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Coupling Modelling of Urban Development and Flood Risk – An Attempt for a Combined Software Framework

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Abstract

We have developed a setup that couples the urban development model DANCE4WATER with the 1D-2D hydraulic model MIKE FLOOD. The setup makes it possible to assess the impact of urban development and infrastructural change scenarios on flood risk in an automated manner. In addition, it permits us to use the results of the hydraulic simulation to condition DANCE4WATER and to account for flood risk in the simulated urban development. In an Australian case study, we demonstrate that future flood risk can be significantly reduced while maintaining the overall speed of urban development.

Keywords

Flooding; Urban development; Urban Planning; 1D-2D Modelling

BACKGROUND AND RELEVANCE

Urban development affects flood risk in urban areas, both because developments may occur in areas that are flood prone, and because the hydrologic characteristics of the catchment may change. Reducing flood risk often involves large investments and strategic planning over several decades. Future changes of, for example, climate and city structure (the urban layout) are hard to foresee over such horizons, but can have strong impacts on the effect of any mitigation strategy. Ideally, adaptive strategies that are able to cope with a multitude of future developments should be applied (see Walker *et al.*, 2001).

The development of adaptive strategies requires that a multitude of potential future scenarios is tested during the planning phase and that the expected flood risk is assessed for each of these scenarios (typically using 1D-2D hydraulic models). Climate change impacts can be considered in flood risk assessment by modifying the inputs to the hydraulic model (Pedersen *et al.* (2012)). Urban development, on the other hand, affects factors such as the number, type and location of buildings, the location and extent of roads and the structure of the drainage network and consequently requires modification of the hydraulic model itself.

The impact of urban development on flood risk was assessed, for example, by Mark *et al.* (2014). However, a combined analysis of urban development and flood risk, that considers a variety of future scenarios and also allows the simulated urban development to account for flood risk, is possible only to a limited extent in existing tools.

METHODOLOGY

The presented software setup couples the urban development model DANCE4Water (Urich and Rauch, 2014) with the 1D-2D hydrodynamic model MIKE FLOOD using Python. The setup is

illustrated in Figure 1. It assumes that the hydraulic model for the catchment in consideration is set up before the simulations. DAnCE4Water then holds all model data and can use the “PreProcessor” module to update the flood risk model with simulated urban layouts by changing the impervious areas and by modifying the digital elevation model to account for new building locations.

Simulations can be started through the “Simulator” module, which generates the model files required for the simulation, as well as rainfall inputs of desired duration and return period. The latter are currently generated from Australian IFD curves (Institution of Engineers Australia, 1987). Finally, the maximal simulated flood depth is read from the simulation results and returned to DAnCE4Water in a grid format. An estimate of expected annual damage (EAD) is determined (see Olsen et al., 2015), where we currently consider how much road area and how many buildings are expected flooded per year (using inundation thresholds of 0.3 and 0.1m, respectively).

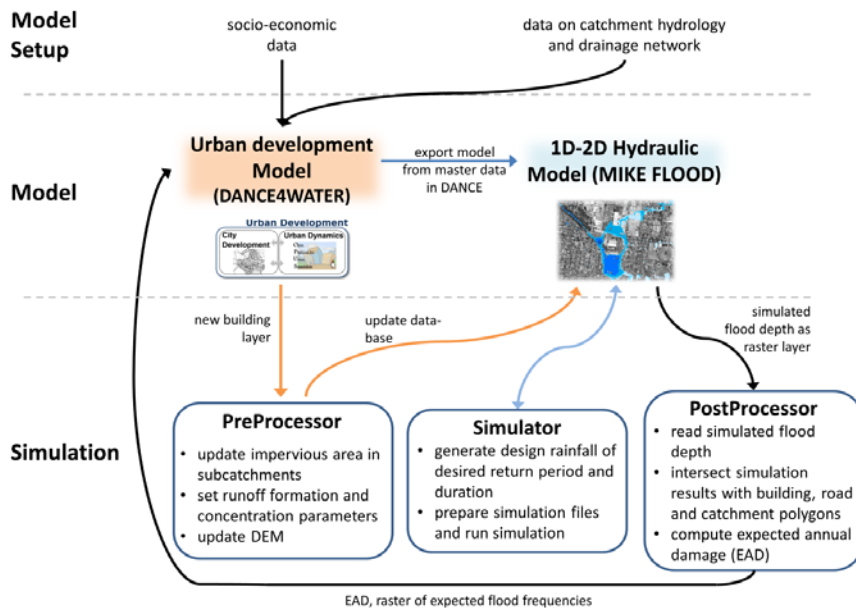


Figure 1. Schematic Layout of the integrated simulation tool.

RESULTS AND DISCUSSION

The tool was applied for a case study in the Scotchman’s Creek catchment in Melbourne, Australia. This catchment has undergone significant urban growth between 1963 and 2010 (scenario “REAL”), which is reflected in a near-doubling of impervious area in this period (Figure 2). The EAD, determined from simulations for return periods of 1, 2, 5, 10, 20, 50 and 100 years, has increased accordingly with significantly larger numbers of buildings and road area at risk (Figure 3).

To describe the expected future development, the period from 2010 to 2041 was simulated in DANCE4WATER. Here, two scenarios were considered. The first scenario corresponds to a “business as usual” development (“BAU”) with continued growth and without particular focus on flooding issues in urban development. In the second scenario penalties were assigned to construction in flood prone areas (“PEN”). Flood risk is first evaluated for the state of the catchment in 2010. The results are then used as input for the simulation of urban development. Buildings that were subject to a risk of flooding for a 10 year event were relocated in the beginning of the simulation. Further developments were not permitted in areas subject to flood risk for a 100

year event and existing buildings located in such areas were emptied with a probability of 3% in any year.

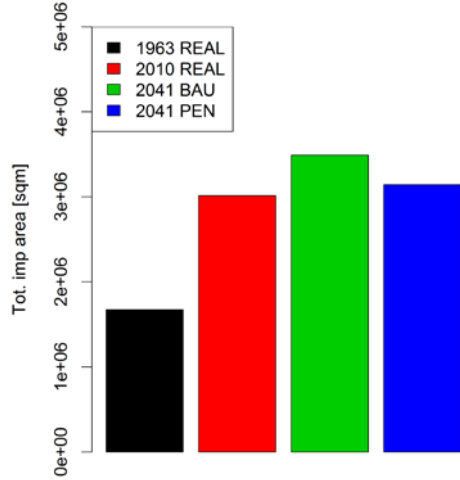


Figure 2. Total impervious area in the considered scenarios.

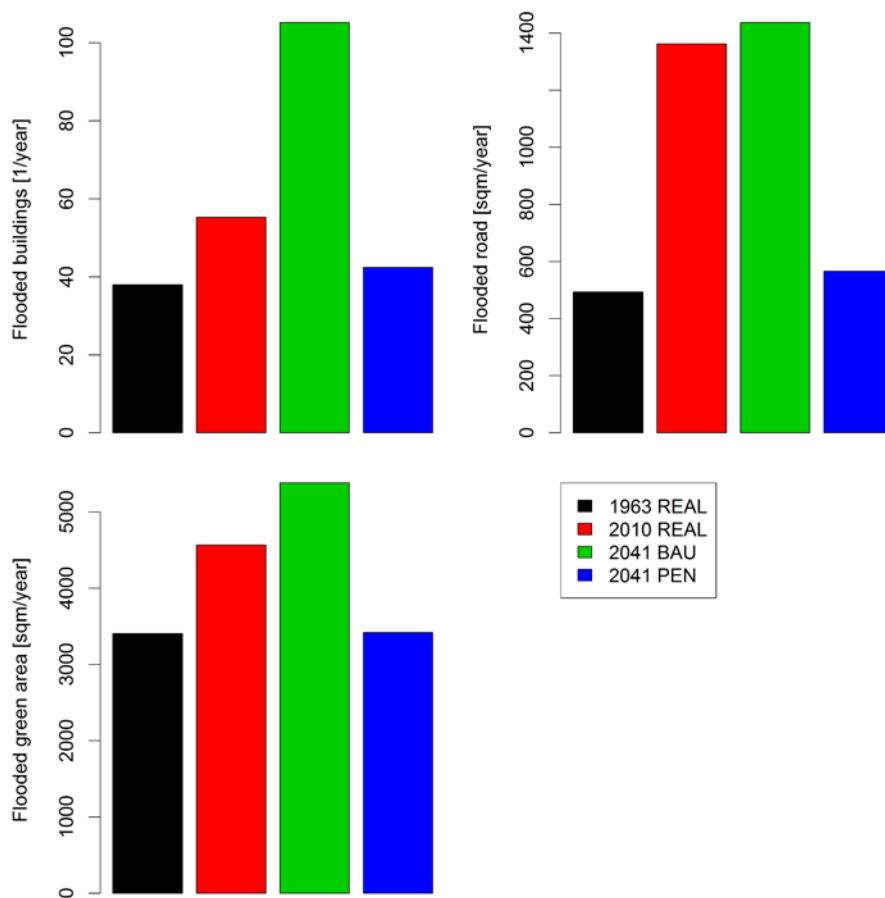


Figure 3. Simulated expected annual damage in the considered scenarios.

The results for these two scenarios demonstrate that accounting for flood hazards in urban development can have a strong impact on future flood risk. While both simulated scenarios show a further increase in impervious area (Figure 1), only the BAU scenario leads to a strong increase in EAD, while flood risk is reduced almost to the level of 1963 in the PEN scenario.

Coupling urban development and 1D-2D hydraulic model has shown that additional aspects need to be considered in order to generate meaningful scenarios of future flood risk. For example, waterways must be provided as an input to the urban development model to ensure that buildings are not created in riverbeds. Similarly, the existing parcel structure in the catchment needs to be considered to ensure that simulated buildings align with the existing drainage network.

While the scenarios considered in this work are simple and merely quantify expected processes, they illustrate the potential in coupling an urban development and a hydraulic model. Current work focuses on comprehensive tests of mitigation options in various urban development and climate scenarios to identify flexible pathways for adaptation.

ACKNOWLEDGEMENTS

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