjust to the added sediment.

Figure 3 shows that the multi-channel approach significantly reduces the gradient in sediment transport and shifts it downstream of the intervention reach. This reach should be extended further downstream. The design needs to be further improved by considering the local geometry and adjusting the main channel and side channel width accordingly.

Reflection

The main conclusion is that both nourishment and a multi-channel approach can arrest the bed erosion in the river Waal. The multi-channel approach has additional benefits beyond erosion control such as a water level increase at

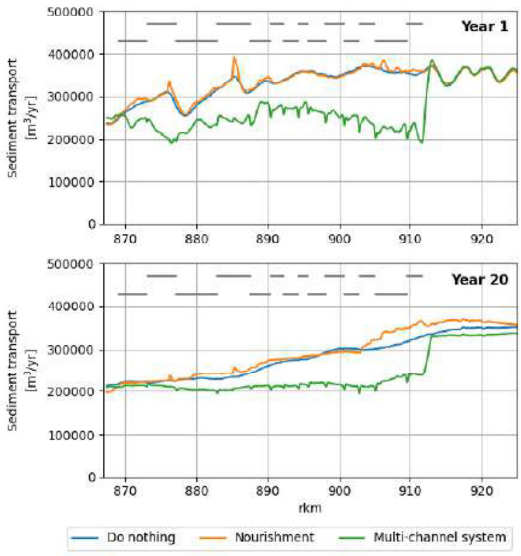

Figure 3 The computed sediment transport in year 1 and 20 for the three strategies with in grey the location of the side channels.

low flows, reduced flood levels and potential for ecological habitat creation.

Main lessons on the multi-channel approach:

- The side channels need to increase in size in downstream direction to remove the sediment transport gradient and therefore will become very large (about half the main channel).
- Side channels must be implemented along the entire river branch. Partial implementation leaves non-widened sections with high transport capacity, resulting in localized intense erosion and bed degradation.
- The side channels shift the gradient in sediment transport further downstream. For a stable system, the multi-channel approach needs to be continued even past Zaltbommel.
- Attention should be paid to the spatial integration in the existing river geometry and with the surrounding side channels to mitigate local erosion and deposition.
- The increased bed dynamics can increase the maintenance need of the navigation channel and the side channels need to be maintained regularly to remain effective.

References

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