# Non-Structural measures: Carlisle Case Study

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## KULTURisk methodology themed teaching material


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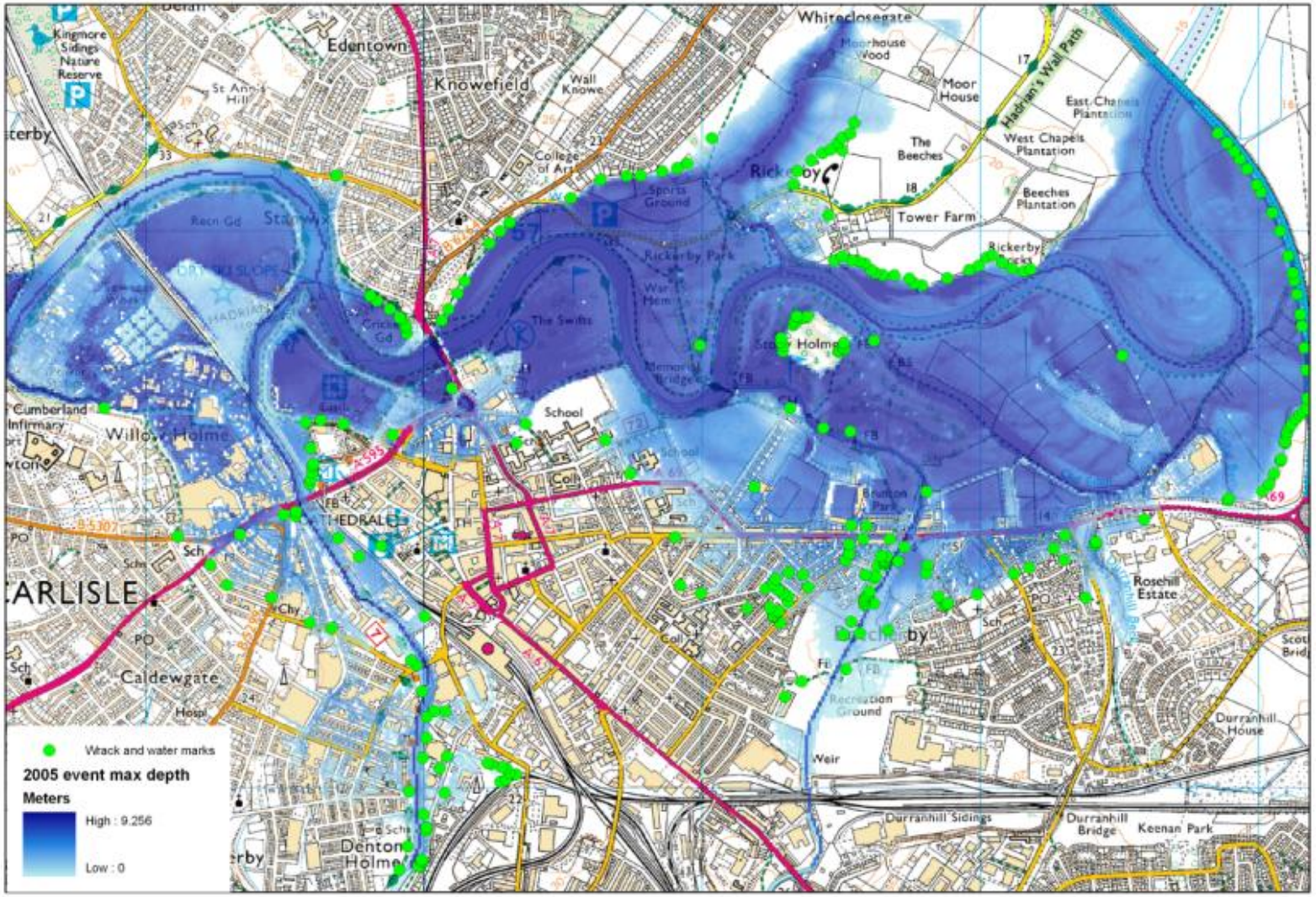
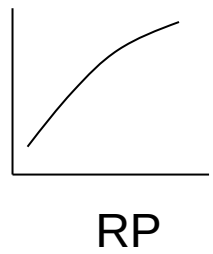
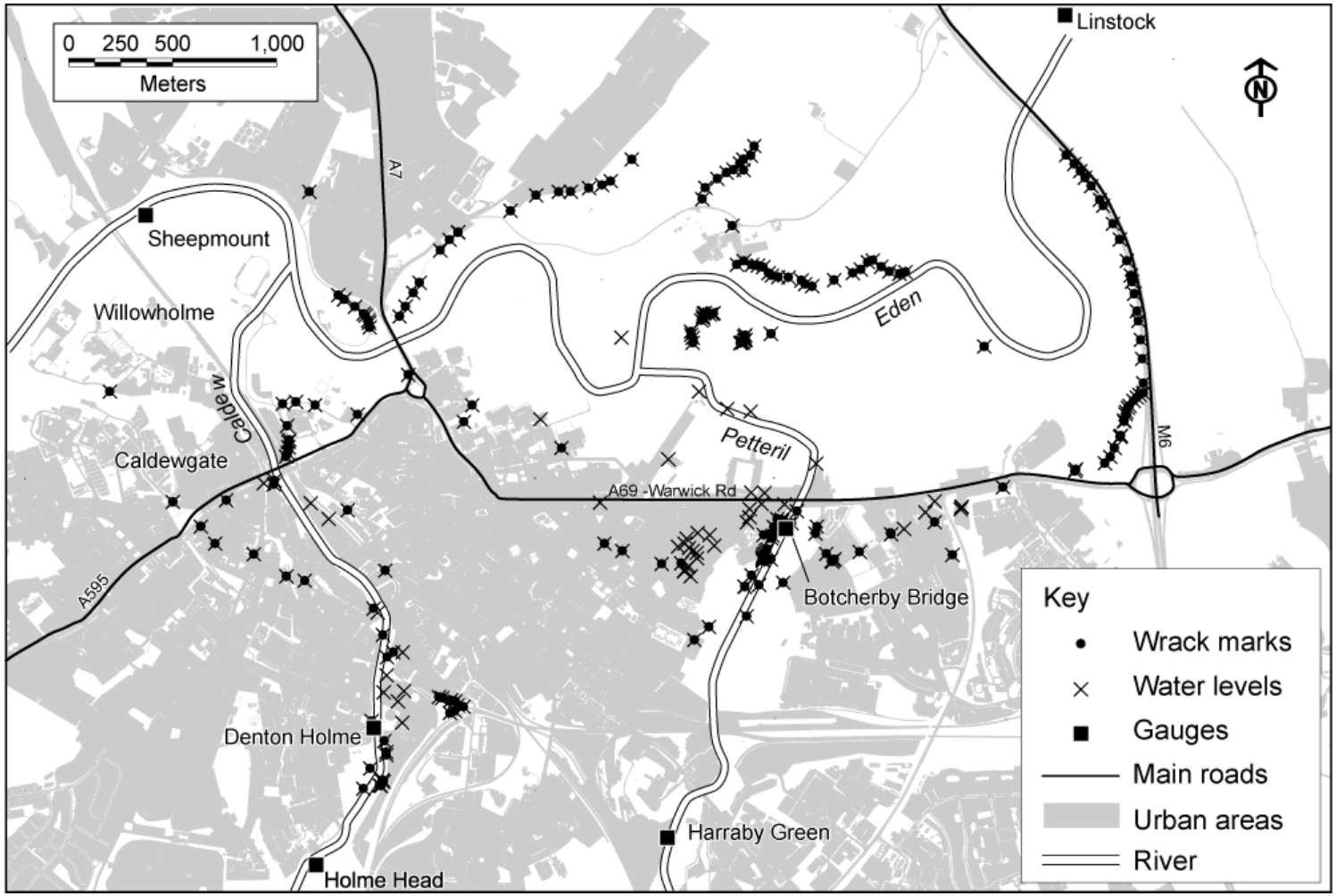
# Carlisle Case Study: Flooding in 2005



# The problem at confluences

- This definition causes a problem at confluences



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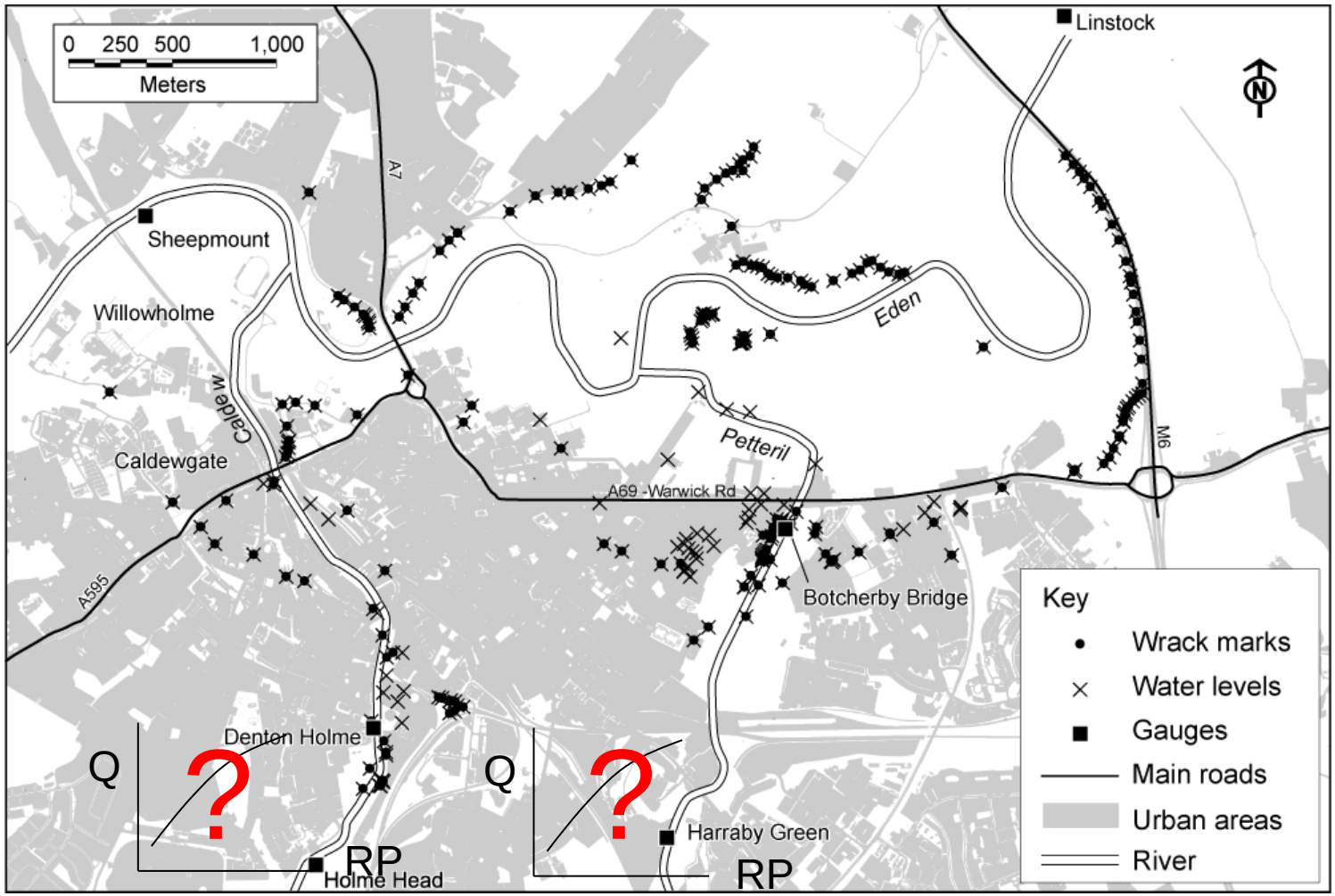
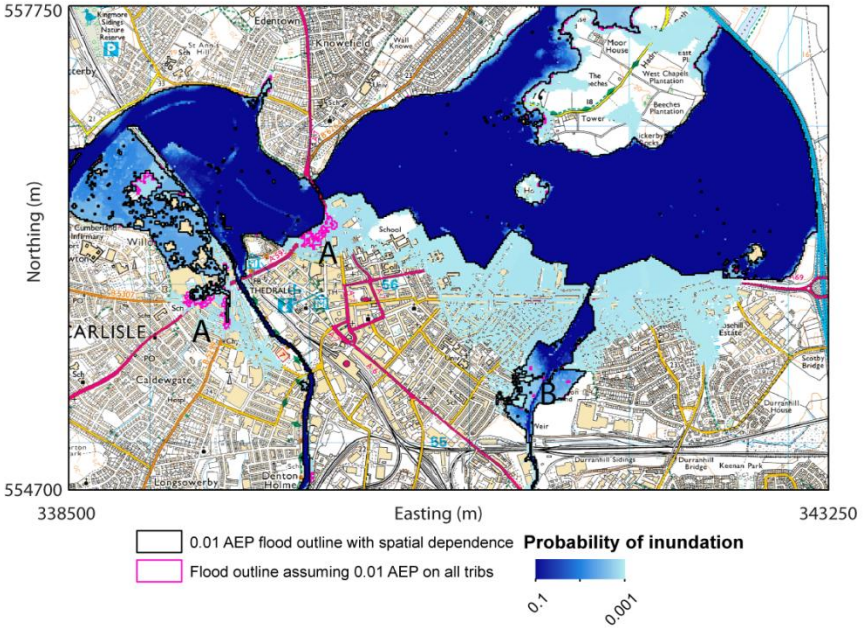
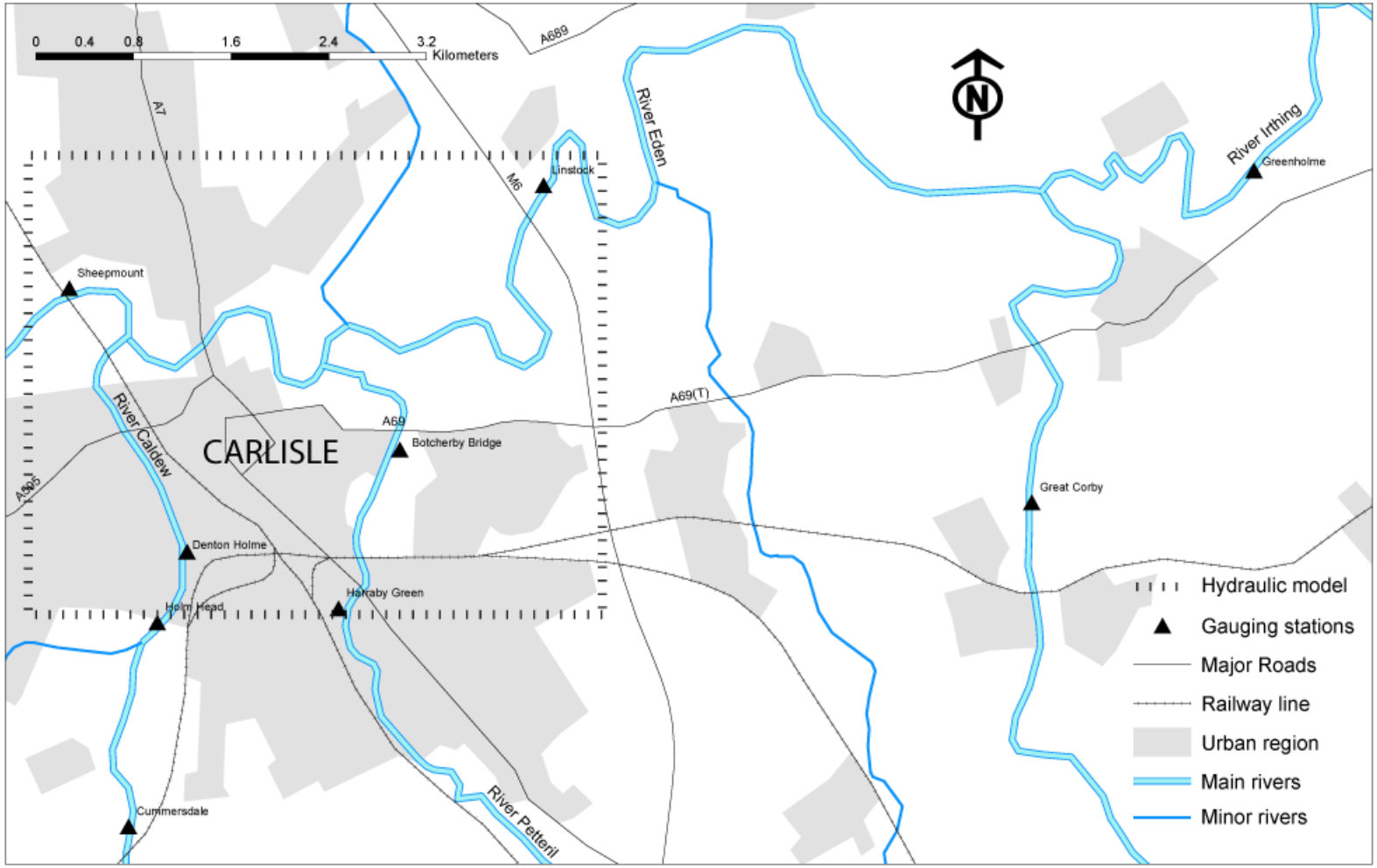


# KUTURisk Scenarios

- Baseline scenario
  - Deterministic mapping of flood hazard, 1 in 100 year flood
    - Analogous to the deterministic mapping that the Environment Agency would carry out as part of a flood risk assessment.
- Alternate scenario
  - Probabilistic mapping of flood hazard with uncertainty due to historical record length.
  - Statistical event generator
    - Simulate many possible events
    - Simulate flood extent
    - Combine into probabilistic map
    - Repeat process to consider uncertainty

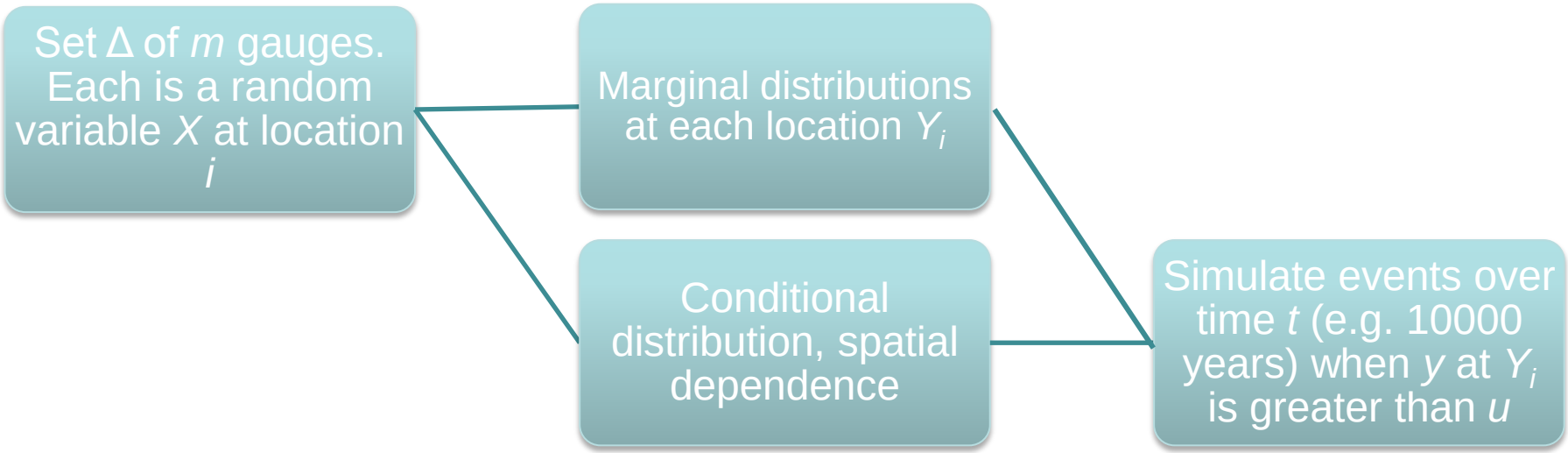


# Statistical modelling of gauge flows

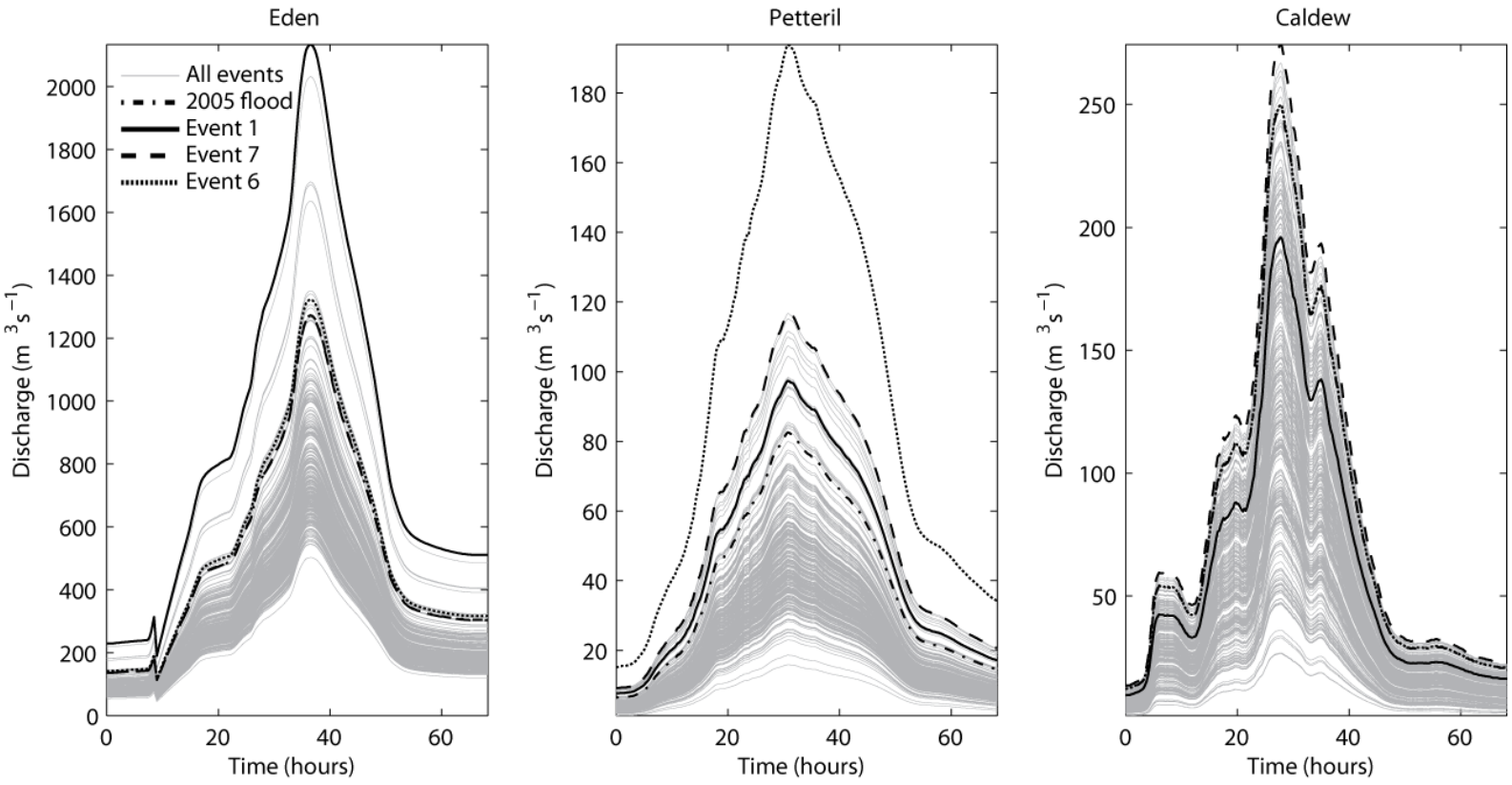


# The problem at confluences

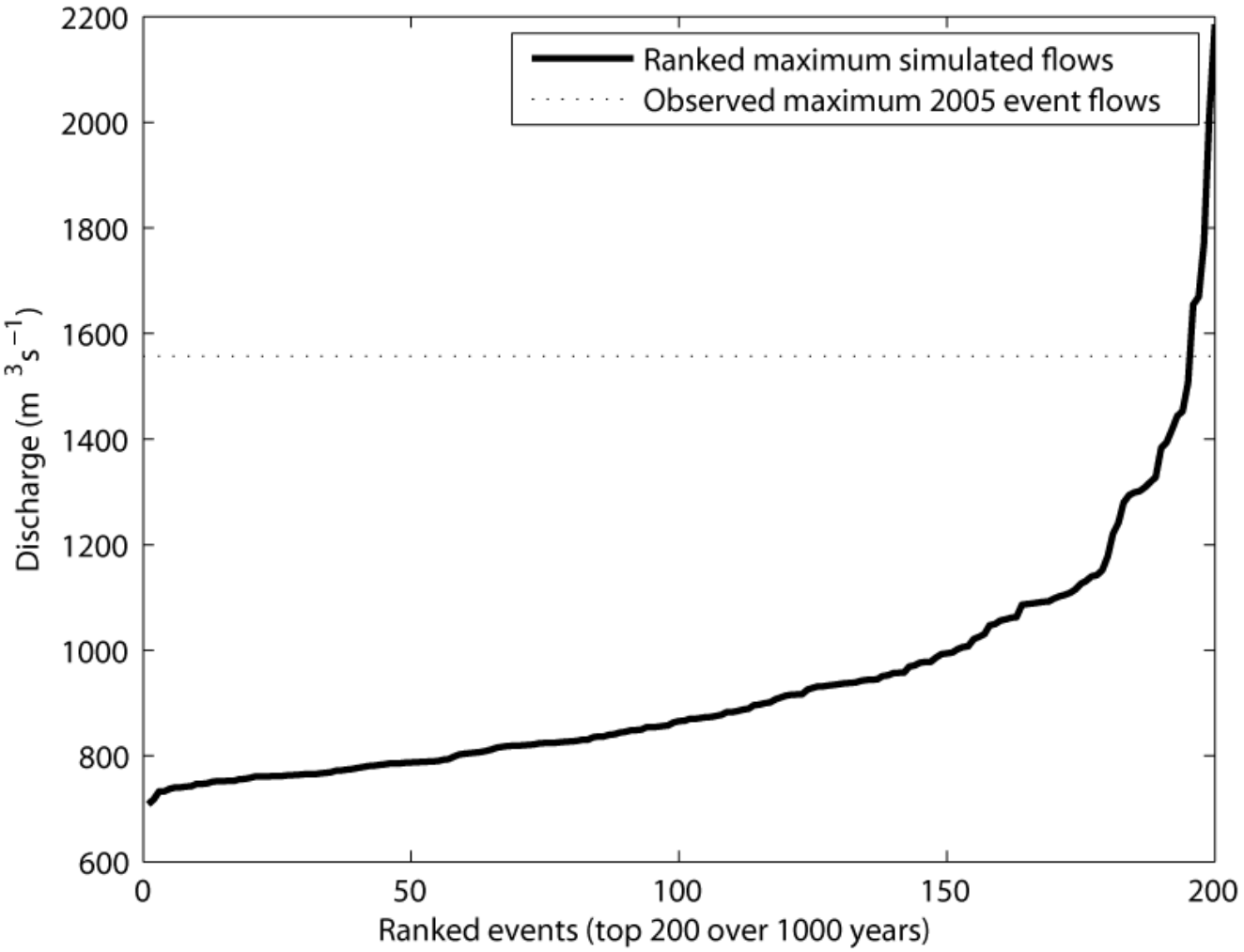
- Model the conditional distribution of a set of variables given that one of these variables exceeds a high threshold (Heffernan and Tawn, 2004).
- Take a Copula approach
  - Marginal distributions modelled using generalised Pareto



# Event hydrographs

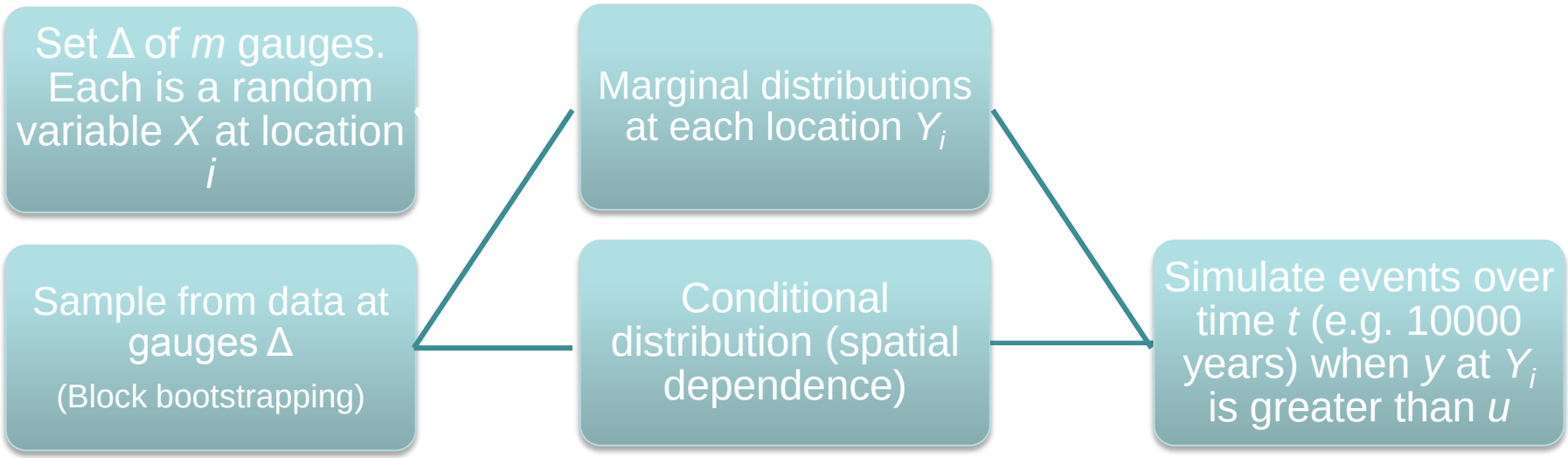


# Simulated discharge



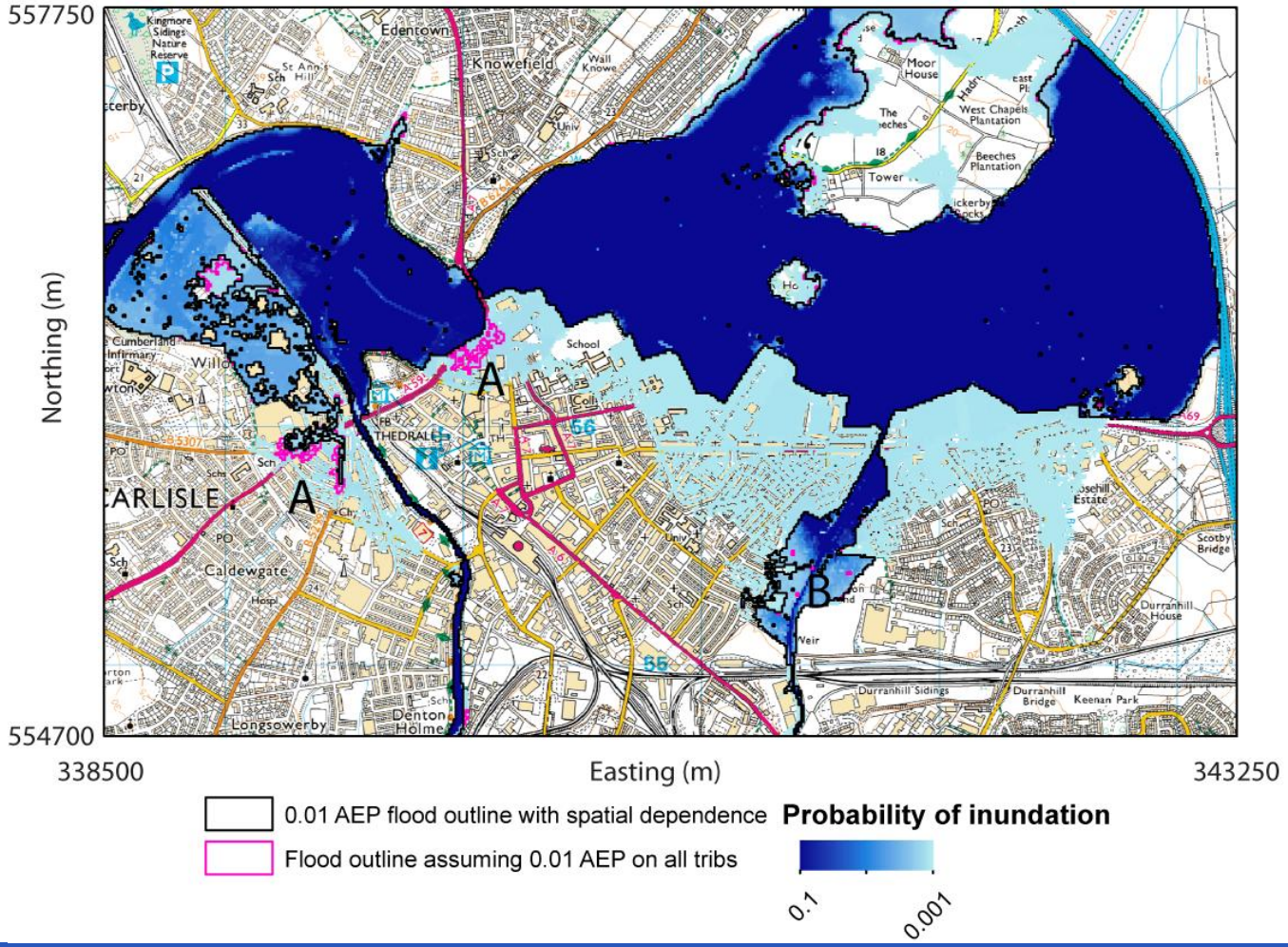
# The problem at confluences (uncertainty)

Refit to data and run event generator may times to approximate uncertainty

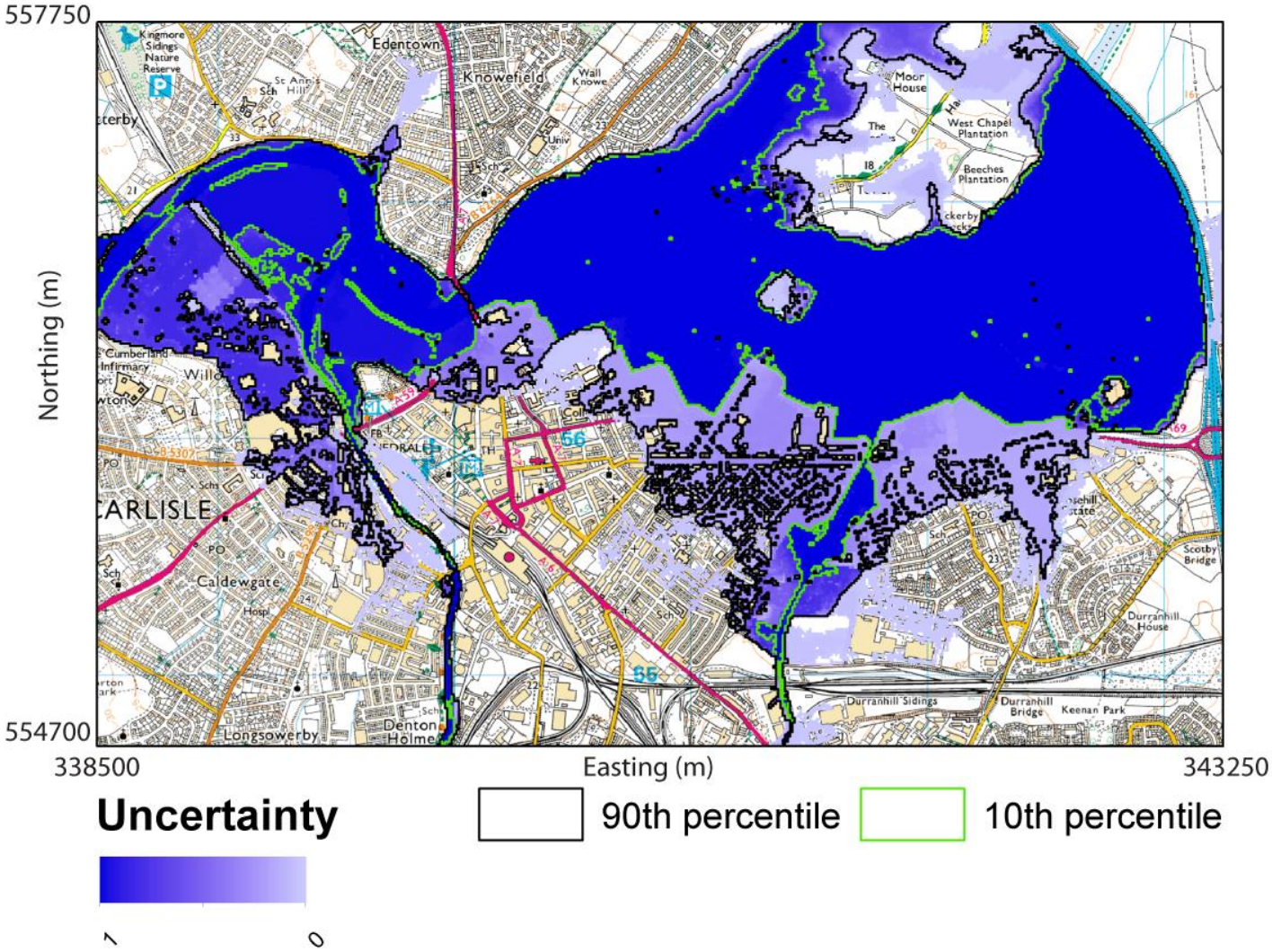


# Probability of inundation

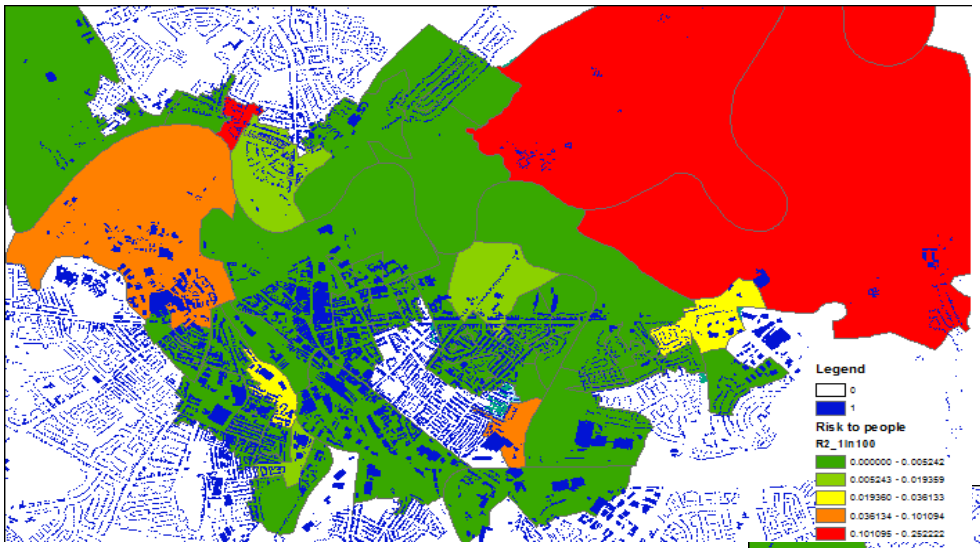
- Run 1 of the event generator using all flow data



# Uncertainty in the 0.01 AEP extent



# Risk to people by district




←
Baseline scenario
1 in 100 year flood

0.35 fatalities in total

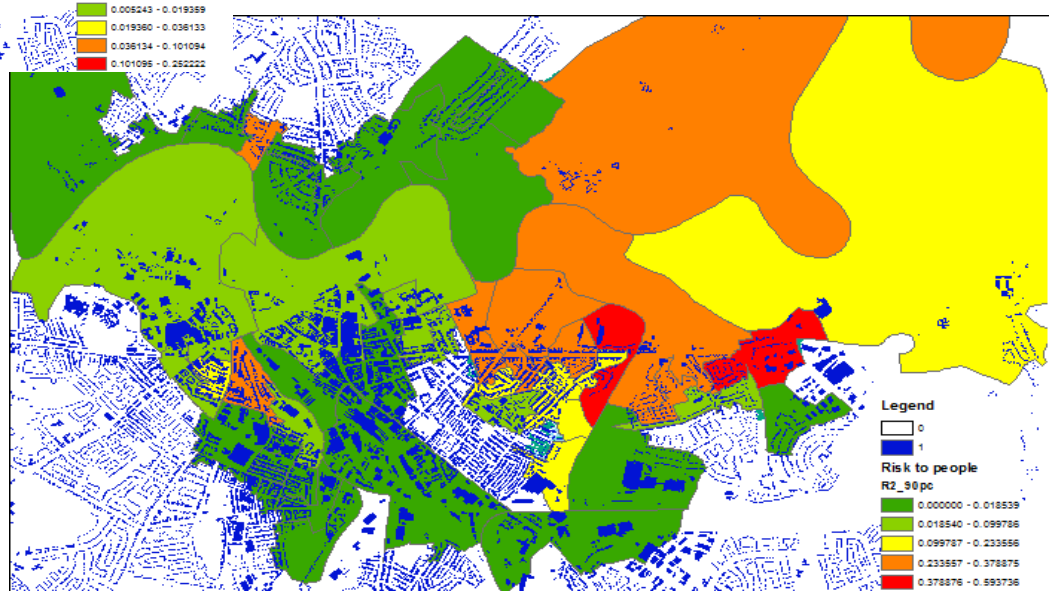
Risk focused in rural areas

Alternate scenario
90th percentile of 1 in 100 year flood

2 fatalities in total

Risk focused in urban areas

→

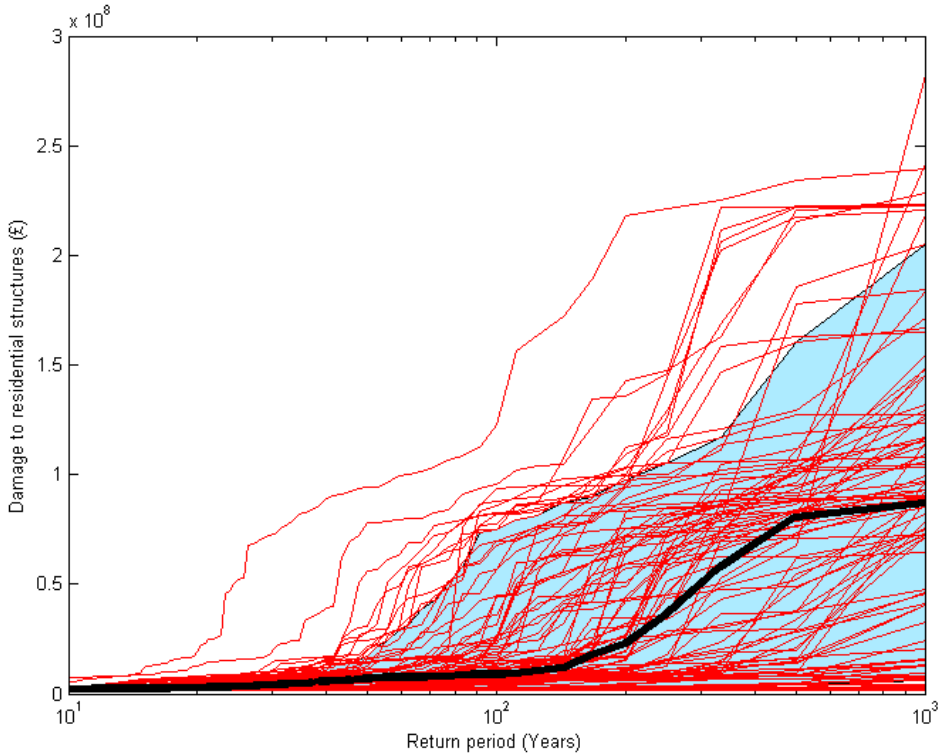


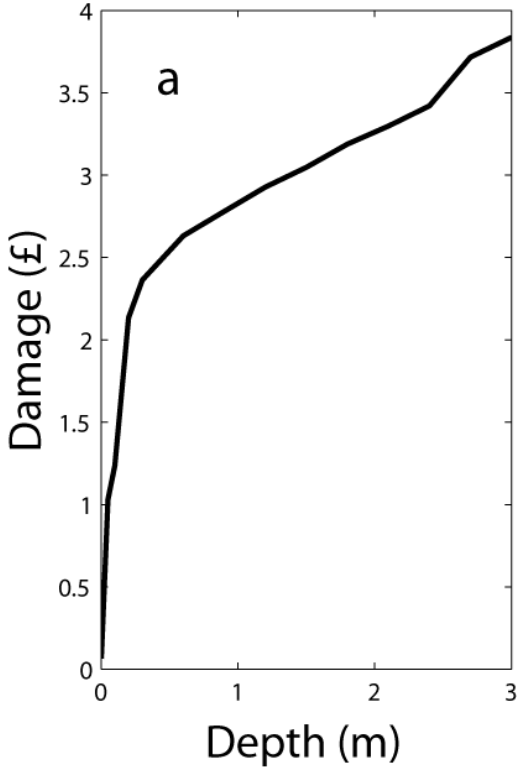
# Results

| RRA | Baseline | Alternative |
|---|---|---|
| Number of injuries | 34 people | 203 people |
| Number of deaths | 1 person | 6 people |
| Inundated buildings (Urban) | 34700 $m^2$ | 255000 $m^2$ |
| Inundated buildings (Industry) | 37800 $m^2$ | 45100 $m^2$ |
| Inundated roads | 6850 m | 22410 m |
| SERRA | | |
| People | | |
| Number of injuries (SERRA adjusted) | 11 people | 67 people |
| Number of deaths (SERRA adjusted) | 0.35 people | 2 people |
| Cost of Injuries | £0.59M | £3.5M |
| Cost of Deaths | £0.89M | £5.2M |
| Cost of Trauma | £9.2M | £62.5M |
| Cost of Disruption | £0.1M | £0.6M |
| Cost of Emergency response & evacuation (10.7% of Buildings cost) | £2.7M | £20.5M |
| Total cost to people | £13.6M | £92.5M |
| Buildings | | |
| Damage to Structures | £9.05M | £75.0M |
| Damage to Contents | £5.85M | £44.2M |
| Total Damage to Structures | £14.9M | £119.2M |
| Total Cost | £28.5M | £211.7M |

# Risk

- MasterMap building outlines
- Depth damage curve
- Calculate damage from each event



# Conclusions

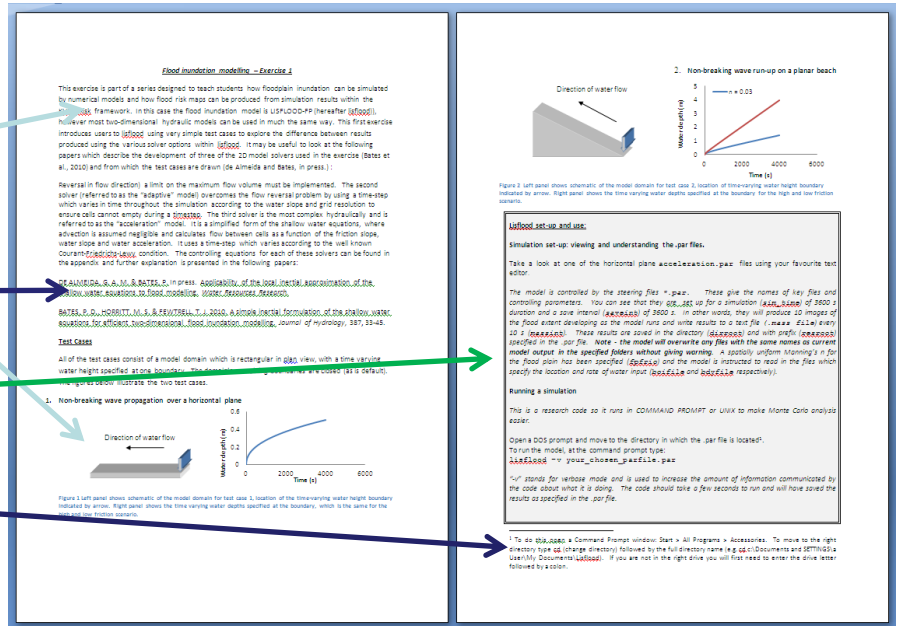
- Flooding at confluences is critical to the basin-wide development of flood hazard and depends on the joint spatial distribution of flows.
- The maximum flood outline was a combination of multiple events.
  - Cannot assume the same return period on all tributaries
- Risk assessment using the event data was demonstrated.
  - Expected damages increase nonlinearly.
  - Areas at highest risk can change when uncertainty is considered
- As expected a few events caused most of the damage.

# Independent Teaching Material

- Five exercises each 1-3 hrs
- Explore key KULTURisk themes
- Designed for independent working
- Available from UoB, hydrology website and KULTURisk link database
- Methods and instructions  suitably generic for a range of software

Typical structure

- Introduction/background information
- Suggestions for further reading
- Boxed exercise tasks with instructions
- Further hints/tips



*Flood inundation modelling – Exercise 1*

This exercise is part of a series designed to teach students how floodplain inundation can be simulated by numerical models and how flood risk maps can be produced from simulation results within the [illegible]risk framework. In this case the flood inundation model is LISFLOOD-FP (hereafter (*lisflood*)). However most two-dimensional hydraulic models can be used in much the same way. This first exercise introduces users to *lisflood* using very simple test cases to explore the difference between results produced using the various solver options within *lisflood*. It may be useful to look at the following papers which describe the development of three of the 1D model solvers used in the exercise (Bates et al., 2010) and from which the test cases are drawn (de Almeida and Bates, in press.) :

Reversal in flow direction) a limit on the maximum flow volume must be implemented. The second solver (referred to as the "adaptive" model) overcomes the flow reversal problem by using a time-step which varies in time throughout the simulation according to the water slope and grid resolution to ensure cells cannot empty during a timestep. The third solver is the most complex hydraulically and is referred to as the "acceleration" model. It is a simplified form of the shallow water equations, where advection is assumed negligible and calculates flow between cells as a function of the friction slope, water slope and water acceleration. It uses a time-step which varies according to the well known Courant-Friedrich-Lewy condition. The controlling equations for each of these solvers can be found in the appendix and further explanation is presented in the following papers:

DE ALMEIDA, G. A. M. & BATES, P. in press. Applicability of the local inertial approximation of the shallow water equations to flood modeling. *Water Resources Research*.

BATES, P. D., HORRITT, M. S. & FEWTRELL, T. J. 2010. A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling. *Journal of Hydrology*, 387, 33-45.

**Test Cases**

All of the test cases consist of a model domain which is rectangular in plan view, with a time varying water height specified at one boundary. The [illegible] as a closed (as is default).

The figures below illustrate the two test cases.

1. **Non-breaking wave propagation over a horizontal plane**




Figure 1 Left panel shows schematic of the model domain for test case 1, location of the time-varying water height boundary indicated by arrow. Right panel shows the time varying water depths specified at the boundary, which is the same for the high and low friction scenario.

2. **Non-breaking wave run-up on a planar beach**




Figure 2 Left panel shows schematic of the model domain for test case 2, location of time-varying water height boundary indicated by arrow. Right panel shows the time varying water depths specified at the boundary for the high and low friction scenario.

**Lisflood set-up and use:**

**Simulation set-up: viewing and understanding the .par files.**

Take a look at one of the horizontal plane `acceleration.par` files using your favourite text editor

*The model is controlled by the steering files `*.par`. These give the names of key files and controlling parameters. You can see that they are set up for a simulation (`sim_time`) of 3600 s duration and a save interval (`saveint`) of 3600 s. In other words, they will produce 10 images of the flood extent developing as the model runs and write results to a text file (`.mass file`) every 10 s (`massint`). These results are saved in the directory (`dirroot`) and with prefix (`resroot`) specified in the .par file. Note - the model will overwrite any files with the same names as current model output in the specified folders without giving warning. A spatially uniform Manning's n for the flood plain has been specified (`fpfric`) and the model is instructed to read in the files which specify the location and rate of water input (`bcifile` and `bdyfile` respectively).*

**Running a simulation**

*This is a research code so it runs in COMMAND PROMPT or UNIX to make Monte Carlo analysis easier.*

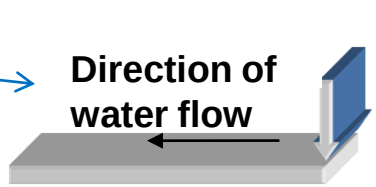
Open a DOS prompt and move to the directory in which the .par file is located[1].
To run the model, at the command prompt type:
`lisflood -v your_chosen_parfile.par`

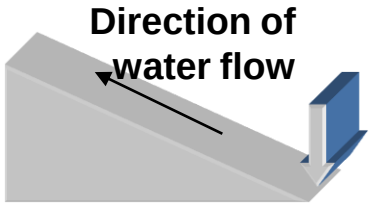
*"-v" stands for verbose mode and is used to increase the amount of information communicated by the code about what it is doing. The code should take a few seconds to run and will have saved the results as specified in the .par file.*

[1] To do this open a Command Prompt window: Start > All Programs > Accessories. To move to the right directory type cd (change directory) followed by the full directory name (e.g. cd c:\Documents and SETTINGS\a User\My Documents\Lisflood). If you are not in the right drive you will first need to enter the drive letter followed by a colon.

# Exercises

Theoretical test-cases




Simple theoretical test cases

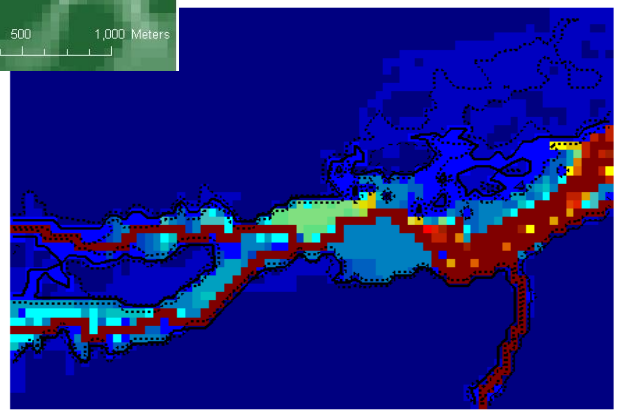
1. Introduction to lisflood – 2D solvers

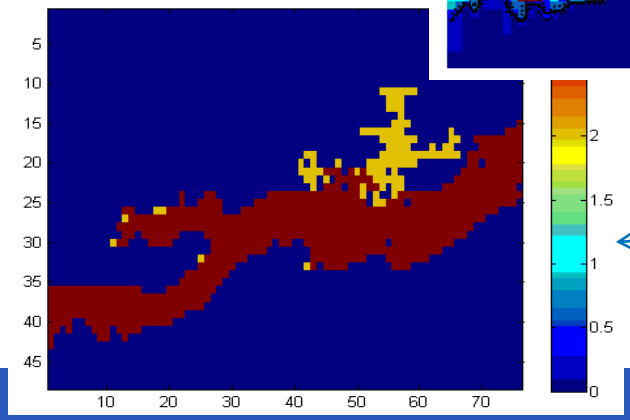
Real-world test case

2. Simulate river flooding
3. Use exercise 2 output to create risk map (simplified KULTURisk methodology)
4. Probabilistic risk mapping, spatial dependence and uncertainty
5. Exploring lisflood – assessing flood prevention measures by modifying input files


Real-world test-case

Probabilistic mapping and uncertainty



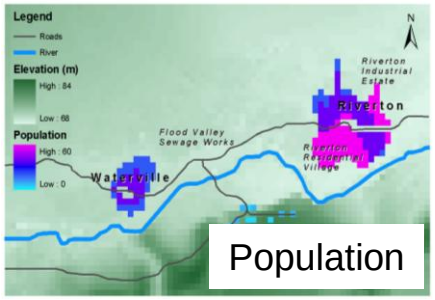


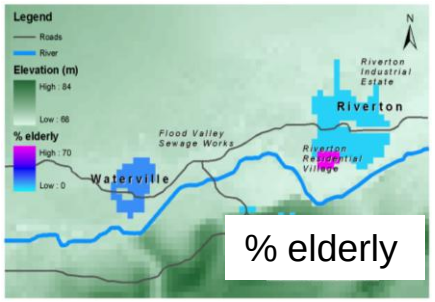

Effect of flood defence

# Exercise 3 – Risk mapping: Data Provided

## Hazard Receptors:

- People - Exposure
  - Vulnerability
- Buildings - Exposure
  - Cost
- Roads - Exposure

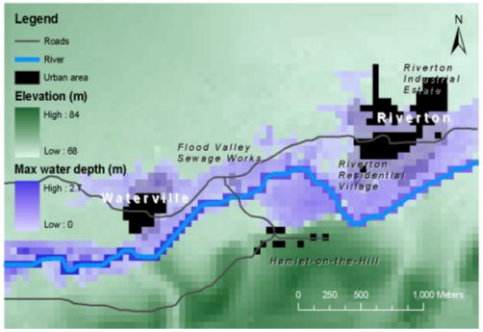



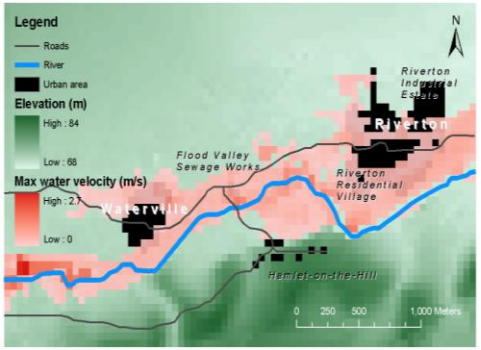


## Hazard Indicators

- Max predicted water depth:



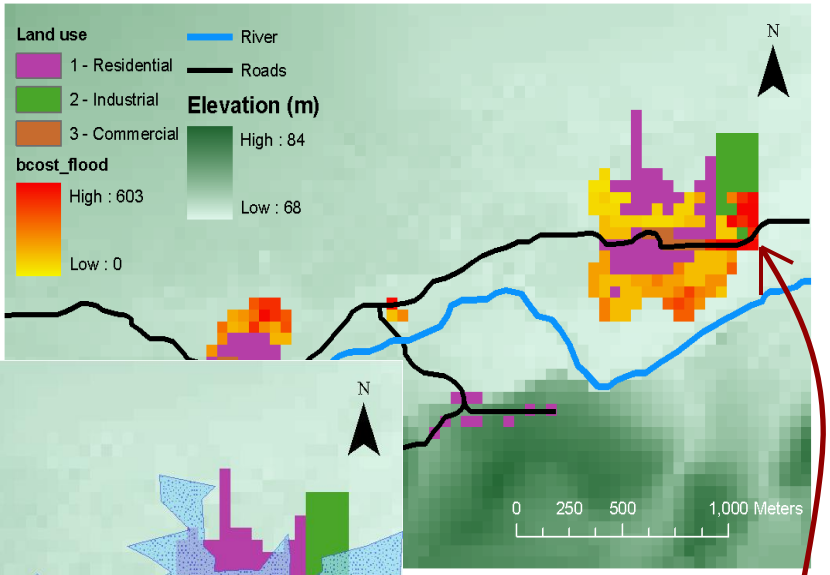

- Max predicted water velocity:

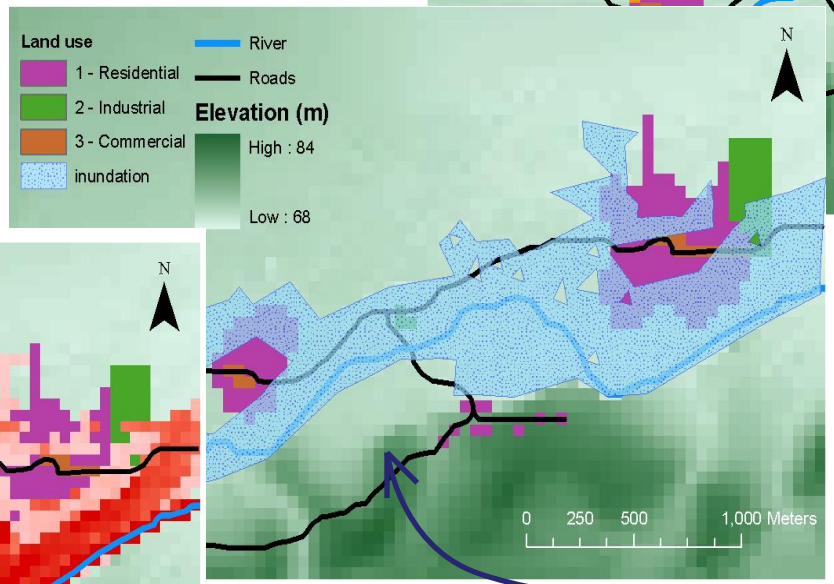


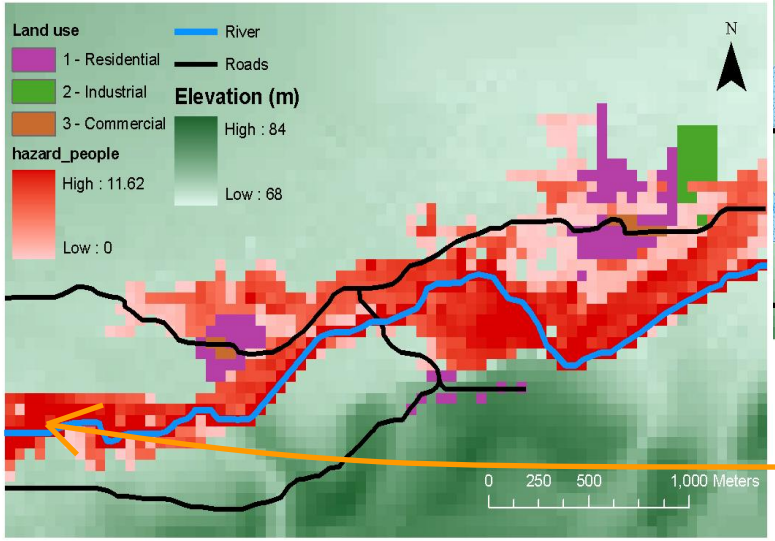
# Exercise 3 – Risk mapping: Tasks

Calculate/identify the following:

- Physical hazard to people and buildings
- Risk of injury/risk of fatality per cell
- Areas of likely road inundation
- Likely economic costs due to building damage




Example questions:

Which cell has the highest economic cost to buildings?

What is the total length of roads inundated?

Where is the highest physical risk to people?