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Impact of Groyne Lowering on Groyne Field Bathymetry

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Introduction

Groynes are commonly found in lowland rivers, where they help maintain a navigable main channel depth and prevent bank erosion. The areas between them, the groyne fields, mainly consist of sediments. The morphodynamics of groyne fields have been studied through laboratory experiments (Yossef & De Vriend, 2010) and numerical models (McCoy et al., 2008; Constantinescu et al., 2009). However, these controlled experiments do not capture the spatial variability observed in natural settings. Based on field measurements Ten Brinke et al. (2004) hypothesized that groyne fields gradually erode under the influence of shipping, while substantial sedimentation occurs during floods. Our objective is to provide a more thorough understanding of the natural variability in groyne field bed level changes with the ultimate purpose to assess the potential and efficacy of groyne field nourishments. To this end, we first establish a baseline representing the natural variability in groyne field bed level changes. Additionally, understanding the factors that govern this baseline is essential.

Methodology

To determine the bed level changes of 40 groyne fields in three sections along the Waal River, we use multibeam data of 2018 and 2021 as an example (Figures 1a-b). Section 1 is located on the right (northern) bank in a large outer bend and features non-lowered groynes. Section 2 sits on the left (southern) bank in a reach with smaller bends, where the groynes are lowered. Section 3 is positioned on the right bank just downstream of section 2, also with lowered groynes. In sections 2 and 3, the groynes were lowered by 1.5-2 meters between 2008 and 2010. We define a groyne field as the area between two consecutive groynes, the normal line between their tips and the vegetation line (Figure 1c). Bed level changes are normalized by the groyne field areas for direct comparison of sedimentation rates.

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Preliminary Results

Figure 2 presents the measured bed level changes for the three sections. For sections 2 and 3, the erosion rates reach up to almost 15 cm/year, which is about 10-15 times larger than section 1 with non-lowered groynes. For reference, the erosional trend in the main channel is about 1-2 cm/year (Chowdhury et al., 2023). The differences in erosion rates between the lowered and non-lowered reaches can be attributed to the fact that lowered groynes are submerged more often (approximately 10% and 40% of the time for non-lowered and lowered groynes, respectively). For fields with lowered groynes, this increased submergence leads to higher flow velocities for a longer duration, resulting in increased erosion. Similar observations were made by Busnelli et al. (2011) who considered the initial response of groyne fields to groyne lowering. Interestingly, the rates of bed level change differ significantly between the different fields with lowered groynes. We hypothesize that the large variation between the bed level changes of fields with lowered groynes is dominated by two factors: secondary flow effects in river bends and the differences in navigation specifications (e.g., vessel dimensions, draught, distance to groyne field) between the left and right bank of the river.

Future Work

Continued research will evaluate our hypothesis regarding the influence of secondary flow in river bends and the navigation specifications on the sedimentation rates. Furthermore, we will investigate the spatio-temporal variations within groyne fields by identifying dominant morphological features, such as representative bed profiles and deposition patterns of groyne fields. To better understand large-scale temporal changes, we will analyze LIDAR data of bed level in emerged parts of the groyne fields before and after the major river interventions, creating a time series of measured bed level changes. The integration of these analyses will offer a more comprehensive understanding of the spatio-temporal variations observed in groyne fields along the Waal River.

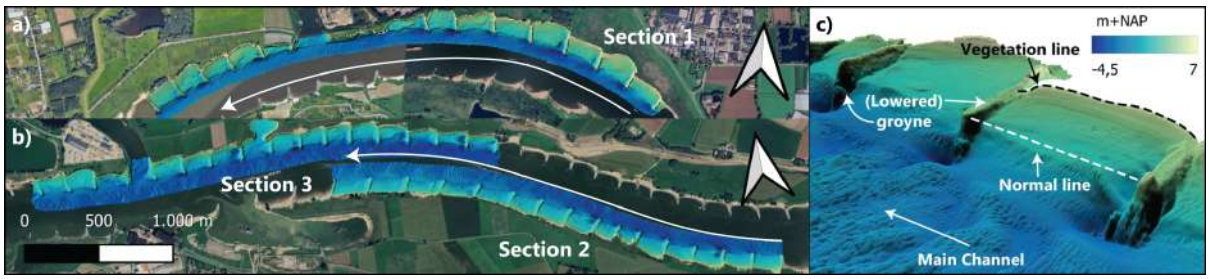

Figure 1: a) Section 1 near Gendt (rkms 877-881) and b) section 2 near Winssen (rkms 894-897) and section 3 near Dodewaard (rkms 896-899). The main channel flows from right to left. c) Close-up of some groyne fields. A distinction can be made between lowered and not yet lowered groynes. The vertical scale is exaggerated with a factor 7.

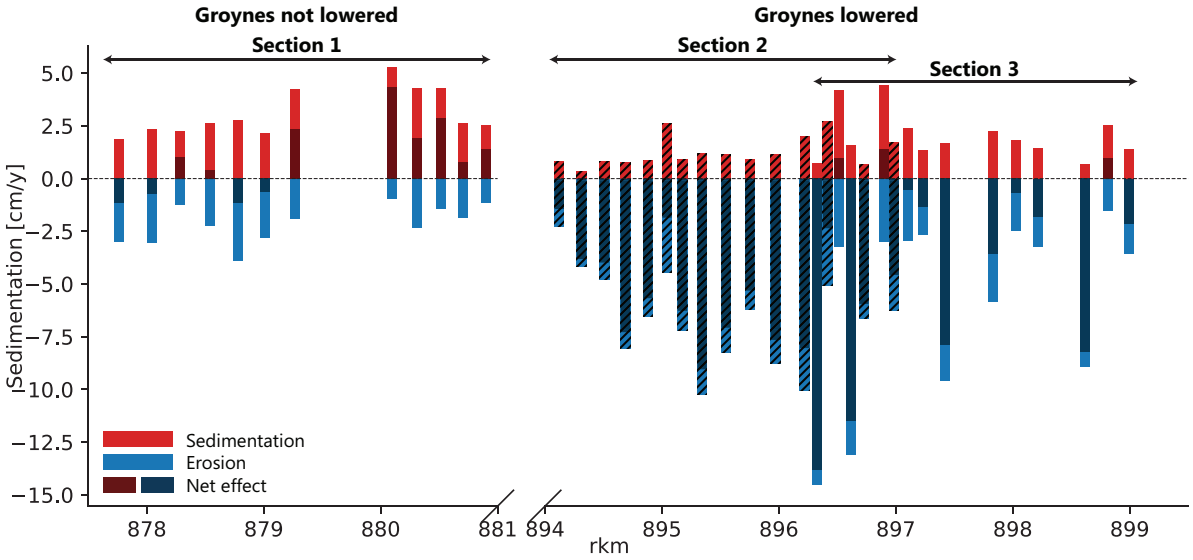

Figure 2: Measured bed level change rates between January 2018 and July 2021 for the three different sections. The lighter bars represent the amount of sedimentation and erosion present per groyne field, whereas the darker bars represent their combined net effect. The bars for section 2 (left bank) are marked to distinguish them from section 3 (right bank).

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