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LARGE-SCALE DIKE BREACH EXPERIMENTS WITH FORESHORES

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1 INTRODUCTION

Coastal flood risk is expected to increase substantially in the near future. Main drivers are climate induced sea level rise, increased storm surge and land subsidence. Meanwhile, land subsidence compounds to increased extreme water levels as more land is susceptible to flooding. Without coastal defense or adaptation 50% more people are exposed to flooding than present day (Kireczi et al., 2020).

Coastal regions are currently primarily protected by hard (grey) flood defenses such as storm surge barriers, seawall, dikes and dunes. Periodically, strengthening of these grey structures is necessary to comply with current or updated safety standards. For dikes, conventional strengthening methods are crest heightening or (base) widening. However, these methods have structural and financial limits. Instead, more sustainable methods are explored in which nature also plays a larger role. These solutions are known as Nature based Solutions (NbS).

For flood protection, tidal marshes have gained great interest as a Nature based Solution in the past two decades. Tidal marshes provide a lot of ecosystem services (Barbier et al., 2011). One such service is flood protection, attributed to wave attenuation (Vuik et al, 2016). A secondary effect is flood impact reduction (Zhu et al., 2020) due to the high elevation of tidal marshes limiting the inflow to the breach. Secondly, the tidal marsh can act as a sill in front of the breach when water levels drop below the tidal marsh level.

To quantify the effect of tidal marshes on flood impact the breaching process in combination with a tidal marsh (or foreshore in general) needs to be understood. In this study we performed a large-scale physical dike experiment where we breached a dike seven times. Three tests are done without a sediment layer in front of the dike (no foreshore), two with a sandy layer (sandy beach) and two with a clay layer (tidal marsh without vegetation). From the experiments we gain insight into differences in the dike breaching process with and without an erodible sediment layer in front of the dike.

2 METHODS

The dike experiment was approximately 1.8 m high, with 1:2 to 1:3 slopes and build completely from sand (source: North Sea, thus including some sea shells). No clay cover layer was placed on top. Pressure sensors measured water levels up- and downstream of the breach and velocimeters measured flow velocities upstream of the breach. Three cameras recorded the experiments from three different angles (front, side, back) and another two cameras recorded a top view of the breach (facing upstream or downstream). Four pumps were installed in the basin to circulate water downstream to upstream and lengthen the experiments. The basin was filled with water from a separate basin by opening a valve. The breach process was started by manually digging an incision at the crest. After each experiment another pump emptied the basin. 3D scans were made before and after the tests with a sandy and clay foreshore. To repair the breach, eroded material was removed from the basin and the dike rebuild with new sediment from a depot. An impression of the situation is shown in Figure 1. Soil properties of the sand and clay were measured in a laboratory via (wet) sieve analysis, constant head tests, Atterberg limit tests and direct shear tests.

Figure 1. Impression of the test facility. On the left the upstream side, on the right the downstream side.

3 PRELIMINARY RESULTS

During the experiments the only the first three stages (Visser, 1995) of the breaching process were observed due to the size of the basins. Unfortunately, the pumps were unable to lengthen the duration of the experiments significantly. Due to this the total breach width at the end of each test was similar and little foreshore erosion was observed. Thus, significant effect of a foreshore in the later stages of the breaching process was not achieved in these experiments. Nonetheless, different hydrodynamics upstream of the breach were observed between tests with and without a foreshore. Without a foreshore the inflow behaves like for broad crested weir, while this was noticeably not the case when a clay foreshore was present. Instead, more headcut like flow was observed, greatly changing the flow characteristics inside the breach. Secondly, the weir shape between sand and clay foreshore was respectively elliptical and straight, as has been observed in real historic dike breaches.

4 CONCLUSIONS

Despite the fact that the later stages of the breaching process were not truly achieved in our experiments, and consequently the quantitative effect of a foreshore or tidal marsh could not be well established, our experiments do show a difference in hydrodynamics which can affect the breaching process. Also, the weir shape observed in the experiments correspond with observations at real historic dike breaches. Based on our first findings we argue that the different inflow hydrodynamics affect the dike erosion process and should be considered when modelling. However, the importance of this difference is still open for debate. Further analysis of the data is required.

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