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Grid-based 2D hydrodynamic modelling for heavy rainfall prevention: Impact of geospatial resolution and the assessment of urban infrastructure vulnerability to flash floods

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In recent years, heavy rainfall and flash flood events have occurred worldwide, leading to wide damage on technical and social infrastructure. Due to climate change, it can be assumed that these water extreme events will increase in future. A water-sensitive urban development is one strategy to address these flash floods and to minimize their consequences. For this purpose, emergency drainage routes are required in order to divert the water masses through urban areas with as little damage as possible. The research project "Urban Flood Resilience – Smart Tools" (FloReST), funded by the German Federal Ministry of Education and Research (BMBF), focuses on the assessment of emergency drainage routes and flow paths with the aim to increase the resilience of infrastructures against flash floods within the context of a water-sensitive urban development.

In this study, both load-independent and load-dependent grid-based analyses for flow path identification were conducted on digital terrain models (DTM) of varying spatial resolutions. The objective is to assess the impact of spatial resolution on modelling results and derive the potential vulnerability of infrastructure to flash floods. To achieve this, freely available geospatial data generated through airborne laser scanning, as well as additional geospatial data collected through terrestrial surveying, are utilized.

Identifying emergency drainage routes requires information on flow paths, water depths, and potential flooding extents. Both one-dimensional analysis and two-dimensional hydrodynamic modelling are typically based on digital terrain models with a resolution of 1 m x 1 m (DTM1). However, for precise planning of emergency drainage routes, the DTM1 is inadequate due to its limited spatial resolution.

In our study area in the Ahr Valley (Germany), various flow path analyses were conducted on DTMs with different spatial resolutions. Analyses based on state-of-the-art methods using the DTM1 showed that the calculated flow paths align with the actual flow paths in rural areas but significantly deviate in urban areas. Local, runoff-relevant structures, such as curbs and smaller walls, were either not covered or inadequately represented with this resolution. However, these structures can have a significant impact on flow paths and flood vulnerability in urban areas.

To simulate water movement more accurately the DTM was refined. Higher-resolution terrain models are generated by processing raw data from freely available geospatial sources and used for 2D hydrodynamic modelling. This approach, allows to identify more detailed flow paths and water depths especially in urban areas. Depending on local conditions, additional surveying may be necessary to capture all runoff-relevant structures. In a further step, a combined DTM is created using both terrestrial surveying and freely available geospatial data generated through airborne laser scanning. Flow path analyses based on this combined DTM enable a detailed assessment of urban infrastructure vulnerability to flash floods as well as a high-resolution planning of measures.