# Quantifying urban flash flood risk in a 1d-2d-model setup

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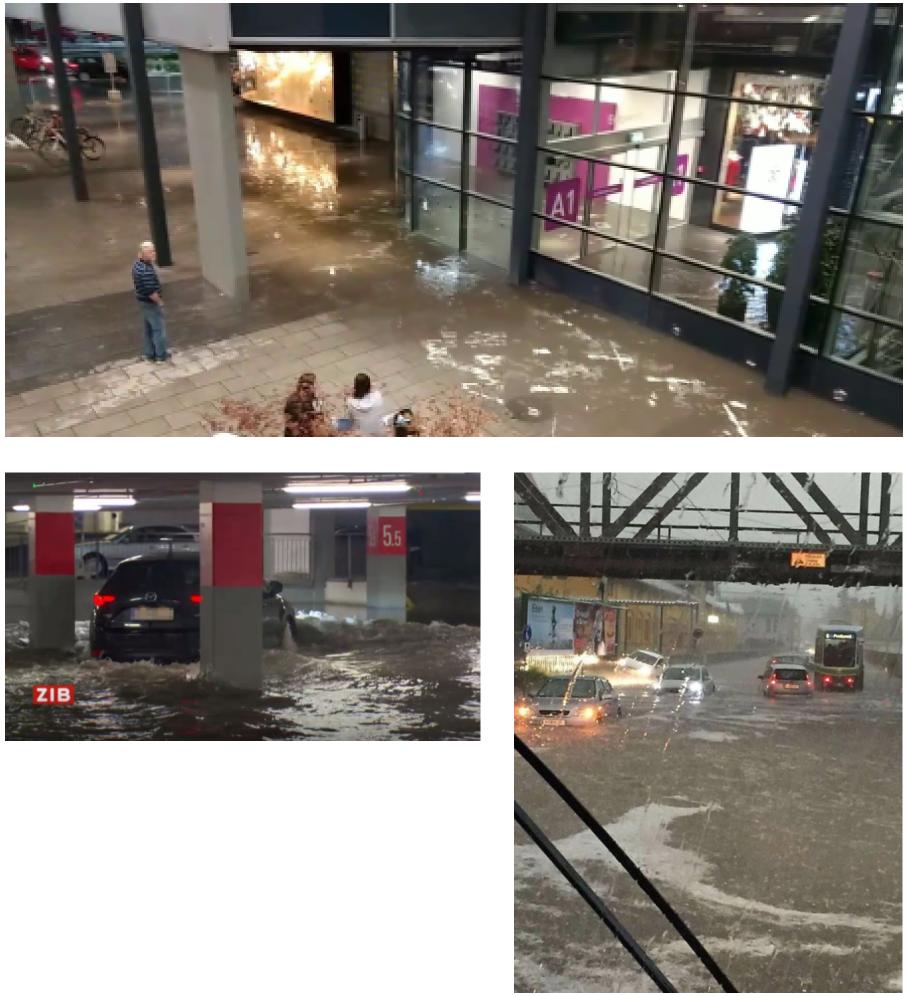
# Introduction

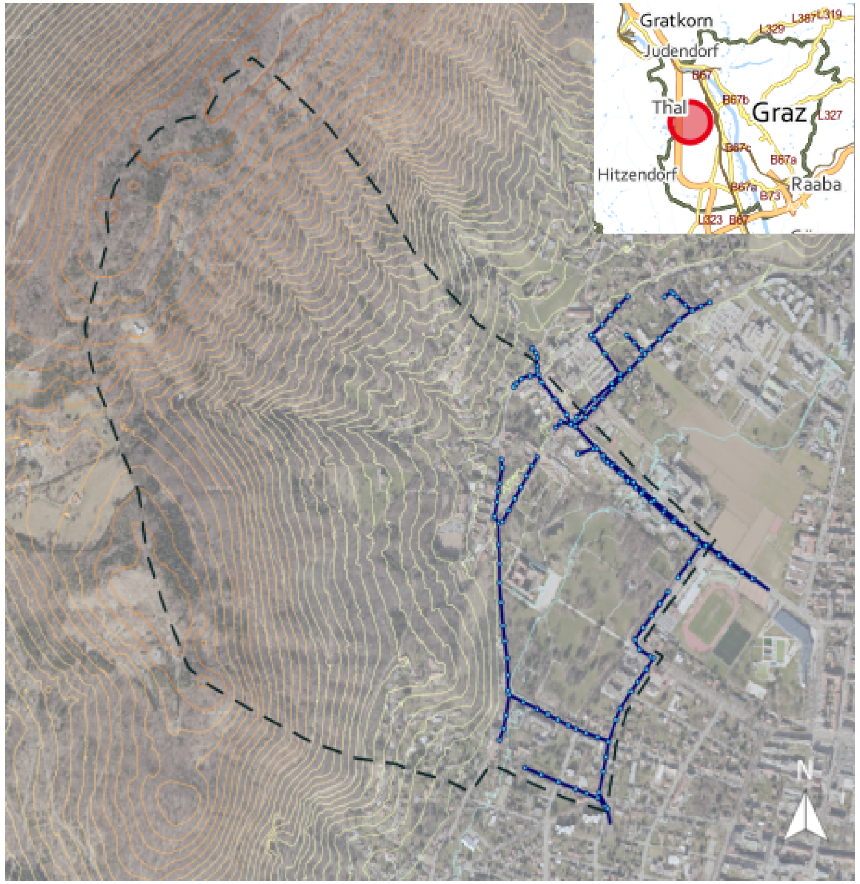
- Recent increase in urban flash floods
- Interreg central Europe project “Rainman”
  - development of practice oriented tools to assess and reduce risk of urban flooding
  - guideline for model based urban flood prevention
  - pilot catchment in the city of Graz, Austria coupled 1d-2d-hydraulic modelling
- Risk maps based on simulation results
  - risk classification based on risk matrices
  - link the vulnerability with the hazard of each object or area




Urban flash flood in Graz, 2018 (ORF.at)

# Catchment and data

- City of Graz, Austria
- 1.3 km² catchment
  - hilly terrain (mainly woodland)
  - flattening out to the east
- Flat areas urbanized
  - drained by combined sewer system.
- Sewer model available (EPA SWMM)
- No measurement data on rainfall or runoff available for catchment or sewer system




Overview of pilot catchment with boundaries (dashed black) and sewers (blue). Top right: Location of the catchment in Graz (marked in red). (Aerial view photo and base map: basemap.at)

# Terrain model

- Data
  - topography (1 m raster ALS)
  - polygons of buildings
  - aerial view photos
  - land use data
  - information on documented flooding and fire brigade operations
- Flowpath analysis in QGIS
- On-site visit
- Terrestrial survey of hydraulic relevant structures
- Basis for triangulated mesh
- Mesh nodes defined at manhole positions of sewer system

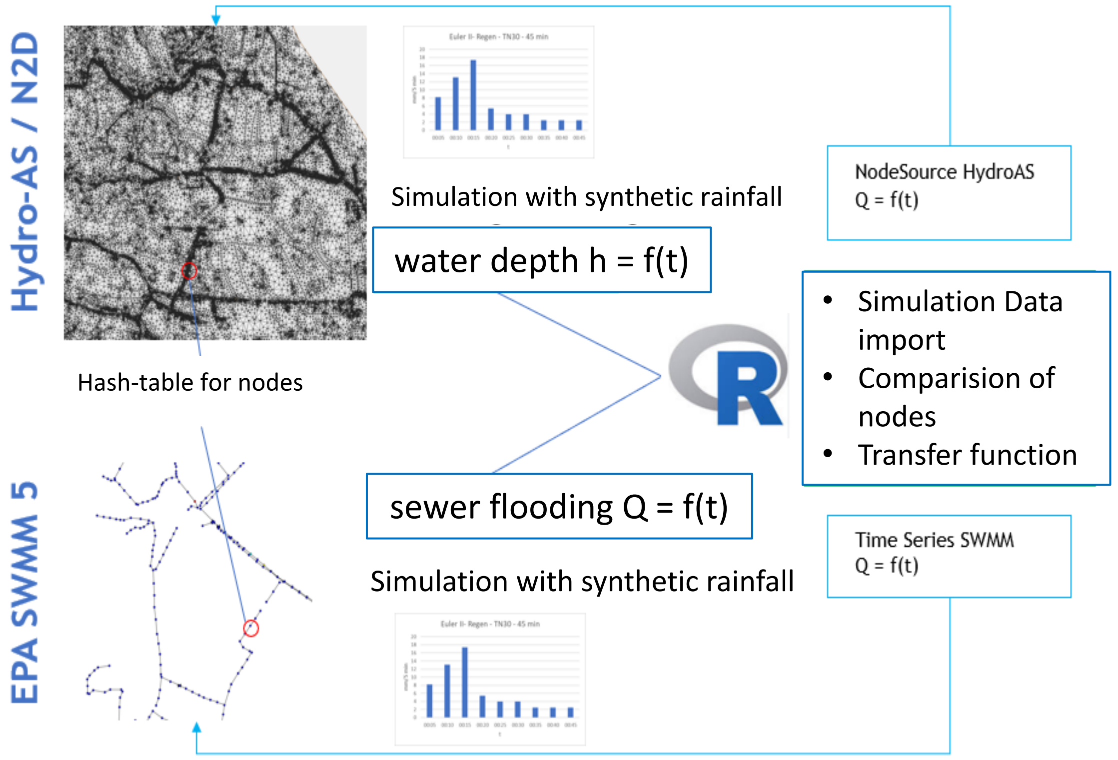
Flowpath analysis in QGIS and evaluation in on-site visit (Aerial view photo and base map: basemap.at, Photos: Monschein)

# Integrated 1d-2d model – submodels

- Integrated model for runoff generation, 2d-hydrodynamic surface runoff and 1d-hydrodynamic sewer runoff
- **Runoff generation** calculated by SCS-CN method (US-SCS, 1972)
  - Curve Number (CN) assigned to each mesh element, based on literature values
  - calculation of effective rainfall
- **Runoff concentration / surface runoff**
  - 2d-hydrodynamic model based on shallow water equations (Hydro_As-2D 4.2.0)
  - input hydrograph calculated based the effective rainfall
  - Strickler roughness values define for each mesh element as water depth dependent
- **Runoff in sewer system**
  - 1d-hydrodynamic sewer model EPA SWMM 5.1.
  - only roof areas connected directly to sewer model

# Integrated 1d-2d model – coupling

- **Model coupling** via interface Hydro-AS-2d - SWMM coded in R Project
- 2d-surface runoff model:
  - definition of inflow (surface flooding from sewer model) or outflow (surface runoff drains into the sewer system where sewer system not overloaded) in corresponding mesh node
- Sewer model:
  - inflows when i) no surface flooding from the sewer system and ii) a surface runoff in the respective 2d-mesh node.
  - inflow defined by Poleni formula, limited with defined maximum capacity
- Iterative simulation



# Integrated 1d-2d model – simulations

- Simulation with **synthetic rainfall**
  - return periods 10, 30 and 100 years
  - based on statistical IDF curves, duration 45 min (after evaluation)
  - distribution: uniform, *mid-centred (DVWK),* Type Euler II
- **Hotspot analysis** for sewer model
  - identification of surcharge and flooding
- **Local sensitivity analysis**
  - CN-value
  - roughness coefficient (Strickler value)
  - rainfall distribution of the synthetic rainfall events

# Risk classification I

- Aim: create risk maps based on simulation results
- **Hazard analysis**
  - possible damage to buildings and structures based on water depth (DWA-M 119)
  - personal injury hazard based on water depth and flow velocity (CHIwater, 2019)
  - assigning hazard class (low, average, high and very high) via automated GIS routine
- **Vulnerability**
  - defined for each building and area based on building/area type according to the classification given in the DWA-M 119 guideline (DWA, 2016) and in Leitner et al. (2020).
  - determined by aerial view photos and on-site visits and assigned to each building/area in QGIS

# Risk classification II

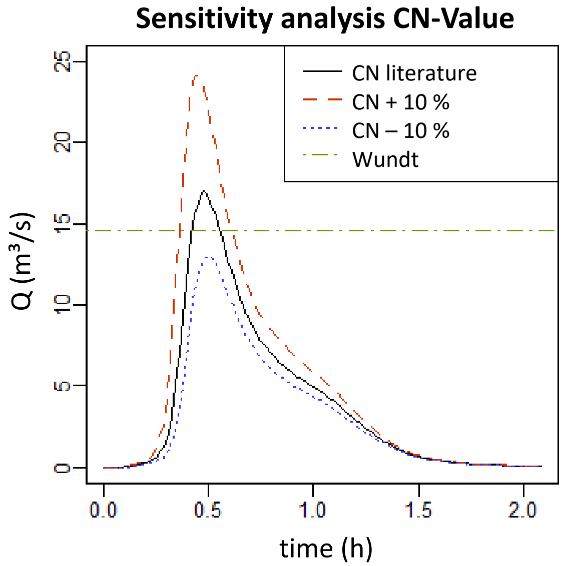
- Classification via **risk matrices** that link respective hazard and vulnerability
- Take probability of occurrence of the precipitation events (return period) into account
- 4 classes, colour coded

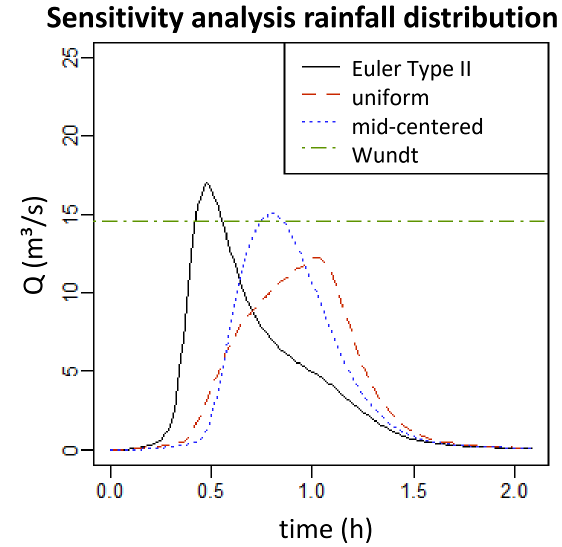
Table 1 : Risk matrix for 30-year return period

| | | Vulnerability (buildings) | | | |
|---|---|---|---|---|---|
| | | low | average | high | very high |
| Hazard | low | low | average | high | high |
| | average | average | average | high | very high |
| | high | average | high | high | very high |
| | very high | average | high | very high | very high |

# Simulation results – sensitivity analysis

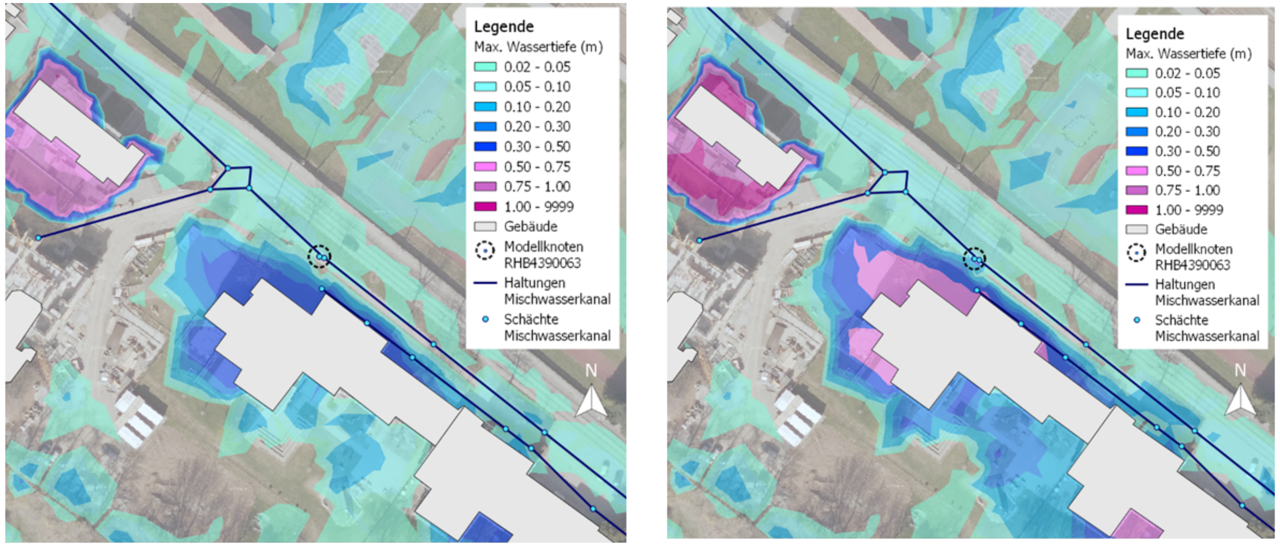
- **CN-value**
  - relatively small changes in parameter values (+/- 10 %) showed significant impact on the results (+ 42 / - 24 %) change in the resulting peak discharge
- **Rainfall distribution**
  - choice of distribution has major impact on runoff hydrograph form and peak discharge (12 to 17 m³/s)
- **Impact on risk classification**



# Simulation results – model coupling

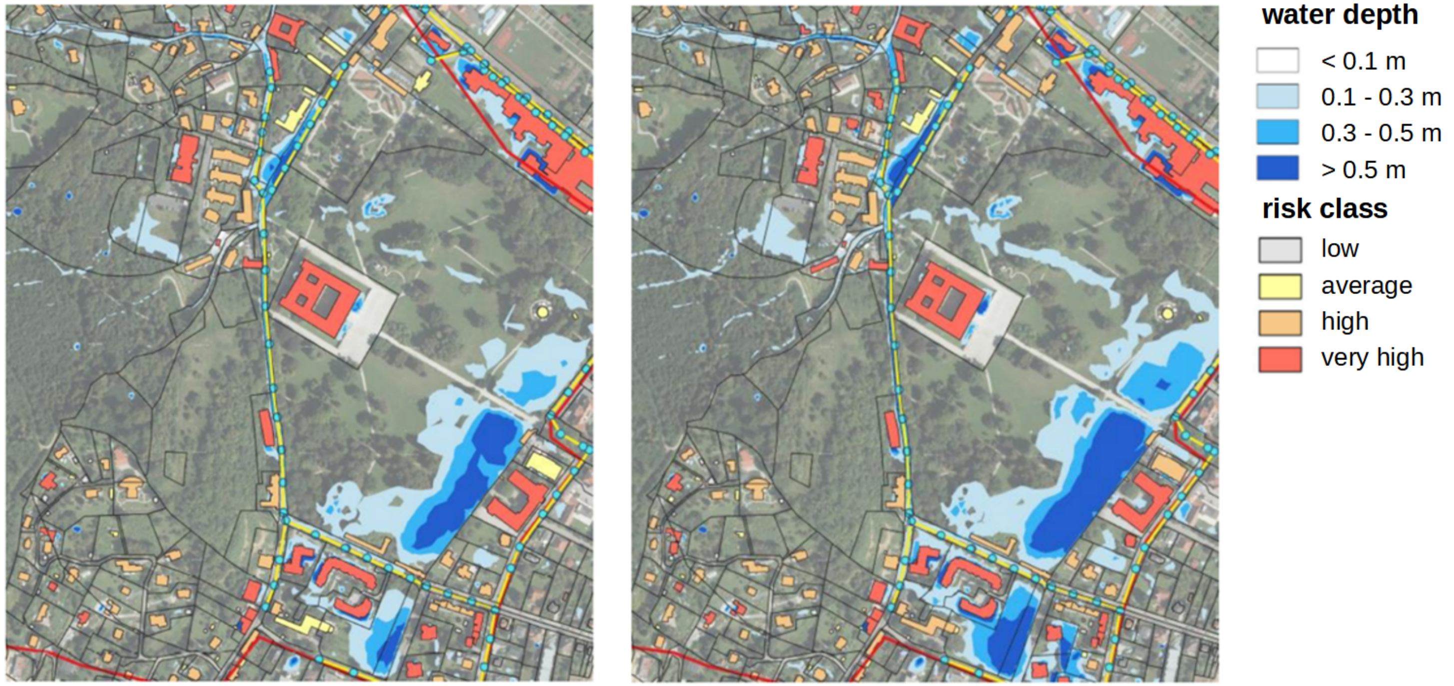
- runoff in sewer system significantly lower than the total surface runoff
- surface runoff
  - Main runoff generated on surfaces not connected to sewer system
  - Locally significant impact from sewer flooding




Exemplary results from 2d-surface runoff model. Left: first run without sewer model; Right: results from coupled model (Aerial view photo: basemap.at)

# Risk mapping

- Risk maps created for all examined return periods
  - risk classification for buildings and structures & areas with risks of personal injuries
  - risk maps for risk classification of buildings include water depth
- Discussion with stakeholders and comparison to past events
- Easily understandable and readable tool - also by stakeholders not familiar with the underlying models or assumptions




Exemplary results of risk map for return period 10 years (left) and 30 years (right) (Aerial view photo: basemap.at)

# Conclusion

- Risk maps provide easily understandable and readable tool
- Classification of hazards, vulnerability and risk based on the automated evaluation worked satisfactorily
  - Plausibility check based on site knowledge indispensable
- Model set up: intensive work on-site and by hand
  - Structures can have significant impact on the flow behaviour
- Model coupling locally showed significant impact of coupled model vs. single models
- Large possible bandwidth for results (peak flow as well as runoff volume)
  - Direct consequence on water depth and risk classification, flood protection measures
- Sensible choice of model parameter values is crucial
  - Calibration data rarely available for similar catchments.
- Sensitivity analysis and plausibility check (e.g. with empirical runoff values, expert knowledge from prior events) advocated