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The effect of dike breaches on downstream discharge partitioning near a river bifurcation

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ABSTRACT

Dike breaches near river bifurcations might affect downstream discharge partioning. This study analyses the consequences of dike breaches in a Monte Carlo framework. The Dutch Rhine branches are used as case study.

1 INTRODUCTION

Floods are a major source of disasters in Europe. The Rhine floods of 1993 and 1995 show the need for accurate design of flood defenses according to an appropriate safety level [2]. Flow patterns in the embanked areas as a consequence of inundations due to dike breaches may have a significant impact on the water levels and discharges at downstream locations. The consequences are not always beneficial for downstream areas in terms of lowering of the discharge peak and consequently lowering in water levels. Water may re-enter at a downstream location and so enter a branch with a much lower discharge capacity. Such an event may hence change downstream flood probabilities and risk significantly.

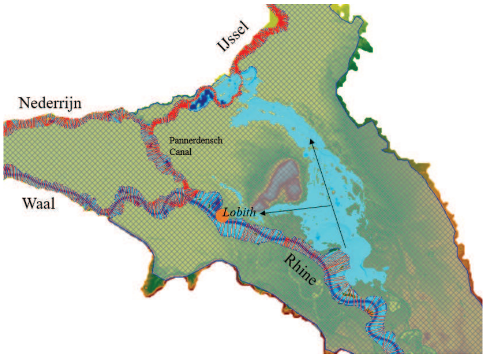

Figure 1: Model set up in which the red lines indicate the 1D cross sections and the 2D grid is shown by the rectangular cells. In blue, a possible flooding scenario is given.

A possible occurrence of such a phenomenon can be found in the Lower Rhine catchment area, close to the German-Dutch border where the location of two bifurcation points results in three different Rhine branches. During normal conditions the flood wave will enter the Netherlands at Lobith, where over a short stretch downstream the water is divided according to a fixed proportion: approximately 2/3 of the discharge will flow towards the Waal, 2/9 towards the Nederrijn and 1/9 towards the IJssel (Fig. 1). However, a dike breach in Germany may change these numbers significantly. As a result of the lower surface area between the upper Rhine and the IJssel, water may flow through the embanked areas towards the IJssel (Fig. 1). Consequently, the IJssel may receive much more water than 1/9 of the discharge wave for which the flood defenses along the IJssel are designed. Large inundations along the river IJssel may be the result. Therefore, we will study the effect of dike breaches on the change in discharge partitioning in the area between the upper Rhine and the IJssel.

2 METHOD

2.1 *Model set-up*

Since the model domain includes a large area, a fully 2D model is not preferred because of its relatively high computation demand. Therefore, a coupled 1D-2D model will be used to perform the hydraulic simulations. The open-source software HEC-RAS is used. In this model, the summer bed and its floodplains are schematized with one dimensional profiles whereas the embanked areas are discretized by a two dimensional grid (Fig. 1). A coupling between the 1D profiles and 2D grid cells is made with the use of a lateral structure, corresponding with the dimensions and alignment of the dikes in this study. Since computation time of the model is relatively low, it is possible to simulate many scenarios of potential dike breaches.

2.2 *Monte Carlo analysis*

A preliminary run in which all embankments were removed from the geometry is performed to identify the potential dike breach locations. The 1926 river

Rhine flood event is used as upstream boundary condition, which corresponds with the largest discharge measured at Lobith. Measured water levels are used as downstream boundary conditions. Locations where flooding of the hinterland occured and which resulted in great overland flow patterns were identified. These locations will be used as potential dike breach locations in the study (Fig. 2). A Monte Carlo analysis framework is set up in which the critical water levels resulting in a dike breach and dike breach dimensions (dike breach width and dike breach duration) are randomly selected. Up till now, it is commonly assumed that a dike breach occurs at maximum water level or when a water level threshold is exceeded for a certain period of time. In this study, failure mechanisms wave overtopping, piping and slope stability are considered. Fragility curves are translated into critical water levels for which the dike fails depending on the three failure mechanisms. The lowest critical water level of the three failure mechanisms is used in the analysis to trigger dike breaches [3]. The width and duration of the dike breach are considered as random parameters and are based on literature. An average breach width of 70.3 meters is used, with a standard deviation of 31.5 meters [1]. For the dike breach duration an average time of 1 hour is used with a standard deviation of 15 minutes [4].

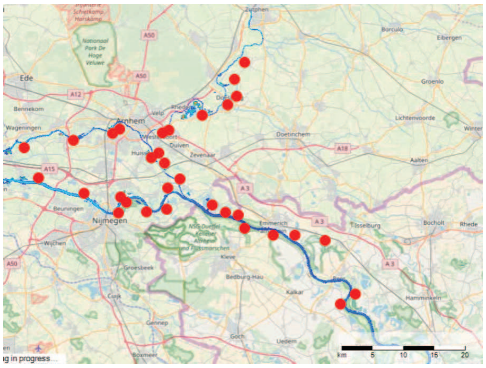

Figure 2: Dike breach locations considered in the study.

A Latin Hybercube sampling is set up resulting in a stratified sample that will be used in the Monte Carlo analysis. The uncertainty of the discharge partitioning along the Dutch river Rhine branches is used as stopping-criteria. When additional simulation runs does not result in a change in the uncertainty of the discharge partitioning the Monte Carlo analysis is stopped and we can assume that the sample is sufficiently large to represent the large amount of possible flood scenarios.

3 RESULTS

The Monte Carlo analysis gives insight in the sensitivity of dike breach location and dike breach dimensions on the discharge distribution along the Dutch river branches. With this information it is possible to identify problematic dike breach locations, i.e. dike breach locations that will result in significant inundations problems along one of the three river branches. Besides, it determines the effect of dike breach width and duration on inundation extent. The effect of dike breach location on discharge partitioning and inundation extent can be used for future design of flood measures by adapting the safety levels along the different dike breach locations. Besides, the simulations may be of use to set-up evacuation plans.

4 ACKNOWLEDGE

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