Methodology for qualitative urban flooding risk assessment

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Urban pluvial flooding

- Caused by intense rainfall
- Limited capacity of the drainage systems

Urban pluvial flooding

Why is urban flood (surface) modelling important?

- Floods have been occurring all over the world... and more often
- The majority of the population (and activities) is concentrated in urban areas and tends to increase
- Infrastructures are mainly located in urban areas

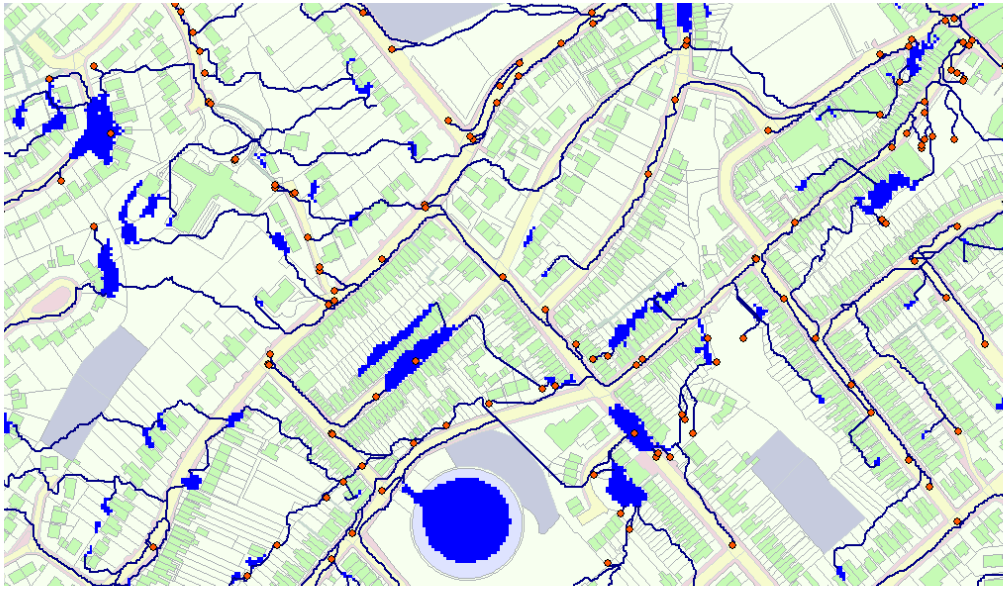
Need for URBAN FLOODING RISK assessment!

Contents

> Methodology for pluvial flooding risk assessment
  - Urban flood modelling
  - Risk assessment
> Case study
> Results and discussion
> Conclusions

Methodology: urban flood modelling

> Dual-drainage concept
> 1D/1D or 1D/2D modelling
> Urban drainage modelling results used to estimate consequences



Methodology: risk assessment

> The risk assessment methodology comprises 3 steps and is applied to each rainfall event
  - Likelihood estimation (based on rainfall probability)
  - Consequence estimation (for each flood prone area)
  - Risk estimation (for each flood prone area)

$$R=f(P,C)$$

Methodology: risk assessment

Likelihood estimation method

- > Definition of 5 likelihood classes
- > Probability calculated using the Poisson distribution

Likelihood classes		Probability range (%)
1	Insignificant	[0; 0.2[
2	Low	[0.2; 1[
3	Moderate	[1; 2[
4	High	[2, 10[
5	Severe	[10; 100[

Methodology: risk assessment

Consequence estimation method

> An event can affect different stakeholders (<u>consequence dimensions</u>)

> Different consequence dimensions
- Impacts on health and safety
- Impacts on other infrastructures (roads, buildings, transports, ...)
- Impacts on the environment
- ...

> It is difficult (if not impossible) to represent all consequence dimensions in financial terms

Methodology: risk assessment

Consequences estimation method

> The classes are <u>equivalent</u> for the considered consequence dimensions

Consequence classes		Consequence dimensions		
		Effect on public transport (> 1h)	**Number of affected buildings**	**Pedestrian safety (*HR**)**
1	Insignificant	No routes affected	0	[0; 0.125[
2	Low	1 route affected	1-10	[0.125; 0.75[
3	Moderate	2-3 routes affected	10-100	[0.75; 1.25[
4	High	3-5 routes affected	100-1,000	[1.25; 2.5[
5	Severe	> 5 routes affected	> 1,000	[2.5; +∞[

**HR* - Hazard rating (Wallingford *et al.*, 2006)

Methodology: risk assessment

Risk estimation method: risk matrix

$$R = f(P, C)$$

		Consequence				
		1	2	3	4	5
Likelihood	5	Low	Medium	High	High	High
	4	Low	Medium	Medium	High	High
	3	Low	Low	Medium	Medium	High
	2	Low	Low	Low	Medium	Medium
	1	Low	Low	Low	Low	Low

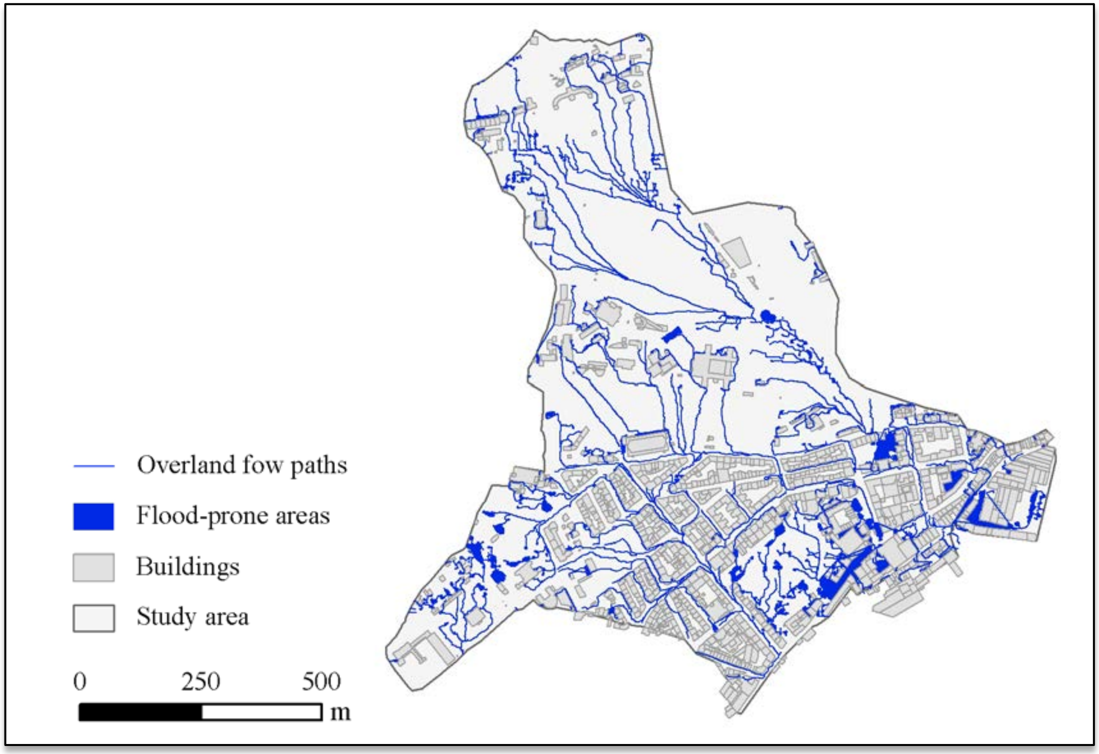
Case study

> Lisbon, Portugal
- Area: 1 km^2
- Elevation range: 0-135 m
- Two distinct areas
  - o *Not urbanised (and steep)*
  - o *Highly urbanised (almost flat)*

Case study

> 1D overland flow network generated using the methodology presented by Maksimovic *et al.* (2009)
- Flood prone areas
- Overland flow paths
- DEM based

> 1D/1D model
- Overland network
- Sewer network



Case study

> Rainfall events

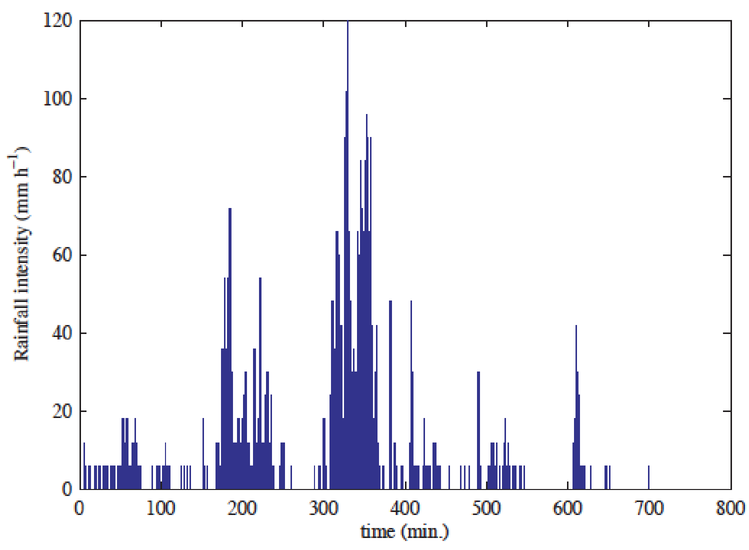
- Storm A – 23h00, 17th Feb 2008 to 12h00, 18th Feb 2008
- Storm B - 15h00, 7th April 2008 to 21h00, 7th April 2008

Rainfall events	Total duration (min.)	Max. intensity 1 min (mm h^{-1})	Total depth (mm)
Storm A	800	120	90.2
Storm B	930	90	16.8

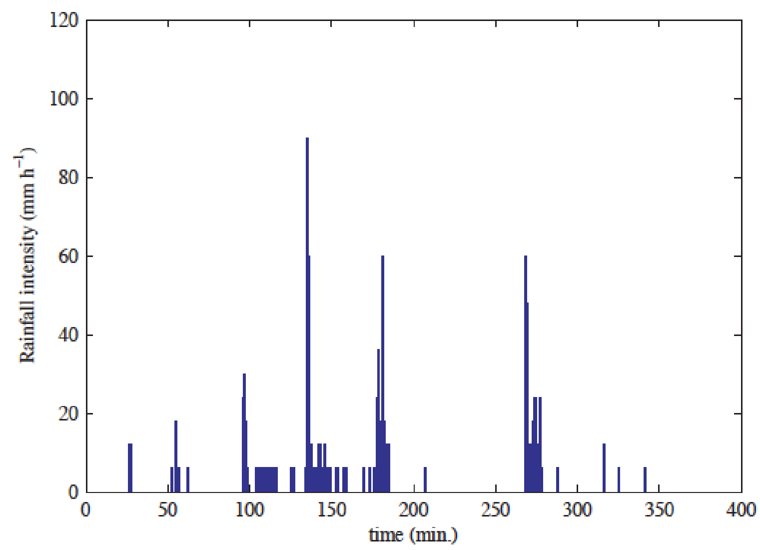
Case study

> Rainfall events

- Storm A – 23h00, 17th Feb 2008 to 12h00, 18th Feb 2008
- Storm B - 15h00, 7th April 2008 to 21h00, 7th April 2008



Storm A hyetograph



Storm B hyetograph

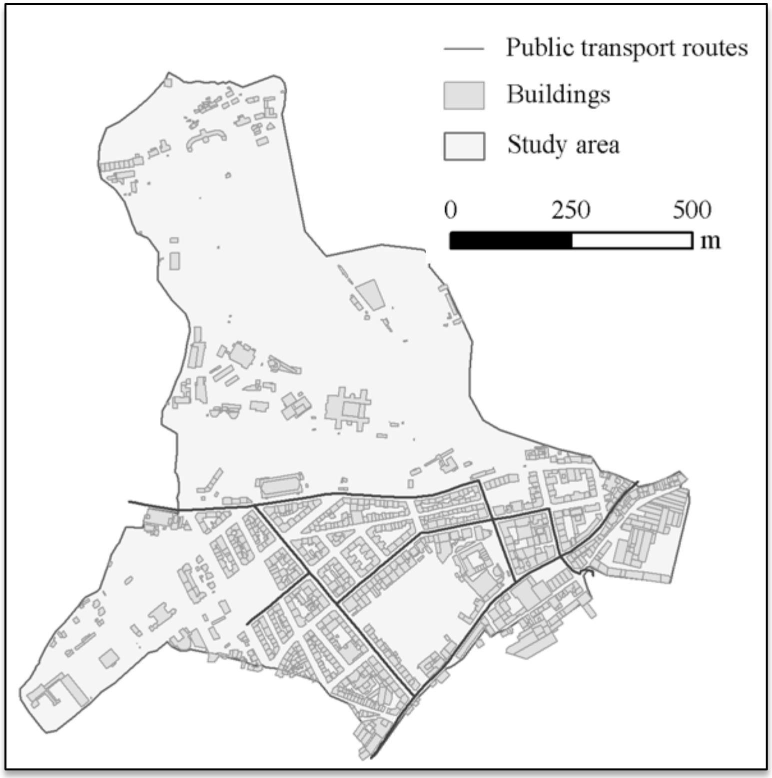
Case study

> Affected properties

- Buildings inside flood-prone areas

> Public transportation services

- >0.3 m water depth, >1 hour
- 2 tram routes
- 8 bus routes



Case study

Consequences for each flood-prone area

> Affected properties
  - Buildings inside flood-prone areas

> Public transportation services
  - >0.3 m water depth, >1 hour
  - 2 tram routes
  - 8 bus routes

> Pedestrian safety
  - $HR=d(v+0.5)+DF$ (HR Wallingford et al, 2006)
    - *V flow velocity* ($m\ s^{-1}$)
    - *d flood depth (m)*
    - *DF debris factor (0 or 1 if water depth <0.25 m or >0.25 m)*

Results

> Assessment of flooding (rainfall) likelihood

- Flooding likelihood depends on the conditions of the catchment (e.g. soil saturation) and sewer system (e.g. sediments)
- Rainfall likelihood based on the IDF curves for Lisbon (Brandão *et al.*, 2001)

Storms	Return period (years)	Probability (%)	Likelihood class
Storm A	350	0.3	**2**
Storm B	2	39.3	**5**

Results

> Estimation of flooding consequences

- Calculated water depths for overland flow paths >0.2 m

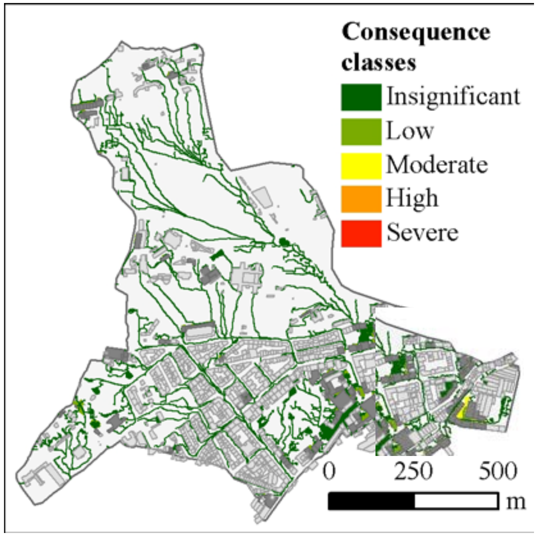
Number of **flood-prone areas**...

Consequence class	**... affecting properties**		**... affecting public transportation services**	
	Storm A	Storm B	Storm A	Storm B
1	695(80.2%)	797(91.1%)	860 (99.2%)	866 (99.9%)
2	166 (19.1%)	69 (8.0%)	0	0
3	6 (0.7%)	1 (0.1%)	5 (0.6%)	1 (0.1%)
4	0	0	0	0
5	0	0	2 (0.2%)	0

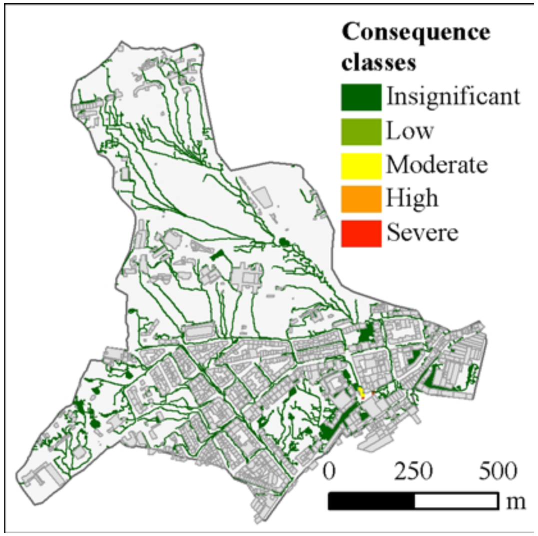
Results

> Estimation of flooding consequences

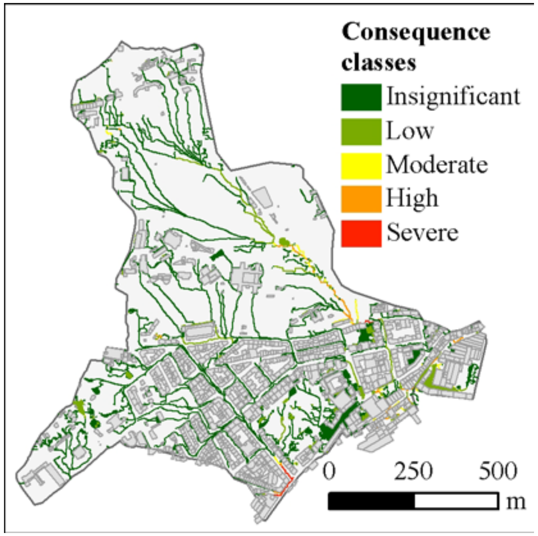
- Calculated water depths for overland flow paths >0.2 m
- Majority (aprox 90%) of flood-prone areas in classes 1 and 2, i.e. insignificant and low consequences



… affecting properties



… affecting public transportation services



… affecting pedestrian safety

Results

> Assessment of flooding consequences

- Calculated water depths for overland flow paths >0.2 m
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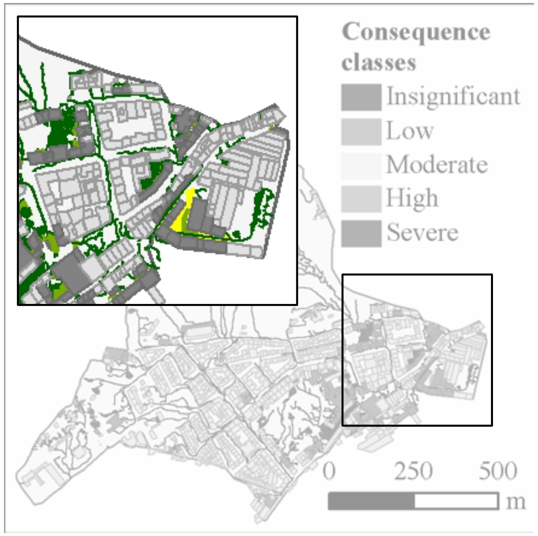


… affecting properties

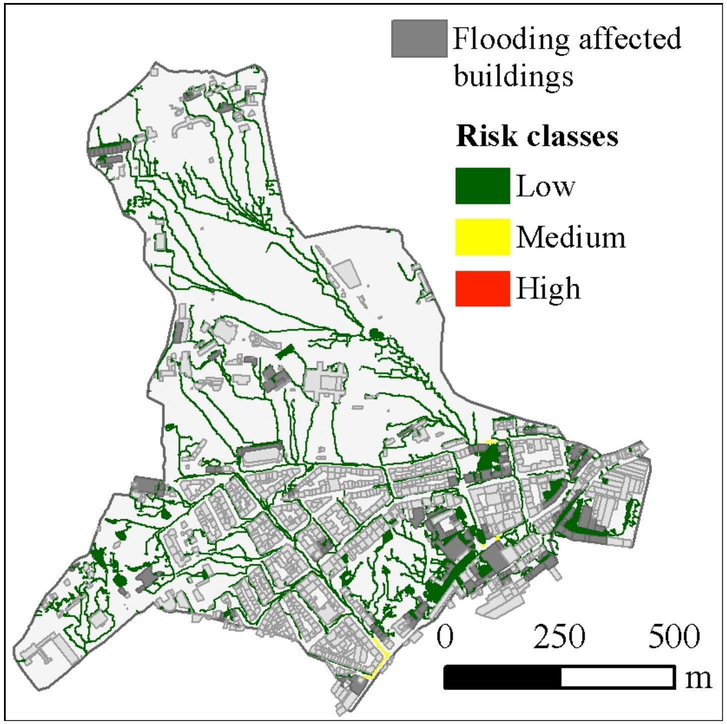
… affecting public transportation services

… affecting pedestrian safety

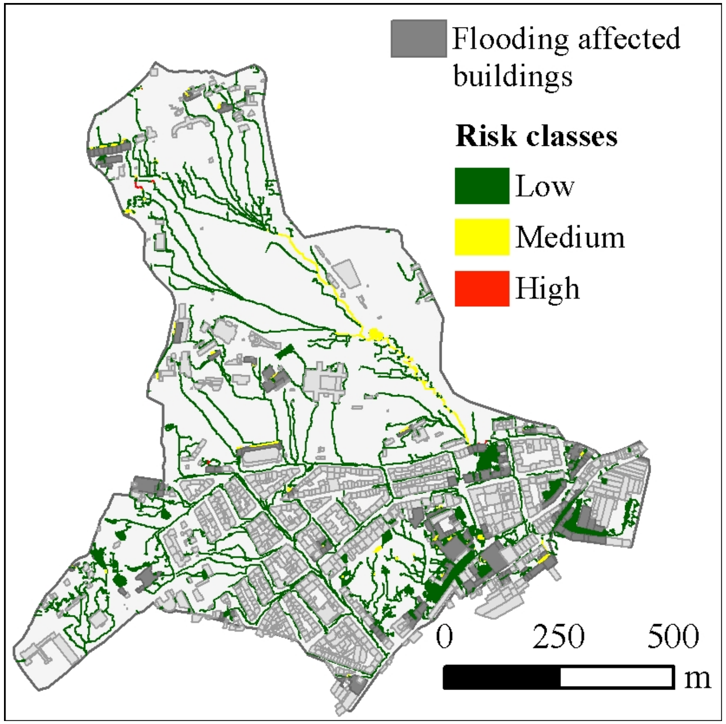
Results

> Flooding risk

- Combination of Likelihood and **maximum** of analysed **Consequence** dimensions



Storm A



Storm

Conclusions

> For the case study, only **localised high flooding risk** was estimated

> **1D/1D and 1D/2D flood models** can produce **useful** results to estimate flood risk
- The methodology presented here can be implemented using both approaches

> The **risk matrix** method is an **easy to implement** method to estimate risk

Conclusions

> Definition of classes (likelihood and consequence) **reduces subjectivity**

> How to deal with **flood event probability / likelihood?**

> Risk matrix can be applied to **different consequence dimensions**

> **Equivalent classes** for different consequence dimensions

Thank for your attention.

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