FACTSHEET RISK ASSESSMENT AND MAPPING ACTIVITIES

Integrated heavy rainfall risk maps for the City of Graz – Catchment Schloss Eggenberg

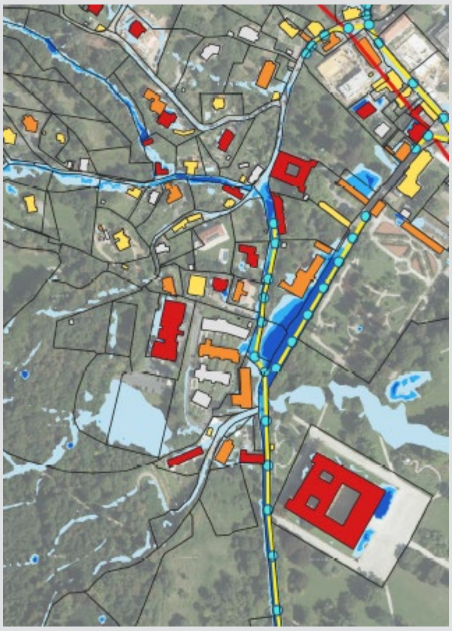
Where was it implemented?

Austria, Steiermark, Graz, catchment Schloss Eggenberg

Problem/background

Parts of the City of Graz were frequently affected by heavy rain events. On 16th April 2018 a major event has the southwestern part of the city centre causing flooding of underpasses, cellars, underground garages and a shopping centre. Future events of a comparable intensity in other parts of the city are possible. Currently only flow path maps are available as indication of a possible threat. Moreover, in case of a heavy rain event the city is facing the challenge of a combined flooding from slope water, streams and sewer system. Hazard and risk maps, considering the subsystems hillside location, urban streams and urban space, will support in particular the city planning department, as well as the department for civil protection to develop appropriate measures.

Map example:



Source: Hydroconsult GmbH

Description of methodological background and outcomes

There were two different types of hydraulic models used to simulate the defined heavy storm events scenarios: the surface runoff model and the sewer transport model.

The surface runoff was simulated in HYDRO_AS-2D. The 2-D hydraulic simulation is based on a 3-D digital ground model and solves the 2-D depth-averaged shallow water equations. For spatial discretisation the finite volume method is used, for time discretization the Runge-Kutta method of second order (explicit). The underlying methods and equations are shown in Nujic (2018). The input data for the hydraulic model is the effective precipitation. The effective precipitation is calculated in WASPI-N2D based on the SCS-Curve Number method and is transferred to the HYDRO_AS-2D model as intensity hydrographs. Detailed information about the SCS-CN method can be found in USDA (1986).

The 1-D hydrodynamic sewer simulation was calculated using EPA SWMM 5.1 (Storm Water Management Model). In dynamic wave routing SWMM solves the full one-dimensional Saint-Venant-Equation. Backwater effects, the storage effect of sewers, flow under pressure, overflow in nodes etc. can be calculated in the model.

The coupling of these two systems is done sequentially with an iterative calculation. Manholes of the channel system are entered in the correct position as model nodes in the terrain model for the 2-D hydraulic simulation. In a first step, the calculations of the two individual models are carried out without considering inflows or outflows. Afterwards in both models those nodes are identified in which an overflow according to the 2-D hydraulic calculation and / or a flooding according to the 1D hydraulic sewer network calculation occurs. In the respective nodes, an inflow or outflow curve is then defined in the surface model and a new 2-D hydraulic simulation is carried out. The inlets in the sewer network model are adjusted accordingly.

The R-Project software is used for the evaluation of results and as an interface for the exchange of the time series. The package swmmr (Leutnant & Doering, 2019) is used as the interface to SWMM, the interface to Hydro_AS is created using a specially developed R-Script.

In order to create risk maps based on the simulation results, it is necessary to overlap the load-dependent hazard analysis and the object-dependent vulnerability.

The hazard analysis was carried out on the one hand for the possible damage to buildings, based on the calculated water level, and on the other hand for the personal injury, based on the calculated water level and the flow velocity. The program used for the hazard analysis is a specially developed R-script as well as QGIS 3.8.3. The QGIS 3.8.3 software is also used to define the vulnerability of the buildings based on findings from building use data, aerial photos and on-site visits. The risk classification is based on risk matrices that link the respective vulnerability with the hazard of the objects. The matrices also take the probability of occurrence of the precipitation events into account. The risk class of each building was defined using a specially developed Python script in QGIS 3.8.3.	
Area and event characterisation	
Area type Urban	**Topography** Hilly / flat
Land cover/land use distribution 30 % discontinuous urban fabric, 70 % forest	**Event** Synthetic events (centre-weighted model rain; duration: 45min; return period: T10, T30, T50, T100)
Receptors Buildings, technical infrastructure	**Flood type** Complex flooding (pluvial and sewer)
Specifications of method/measure and data demands and outputs	
Level of complexity	3
Adressed SPRC element	Source, pathway, receptor, consequence
Method group	Process-based approach for hazard, empirical for vulnerability
Spatial scale(s) of application	Area of the mesh elements: 0.1 to 150 m^2, total area approx. 1.5 km^2
Time scale/resolution	Calculation timesteps: flexible/automatic, output timesteps:30 seconds
Input datasets (type and scale/resolution)	Digital Ground Model (raster, 0.5 m) Land use data (vector: polygon) Buildings (Digital Land Register/Cadastre) (vector: polygon) Sewer system data (vector: line, point) Event documentation (operation protocols of fire departments, social media) (texts, videos, images) Terrestrial survey (vector: line, point) Aerial photos (image) Site visits, photographic documentation (texts, images)
Output datasets (type and scale/resolution)	Vulnerability of buildings and public areas (vector: polygon) Water levels and flow velocities as an output-timeseries (every 30 seconds) along the event duration in each node of the mesh Hazard class for the damage to buildings (vector: polygon) Hazard class for the personal injury (dataset for 2-D mesh) Risk class of buildings (vector: polygon)

DESCRIPTION OF IMPLEMENTATION

Implementation	Users (reported/designated)
• 04/19 – 12/19	• City of Graz, Building Department, Department Green Space and Waters, Department Civil Protection

Initiator/responsible	Involved stakeholders
• Office of the Styrian Govnerment, Department 14 Water Management, Resources and Sustainability • External Contractor: Hydroconsult GmbH	• Graz University of Technology • City of Graz, Building Department • City of Graz, Department Green Space and Waters • City of Graz, Department Civil Protection • Residents during site visits

Lessons-learned

Main success factor:	Main challenge:
• Coupling of a 2-D hydraulic simulation of overland flow and a 1-D hydrodynamic simulation of the sewer system • The simulation results match up with findings from observations of past precipitation events.	• Well-founded choice of the model parameters • Calibration of the models

Synergies/beneficial aspects:	Conflicts/Constraints:
• Combined examination of the hydrology, the surface runoff and the sewer system	• Dependancy on (synthetic) rainfall distribution

Key message to others starting with a similar task	Contact
"The model parameters used in the simulations must be justified by a detailed plausibility and sensitivity analysis." "In urban areas man made constructions have a great influence on the flow paths. On-site inspectations are indispensable."	Office of the Styrian Government, Department 14 Water Management, Resources and Sustainability, abteilung14@stmk.gv.at Hydroconsult GmbH, office@hydroconsult.net

References

Nujic, M. (2018). Benutzerhandbuch HYDRO_AS-2d. Aachen: Hydrotec Ingenieurgesellschaft für Wasser und Umwelt mbH.

USDA - United States Department of Agriculture. (1986). Urban Hydrology for Small Watersheds TR-55.