Experimental study on bed-material transport over entrance sills at longitudinal training walls

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Keywords — Longitudinal training walls, Sills, Sediment transport

Introduction
In a pilot project in the river Waal, longitudinal training walls have been built and the groynes have been removed, see Fig. 1. These training walls divide the flow in a main navigational channel and sheltered channel with more favourable conditions for the fluvial ecosystem (Collas et al., 2018). Due to the alignment with the river banks, training walls produce less flow blockage and resistance at high flows than perpendicular-oriented groynes. This is expected to decrease the erosive action on the river bed that is responsible for large-scale bed degradation.

Figure 1. Longitudinal training wall in the river Waal, the Netherlands.

For large case implementation of these training walls, the effects on morphology have to be understood to prevent excessive dredging costs. The required amount of dredging depends on the sediment transport towards the side channel over the entrance sill. This sill affects the distribution of discharge and sediment between the channels. Currently, operational morphodynamic models cannot reliably compute this sediment flux.

We present laboratory experiments to study the passage of bed sediment at different discharge distributions between the main and sheltered channel, and different degrees of submergence. This will form the basis for proposing a semi-empirical relation that could be implemented as a subgrid structure in operational models.

Methodology
The discharge distribution between the main and sheltered channel and the ratio of sill height to water depth are chosen as key factors in this study. We investigate the effects of these factors in flume experiments at the Environmental Fluid Mechanics Laboratory of Delft University.

Experimental setup
The experiments are carried out in a shallow water flume made of glass. This flume is 20 m long, 3 m width and 20 cm high. The bottom has been plated with white PVC plates. The schematized inlet design of the longitudinal training walls is shown in Fig. 2. This setup consists of a bifurcation with a sill at the entrance of the sheltered channel. The main channel has a width of 1.85 m. The other half of the flume consists of three areas. Upstream there is a zero-discharge zone separated by a wooden plate that forms a schematisation of the river bank. Then there is an inlet area with a length of 2.66 m. Downstream of the inlet, the third zone, is the sheltered channel separated from the main channel by a wooden plate that represents the training wall. The width of the sheltered channel is 1.13 m.
The sill has a height of 51.5 mm, slopes of 1:2.5 and a 27 mm wide crest. The sill at the entrance is extended over the entire length of the experimental setup to reduce secondary flow effects as result of a break in this geometry.

Experimental conditions
The discharge distribution and the sill height to water depth ratio have been varied by adapting the down-stream weir heights, while keeping the total discharge of 35 m³/s constant. The difference in high and low weir heights results in a significant difference in the water depth

above the sill. This can be coupled to the dimensionless ratio of sill height to water depth. Variation of the weir heights of the main and sheltered channel results in different discharge distributions towards the main and sheltered channel.

Measurements
Operational morphodynamic models calculate the flow depth-averaged. The flow near the bottom is the driving force for bed-load transport. To develop a semi-empirical relation of the bed-load transport for operational models, information on the flow near the bottom and on the depth-averaged flow are necessary as well as data to identify the flow patterns.

The flow at mid-depth is assumed to be representative for the depth-averaged flow. Point measurements are performed at mid-depth with Acoustic Doppler Velocimetry (ADV, Nortek Vectrino) at 25 Hz for 180 seconds. To gain more insight into the horizontal flow patterns, flow field measurements are performed with Particle Image Velocimetry (PIV) using floating polypropylene particles of 3 mm diameter. The horizontal flow patterns near the bed are studied with heavier tracer particles and Particle Tracking Velocimetry (PTV). The latter particles have a diameter of 6 mm and a density of 1050 kg/m3. Therefore, they just sink and roll over the bottom. Due to the submerged weight, the particles will contain momentum and behave slightly differently than water. Therefore, some additional point measurements with ADV are done near the bed. Assuming sediment particles that reach the crest do not return, the sediment transport capacity over the entrance sill is dependent on the flow at the upstream side of the sill. Therefore, the locations of the point measurements are chosen upstream of and above the sill.

Future works
The first laboratory experiments are performed. We continue our experimental programme after the deadline for paper submission in January 2020 We expect to present our findings on bed-material transport over inlet sills at longitudinal training walls in February 2020.

Acknowledgment
I would like to thank HKV Consultants for their support during this research.

References
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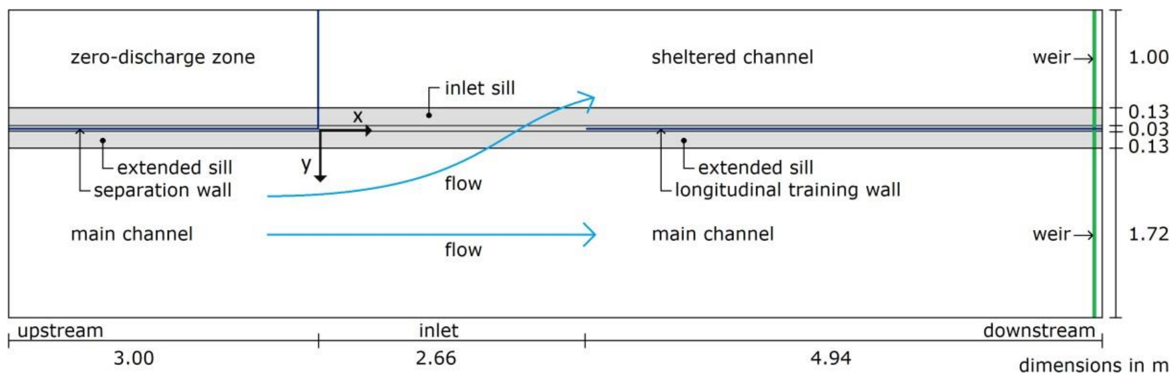

Figure 2. Top view of the experimental setup where the blue arrow indicates the flow direction. The separation wall represents the river bank. The separation wall and longitudinal training dam are simplified by a wooden plate with the same height as the top of the flume. The downstream weirs are replaceable and regulate the discharge distribution and water depths in the main channel and the sheltered channel, respectively.