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Flow patterns around longitudinal training dams

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Introduction

With the intention to reduce the negative effects of ongoing bed erosion, as well as to improve several other river functions such as protection against floods, provision of safe and efficient navigation and ecology, a 'pilot project longitudinal training dams' was initiated. The training dams have recently been implemented in the Waal between Tiel and Sind Andries. In this project, river groynes have been completely removed and replaced by dams that lie parallel to the river bank. With help of the longitudinal training dams, a two-channel river system is created in which the river is divided into a main and side channel. The dams are placed in a continuous manner with openings in between that are relatively small compared to the dam length. At the beginning and end of the dam an inlet and outlet region is situated, as shown in Fig. 1.

The combination of inlet and openings allows for water and sediment to be divided between the main and the side channel. Both inlet and openings are constructed with the help of a porous rock-layer. The crest heights can be altered by adding or removing stones. This is expected to influence the amount of water and sediment entering the side channel and can therefore be used as a regulation tool.

Motivation

The impact of longitudinal training dams on the different river functions is largely influenced by the flow patterns and resulting transport mechanisms of water and sediment between the main and side channel. Extensive research has been conducted on flow patterns and transport mechanisms around groynes (Uijttewaal et al., 2001). However, due to limited experience, similar research on longitudinal training dams is missing. Under the motto 'learning by doing', the longitudinal dams were constructed. Better understanding of the impact of regulating the inlet and opening crest heights is expected to improve the design of river interventions using the concept of longitudinal dams. Also it should result in better regulation strategies such that various river function will be better served. In addition, insights into the flow patterns and transport mechanisms around longitudinal training dams are expected to reduce uncertainties in the modelling of the water and sediment distribution between the channels.

In current hydrodynamical models, such as Waqua and Delft3D, longitudinal training dams are modelled using sub-grid features. However, problems arise in the calculation of sediment transport over weir-like structures (Mosselman, 2001). Secondly, for more fundamental insights these models become difficult to interpret. A simple one-dimensional model could therefore provide quick and useful insights.

Methodology

A one-dimensional model is used to schematize the two channel system created by longitudinal training dams (schematized as shown in Fig. 1). With the help of a numerical predictor-corrector scheme as shown in Eq. (1), the water levels in both the main and side channel are calculated, where h_x and h_{x+1} are the water level at location x and $x+1$, dh/dx is the water slope and dx is the space step.

$$h_{x+1} = h_x - 0.5\left(\frac{dh}{dx}_{pred} + \frac{dh}{dx}_{corr}\right)dx \qquad (1)$$

The discharges over the inlet and openings are modelled using the standard weir equation as shown in Eq. 2, where q_w is the weir discharge, C_D is the weir coefficient, C_S is the submergence coefficient, g is the gravitational acceleration and H is the energy head just upstream of the weir. The porous flow through the inlet and openings is modelled using the general Darcy equation for porous flow as given by Eq. 3, where v_{porous} is the porous flow velocity, k is the permeability and I is the

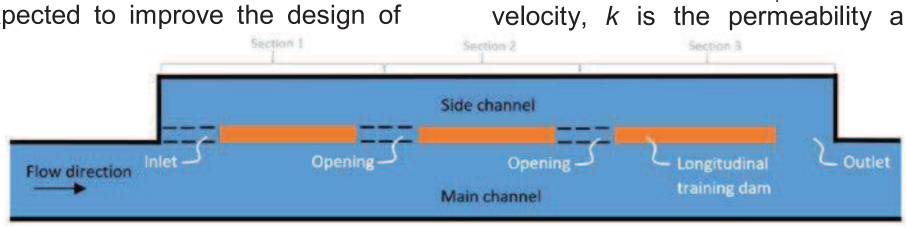

Figure 1. Schematization of the inlet, openings and outlet at the longitudinal training dams.

hydraulic pressure gradient created by the calculated difference in water level between the two channels.

$$q_w = \frac{2}{3} C_D C_S \sqrt{2g} H^{3/2} \quad (2)$$

$$v_{porous} = kI \quad (3)$$

The influence of several parameters on the discharge distribution is calculated, including the inlet crest height, opening crest heights, channel width ratio, river discharge, river bend radius and several other parameters. Basic validation tests of the model have been performed.

Results

Fig. 2 presents the one-dimensional model results when run with the dimensions of the longitudinal training dam near Wamel in the Waal. The top left plot shows a side view of the calculated water and bed levels in the two channels, the lower left plot the difference in water levels and the right plot a top view with the calculated weir discharges and distribution.

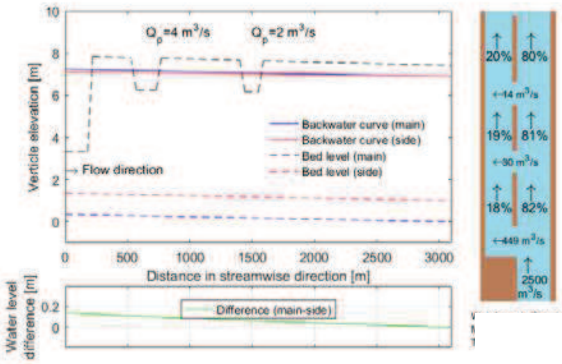

Figure 2. Model results of the one-dimensional model for the longitudinal training dam near Wamel in the Waal.

The influence of several parameters on the discharge distribution between the two channels has been investigated. The results for three parameters are shown in Fig. 3. Fig. 3.a shows that adjusting the inlet crest height between the minimum and maximum height results in considerable changes in the discharge distribution. Adjusting the opening crest heights does not affect the discharge distribution much (see Fig. 3.b) whereas changes in the channel width ratio, that could for instance be caused by sedimentation of the side channel, does result in considerable changes (see Fig. 3.c).

Conclusions

The one-dimensional model provides useful insight in the impacts of regulating or adjusting design parameters of the longitudinal training dams. The model has not been validated for an extended range of discharges on the Waal yet. However, preliminary conclusions include:

1. Adjusting the inlet weir height could influence the discharge distribution towards the side channel between 1% (fully closed but porous inlet) to 30% (fully open inlet).
2. The porous flow through the openings is expected to be negligible compared to the weir flow.
3. The effects of transverse slope and secondary flow in the river bend have a negligible effect on the discharge distribution.

Future work

Hereafter, a schematized Delft3D model of the longitudinal dams will be developed in collaboration with another student from Delft University of Technology (Stefan Jammers). The one-dimensional model will be used to determine boundary conditions for different design choices for which the Delft3D model will be used to analyse flow patterns at the inlet and openings in more detail.

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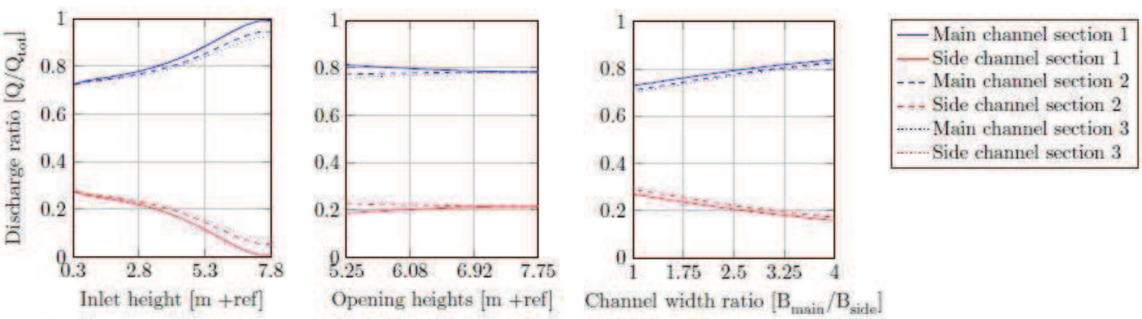

(a) (b) (c)

Figure 3. Sensitivity of the discharge distribution between the main (red) and side (blue) channel in the different river sections as shown in Figure 1 to (a) inlet crest height, (b) opening crest height and (c) channel width ratio.