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Discussion of ''Consequences of dike breaches and dike overflow in a bifurcating river system'' by Anouk Bomers, Ralph M. J. Schielen and Suzanne J. M. H. Hulscher.

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Abstract

In this discussion, the authors will point out that even if Bomers et al. (2019) tackle an important problem, ignoring the uncertainties related to the roughness coefficients, Manning coefficients, the downstream boundary and most importantly the errors of the chosen software, HEC-RAS, are serious shortcomings of their study.

Bomers et al. (2019) present an original contribution " to study the effect of overland flow patterns on downstream discharge partitioning and flood risk capturing the full dynamics of a river delta (therefore including all possible flow patterns due to multiple dike breaches and backwater effects).''

To this end, Bomers et al. (2019) used a 1D-2D coupled hydraulic model, based on the HEC-RAS (v. 5.0.3) software, to simulate the discharge propagation from Andernach, Germany, to the Dutch deltaic area. Then a Monte Carlo analysis is performed, to determine the influence of dike breaches on downstream discharges and flood risk, where "only the parameters that influence dike breach outflow are included as uncertain input parameters. Following the method of Apel et al. (2009) and Vorogushyn et al. (2010), these parameters are:

– Upstream flood wave in terms of hydrograph shape and peak value
– Flood waves of the main tributaries dependent on the upstream flood wave
– Dike breach threshold in terms of critical water level (based on fragility curves) indicating when the dike starts to breach
– Dike breach formation time
– Final breach width"

In this discussion, the authors will point out that even if Bomers et al. (2019) tackle an important problem, ignoring the uncertainties related to the roughness coefficients, Manning coefficients, the downstream boundary and most importantly the errors of the chosen software, HEC-RAS, are serious shortcomings of their study.

Hydraulics Modeling

When performing hydraulics modeling, the choice of the numerical tool is a very important task. In fact, a tool under development should be at least tested and proven to be a good one before been used. Then, during the modeling process, the modeler should use a good modeling domain, well discretize it, impose the right boundary conditions, and perform some numerical tests before using the model. One important test to be done is the choice of the numerical mesh size. Indeed, the numerical solution has to be independent of the mesh size.

Bomers et al. (2019) neither justified their choice of HEC-RAS (v. 5.0.3) software to perform the hydraulics modeling nor performed numerical tests of the mesh size reduction impact on the numerical solution. The discussers do not have access to the original model of Bomers et al. (2019), but their experience in using HEC-RAS (v. 5.0.3) showed that this version of the software is not a good one for hydraulics modeling. In fact, for some simulations performed by the authors, using HEC-RAS (v. 5.0.3), it has been noticed that dividing the mesh cells by a factor of two causes the multiplication of the corresponding water depth by a factor of 20. Moreover, the use of a coupled 1D-2D approach is another error source. Bomers et al. (2019) did not justify this choice especially since using a 2D approach for the entire domain would have save time and reduce the coupling errors.

Bomers et al. (2019) used the diffusive wave equation instead of the full dynamic wave one to perform their calculations. They justified their choice by “Test runs with both sets of equations were performed. Both runs provided almost the same results, as was also found by Moya Quiroga et al. (2016). The maximum discharge at Lobith deviated only 0.3%, and also no significant deviation in flood extent was found. However, the computation time of the run solving the diffusive wave equations was significantly faster. Therefore, the diffusive wave equations are used to compute the flow characteristics (e.g. water level, flow velocity) at each 1D-profile and 2D grid cell.” While dealing with the uncertainties effects on modeling it would have been better to use the dynamic equation. In fact, the tests performed by Bomers et al. (2019) to choose the diffusive wave approximation using HEC-RAS (v. 5.0.3) are misleading, and their results may be explained by what was reported later by the developers of HEC-RAS (v. 5.0.3). In fact, in the HEC-RAS release note (USACE, 2019), it is reported that “In the shallow water 2D solver, it was noticed that some simulations had flattened velocity profiles across the direction of flow. Numerical diffusion in the advection terms was identified as the cause of the problem, particularly the scheme used for tracking velocity and velocity interpolation in the middle of cells. The interpolation formula was changed and is now computed using a more compact stencil, resulting in less numerical diffusion and more accurate results.” and it is well mentioned that “In general, the new formulation will have less numerical diffusion, and therefore potentially higher velocities and lower water surface elevations. Previously developed/calibrated models may need to have minor Manning’s n value adjustments (increased Manning’s n values) and/or increased turbulent diffusion coefficient (or turn turbulence on if it was not previously on) in order to reproduce previous version results.” Moreover, several developed software, such as FLDWAV (Fread and Lewis, 1998), SRH-1D (Greimann and Huang, 2018) and MIKE11(DHI, 2009), introduce artificial damping of the inertia terms of the full dynamic wave equation when numerical instabilities occur without using the diffusive wave equation in the whole domain.

Downstream boundary condition

Bomers et al. (2019) did not consider the influence of the downstream boundary condition when performing a Monte Carlo analysis, to determine the influence of dike breaches on downstream discharges and flood risk. In fact, it is well known that for subcritical flow the downstream boundary condition influences the solution in the domain and so the uncertainties related to this boundary condition (e.g., Cunge et al., 1980; Chaudhry, 2008, and Szymkiewicz, 2010). Choosing a uniform boundary condition is note justified and ignoring its uncertainties effects on the solution is a serious shortcoming of Bomers et al. (2019) study.

Moreover, when dyke breaching occurs, the 2D flow modeling needs downstream boundary conditions. Bomers et al. (2019) neither mentioned these boundaries conditions in their paper, nor dealt with the associated uncertainties.

Manning coefficient

For hydraulics modeling in open channel flow, it is well known that Manning coefficient is among the very important parameters that influence the solution. Bomers et al. (2019) used the diffusive wave equations which leads to wrong results, then their calibration and validation are wrong since one is forcing the wrong results to fit the observed values.

Bomers et al. (2019) did the calibration and validation to choose Manning coefficients for their study. Firstly, as it can be seen, from their tables 1 and 2, that for discharge reduction of 7% , causing a change in the observed water levels ranging from -32 cm to 21 cm, the change in the simulated water levels ranges from -22 cm to 11 cm, for the same adopted values of Manning's coefficients. Note that the downstream part or the reach do not experience a significant change because of the downstream boundary conditions effects. So the uncertainty of Manning's coefficients do impact the solution. One cannot ignore this uncertainty when performing uncertainty analysis on the flow discharge in the domain even if the breach parameters' uncertainty are considered.

Secondly, since the available data (water depth and discharge) do not cover the entire numerical domain, the choose of Manning coefficients for the entire domain must be followed by taking account of the associated uncertainty when performing a Monte Carlo analysis to determine the influence of dike breaches on downstream discharges and flood risk. Several researchers analyzed the effect of Manning coefficients' uncertainties for flood inundation modelling (for e.g., Ying, H. and Xiaosheng, Q., 2014, and Bellos et al., 2017)

Conclusion

Bomers et al. (2019) are to be commended for their efforts to treat the effect of overland flow patterns on downstream discharge partitioning and flood risk. However, the original paper has the following shortcomings:

- Using software HEC-RAS (v. 5.0.3), developed by the Hydrologic Engineering Centre (HEC) of the US Army Corps of Engineers, is not the right choice because numerical results of this version of the software are less accurate;
- Using a coupled approach 1D-2D introduces more modeling errors, especially at rivers' junctions;
- Ignoring the effects of the downstream boundary condition's uncertainties is incorrect since the downstream boundary, and its uncertainties, influence the solution;
- Ignoring the effect of Manning coefficients' uncertainties is unjustifiable since these coefficients, and their uncertainties, influence directly the solution.

Addressing these points will introduce more clarity to the authors' work, which proposes a promising method for studying the effect of overland flow patterns on downstream discharge partitioning and flood risk.

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