A multi-site approach to risk assessment for the insurance industry

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HydroPredict, Prague 2010

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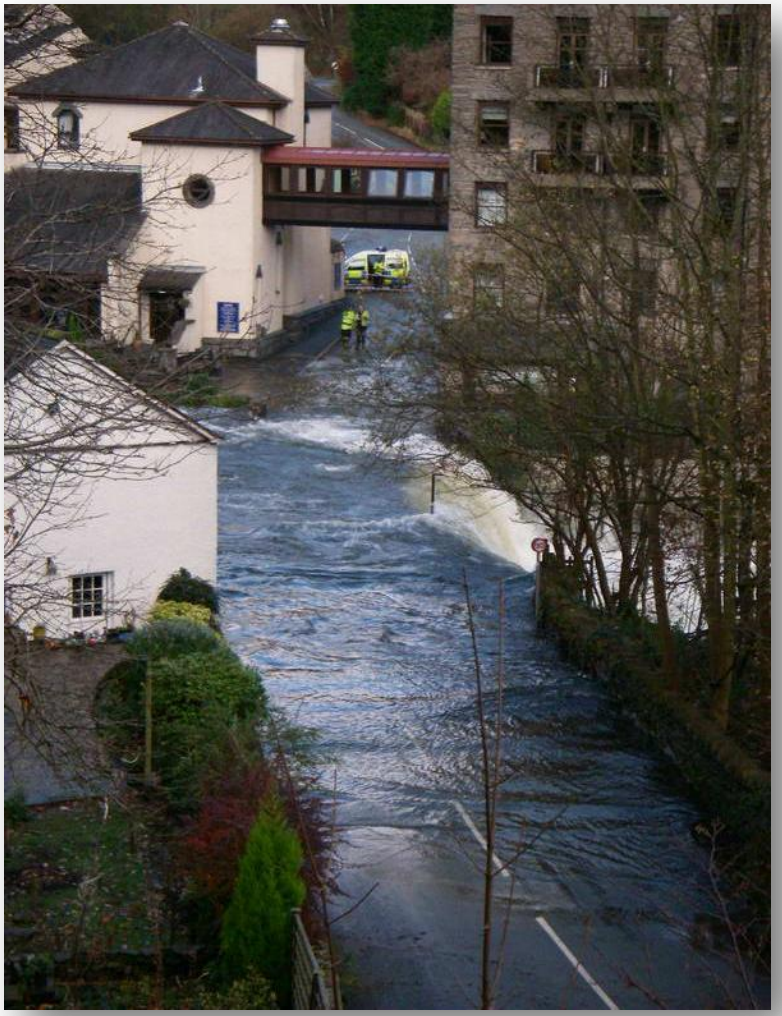
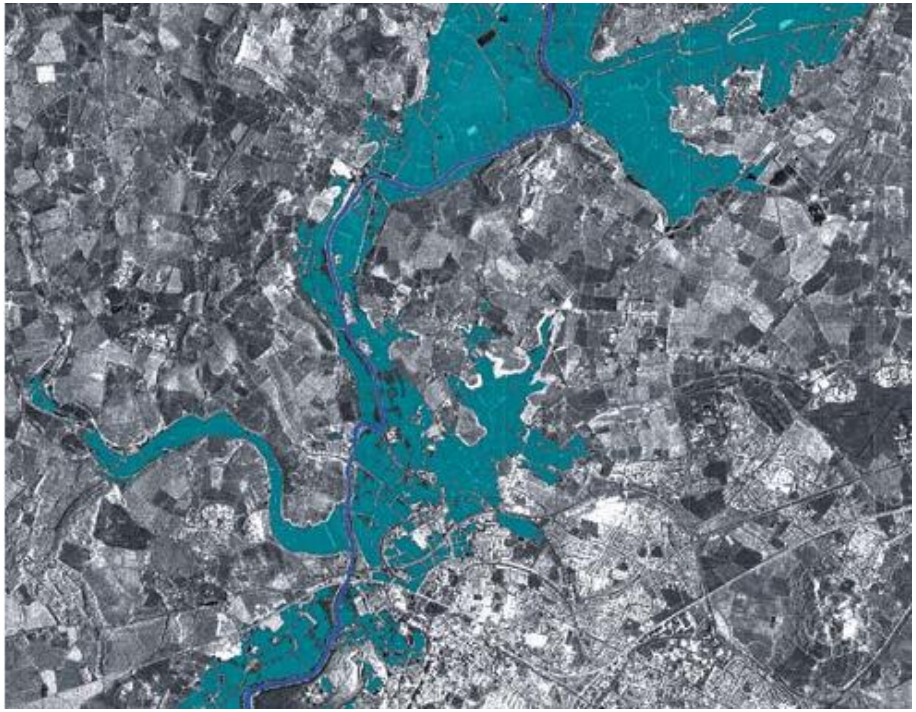
Outline

- Introduction
- Methodology
  - Modelling extreme events
  - Flood defences
- Calculating Risk
- Conclusions



Catastrophe Models

Premium = AAL + Risk Load + Expense Load



AIR model output

EQECAT

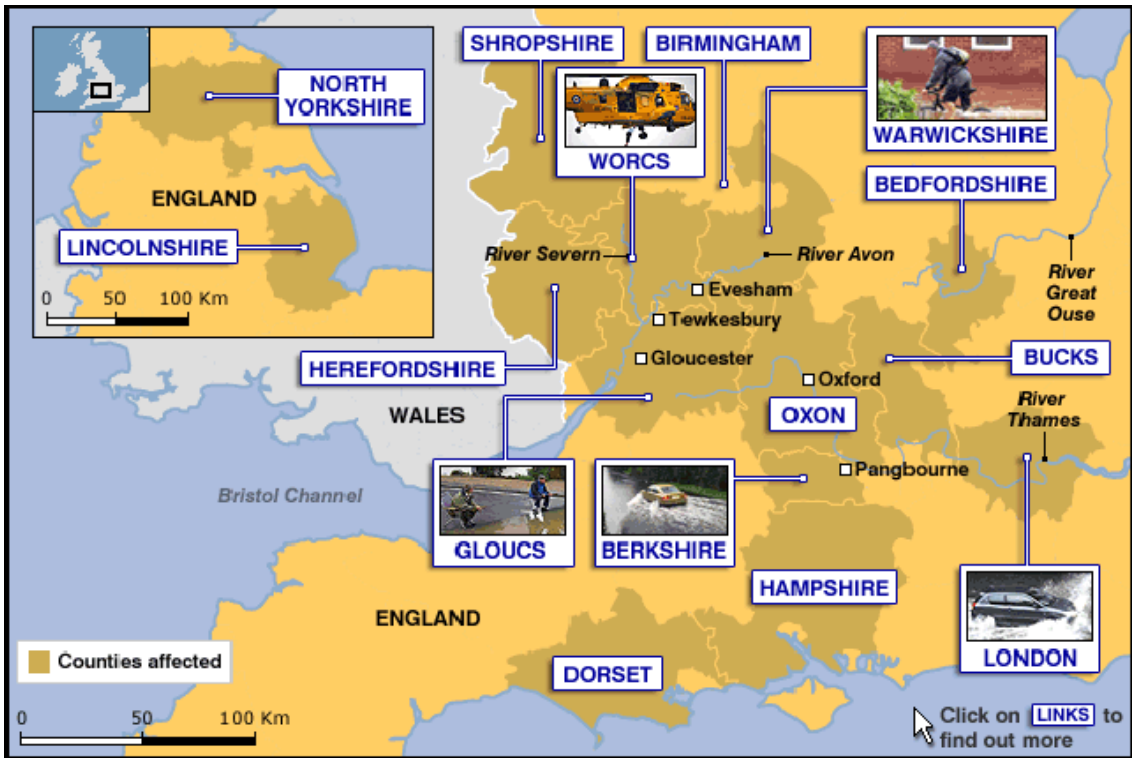
AIR WORLDWIDE

JBA consulting

RMS

Aims and Objectives

To develop a method for multi-site concurrent damages due to weather related extremes



2007 Flood (BBC News)

Spatial dependencies at multiple scales

Methodology

Source

weather related extremes

Pathway

catchments, rivers and defence systems

Receptor

UK caravan sites

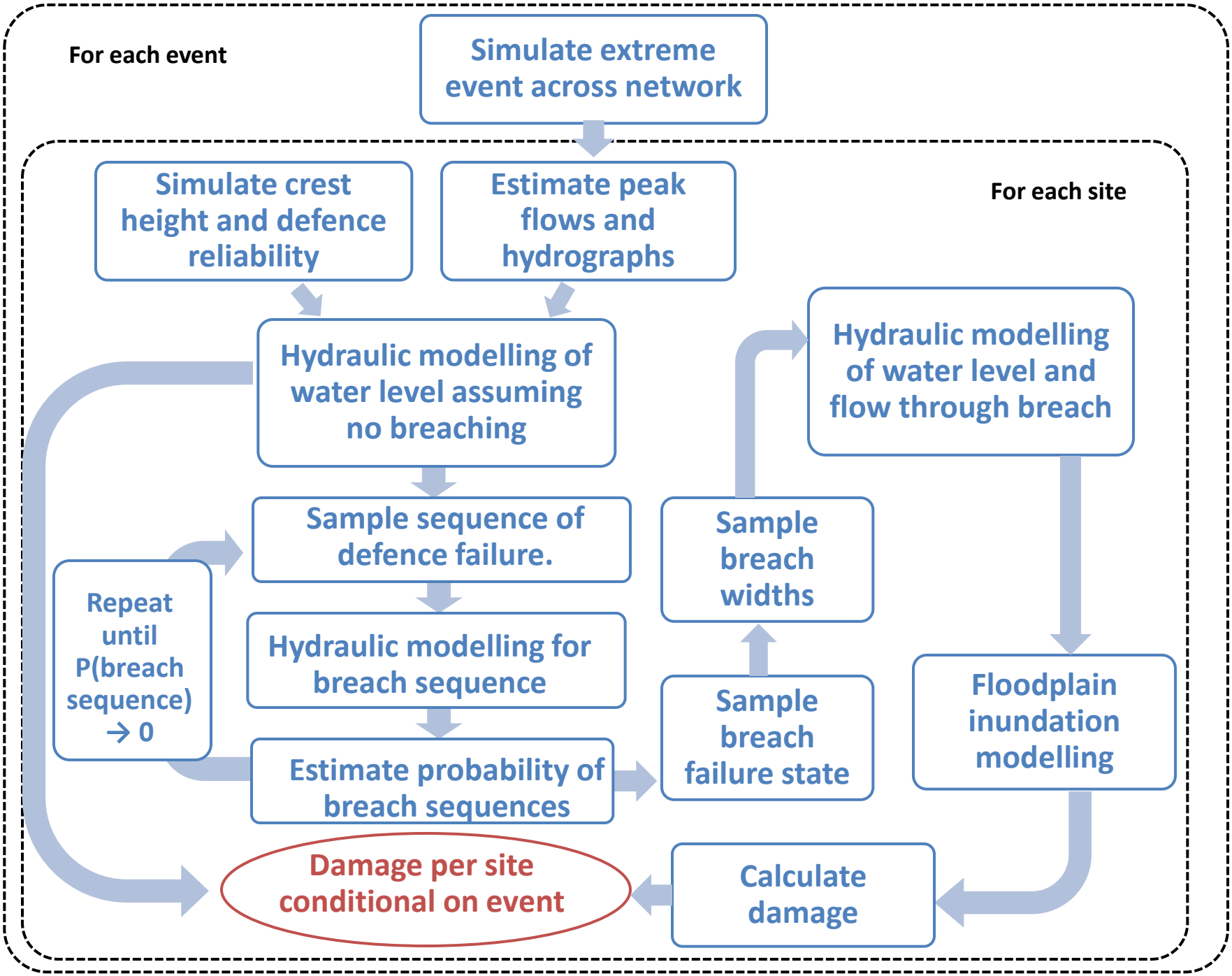
Statistical modelling of extreme events

Statistical modelling of flood defence failure

Process based modelling of water level & floodplain inundation

Multiple sites nested in national framework

Deterministic calculation of damage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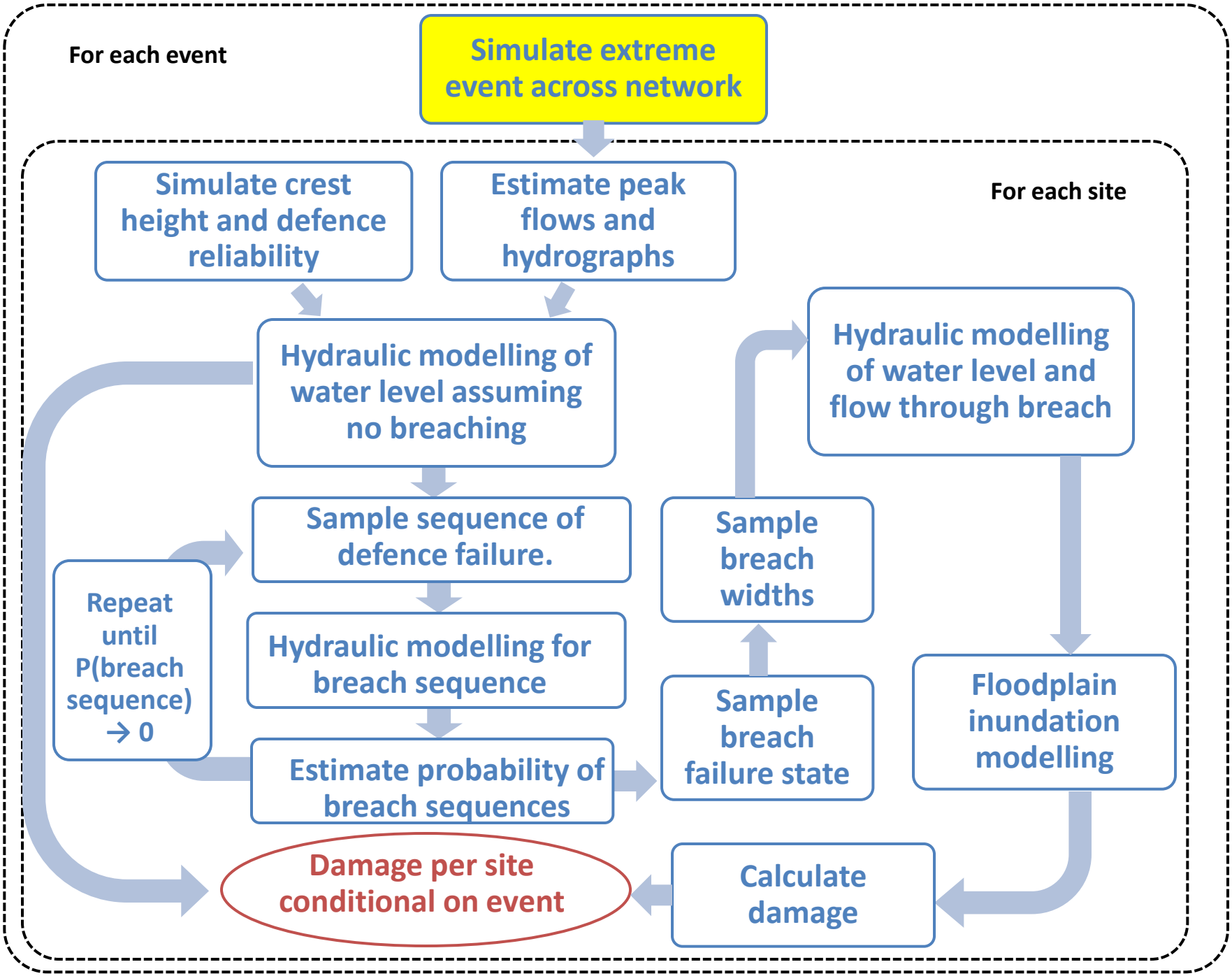
Simulate extreme event across network
For each site
Simulate crest height and defence reliability
Estimate peak flows and hydrographs
Hydraulic modelling of water level assuming no breaching
Sample sequence of defence failure.
Hydraulic modelling for breach sequence
Estimate probability of breach sequences
Repeat until P(breach sequence) → 0
Sample breach failure state
Sample breach widths
Hydraulic modelling of water level and flow through breach
Floodplain inundation modelling
Calculate damage
Damage per site conditional on event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Modelling extreme events

- **Aim**
  - Spatial dependency between events
  - Large scale model for UK
  - Good representation of extremes
- **Method**
  - Conditional dependence model of Heffernan and Tawn (2004) applied by Keef et al (2009)

$$\mathbf{Y} \mid X, x > u_x$$

Y = set of gauges

X = conditional gauge

x = daily mean flow

u_x = threshold

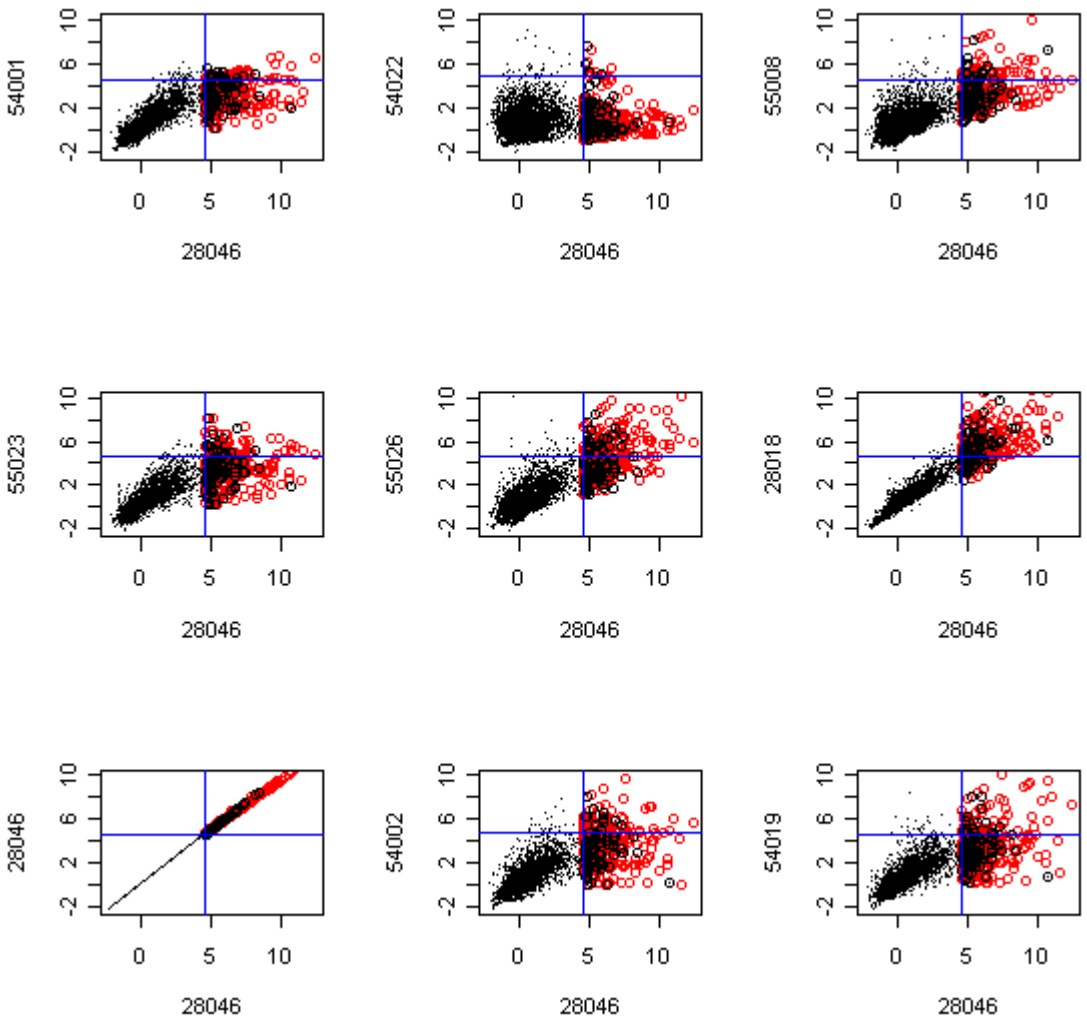
$$\mathbf{Y} = a(x) + b(x)Z$$

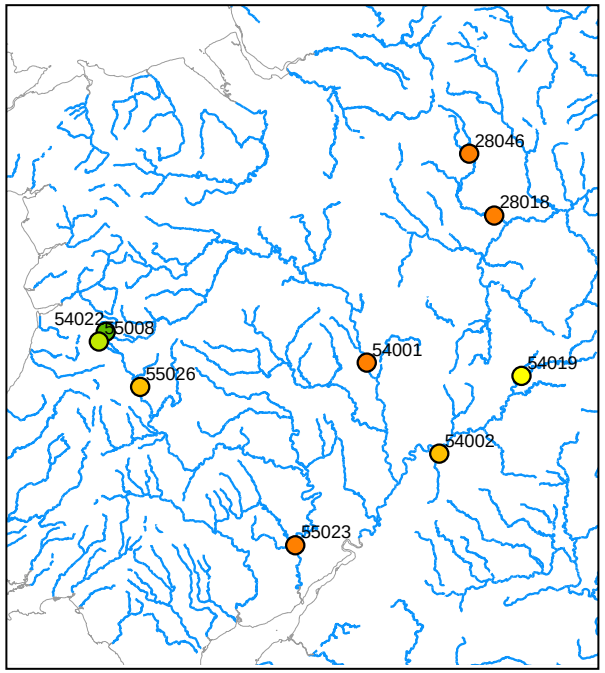
a = strength of dependences

b = changing dependence

Z = residuals

Example application

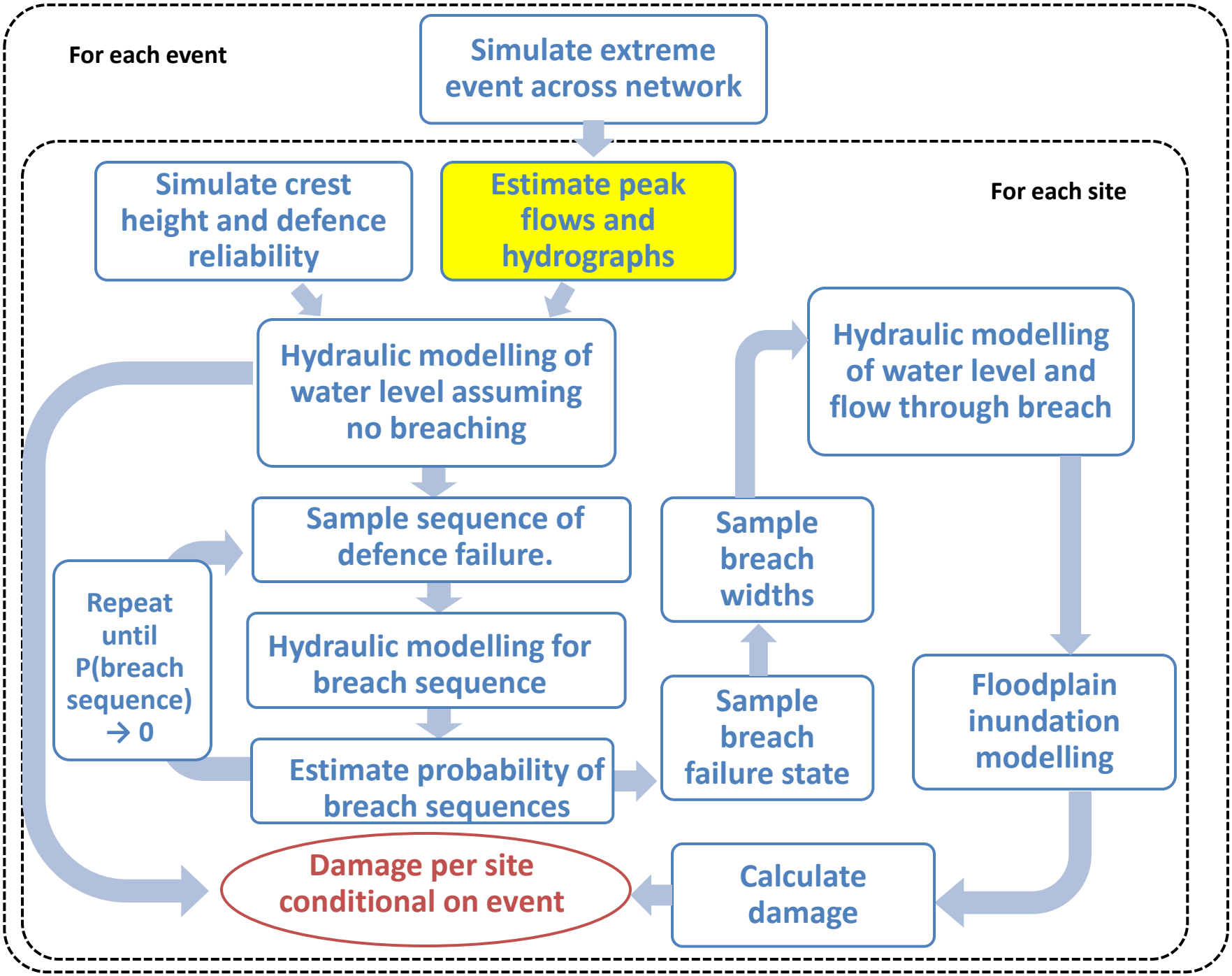




· = observed below threshold

o = observed

o = simulated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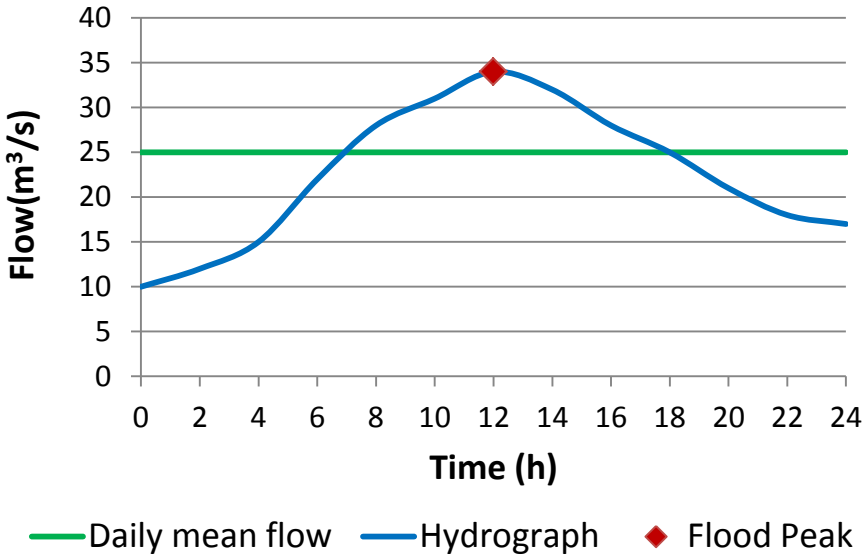
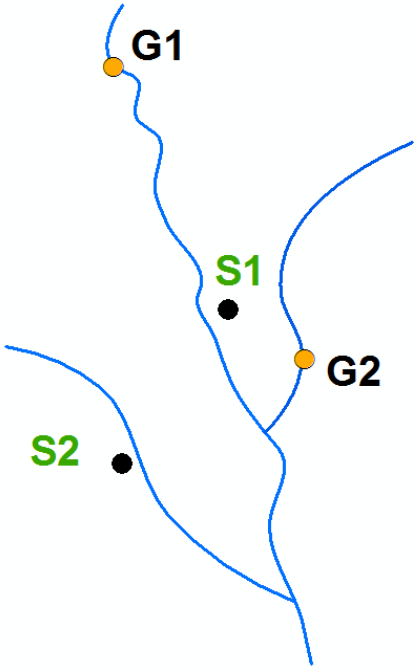
Estimating peak flows at site



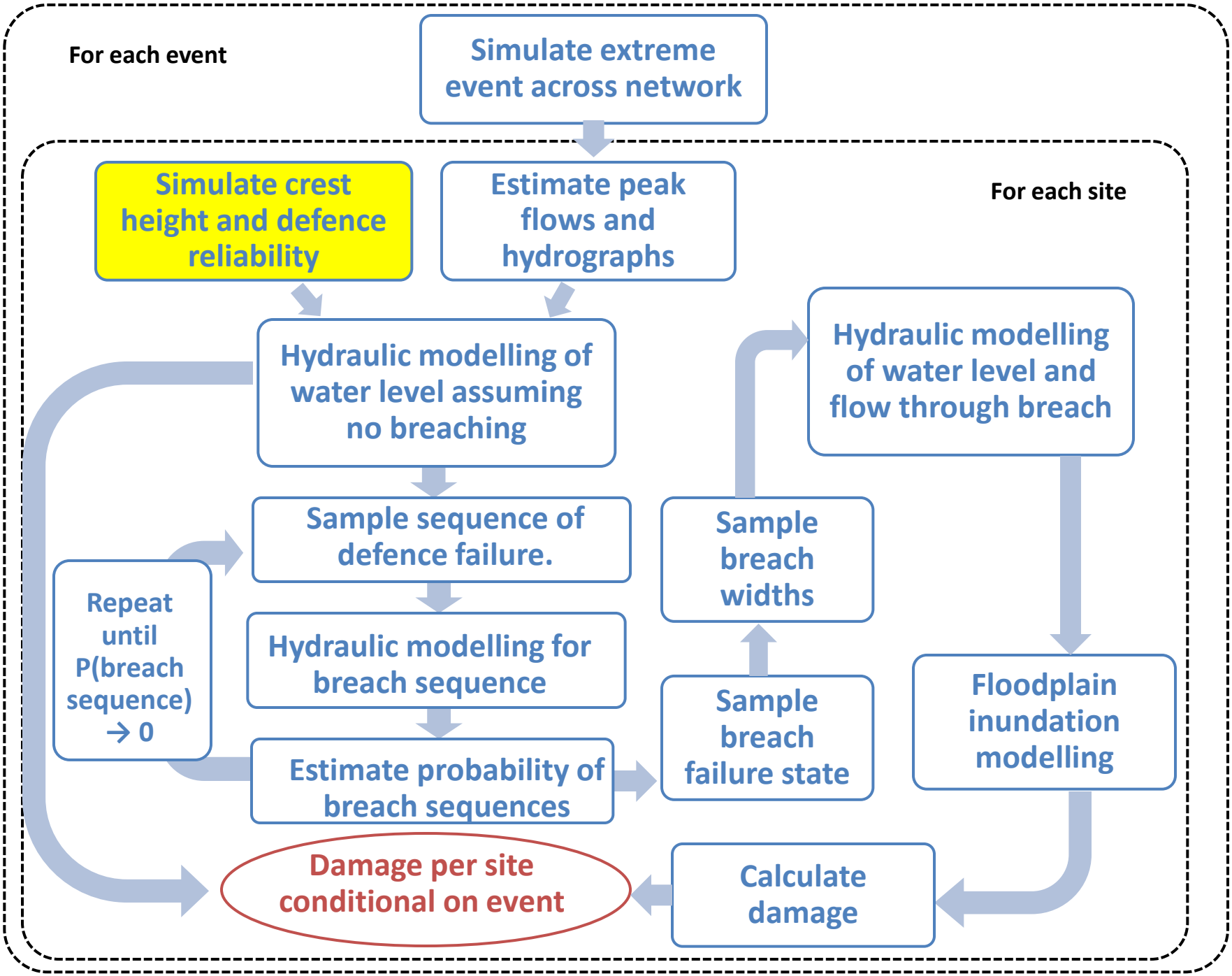


Peak flow conversion methods

- Shape of hydrograph
- Catchment characteristics

Ungauged site transfer methods

- Analogue sites
- Weighted by distance and catchment characteristics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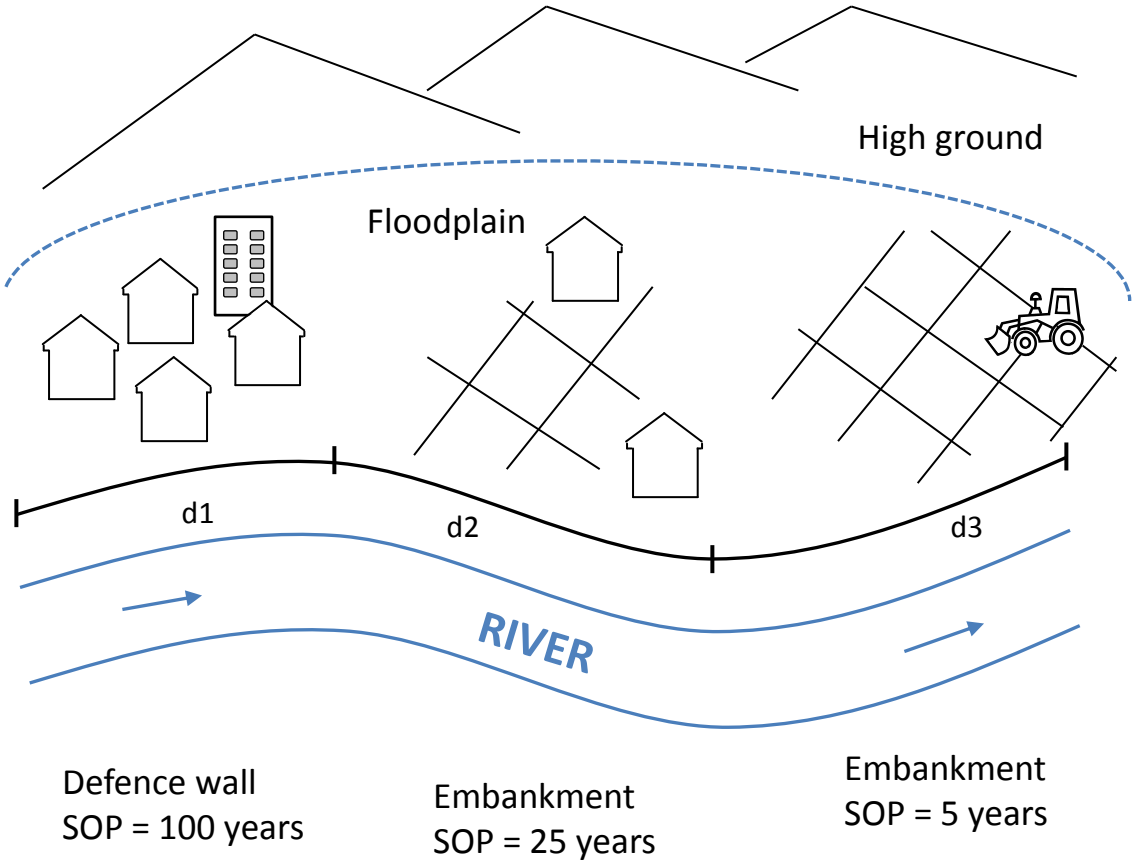
Flood defence system



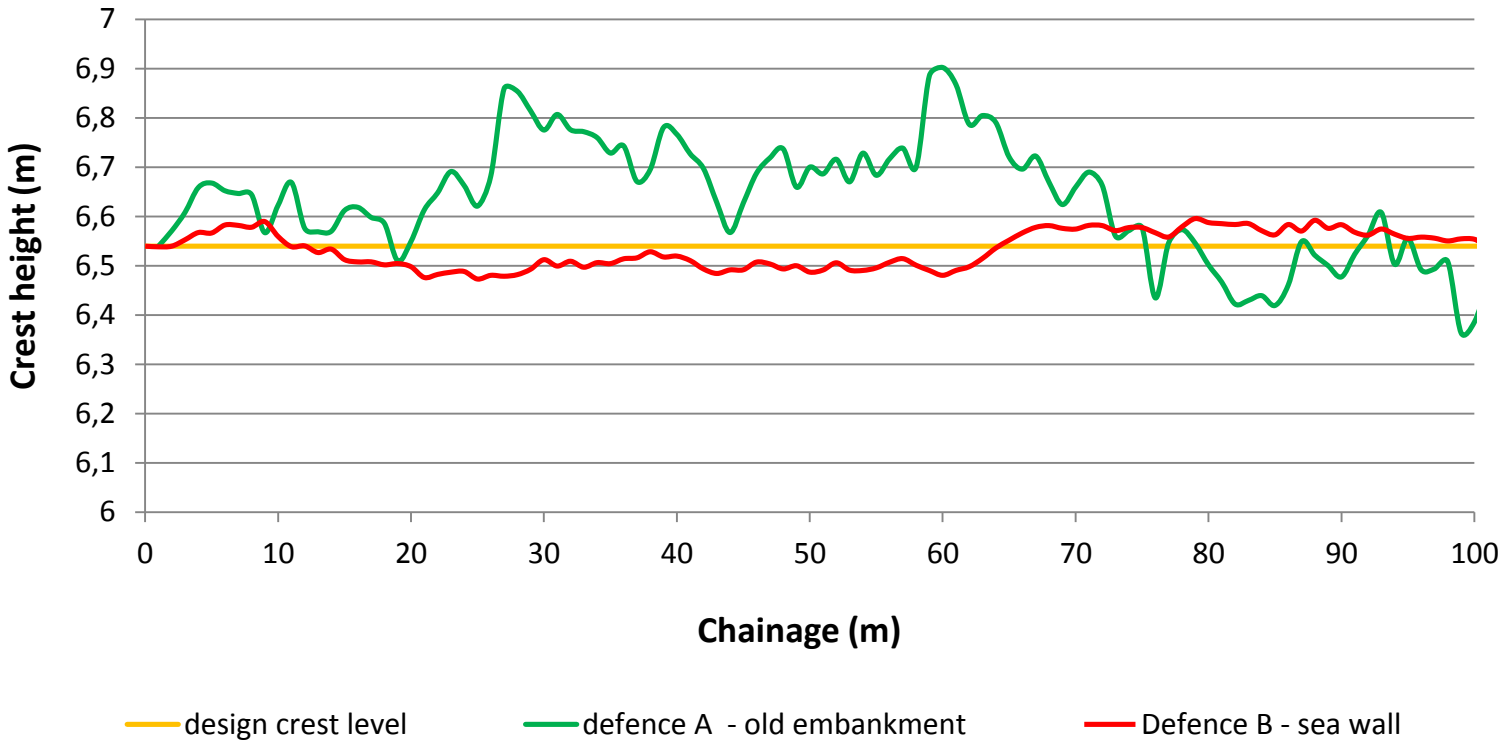
Characterised by

- Design standard
- Construction type

Novel aspects

- No restriction on length
- Consideration of upstream breaches

Sampling crest heights

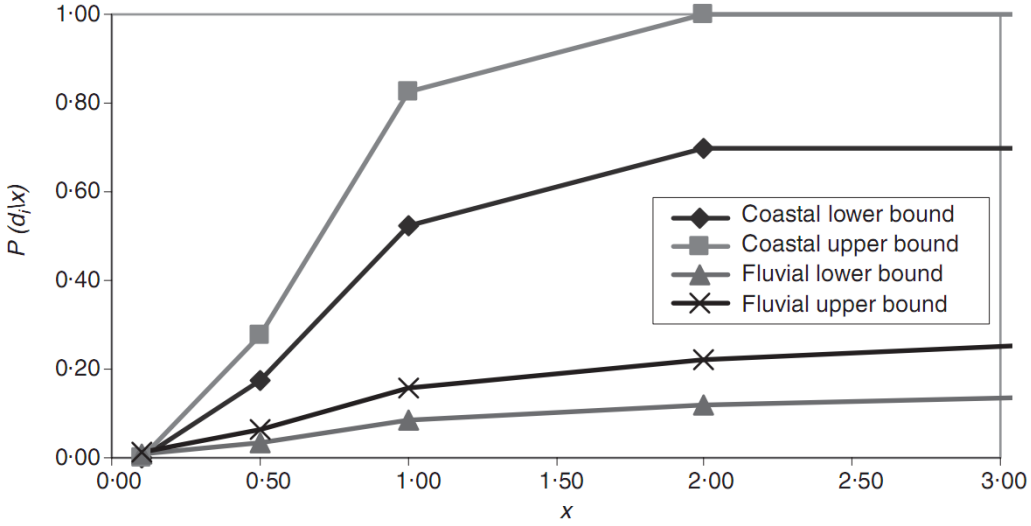


Autocorrelation function for crest height =

***f* (defence type, age, condition, data quality)**

Defence reliability

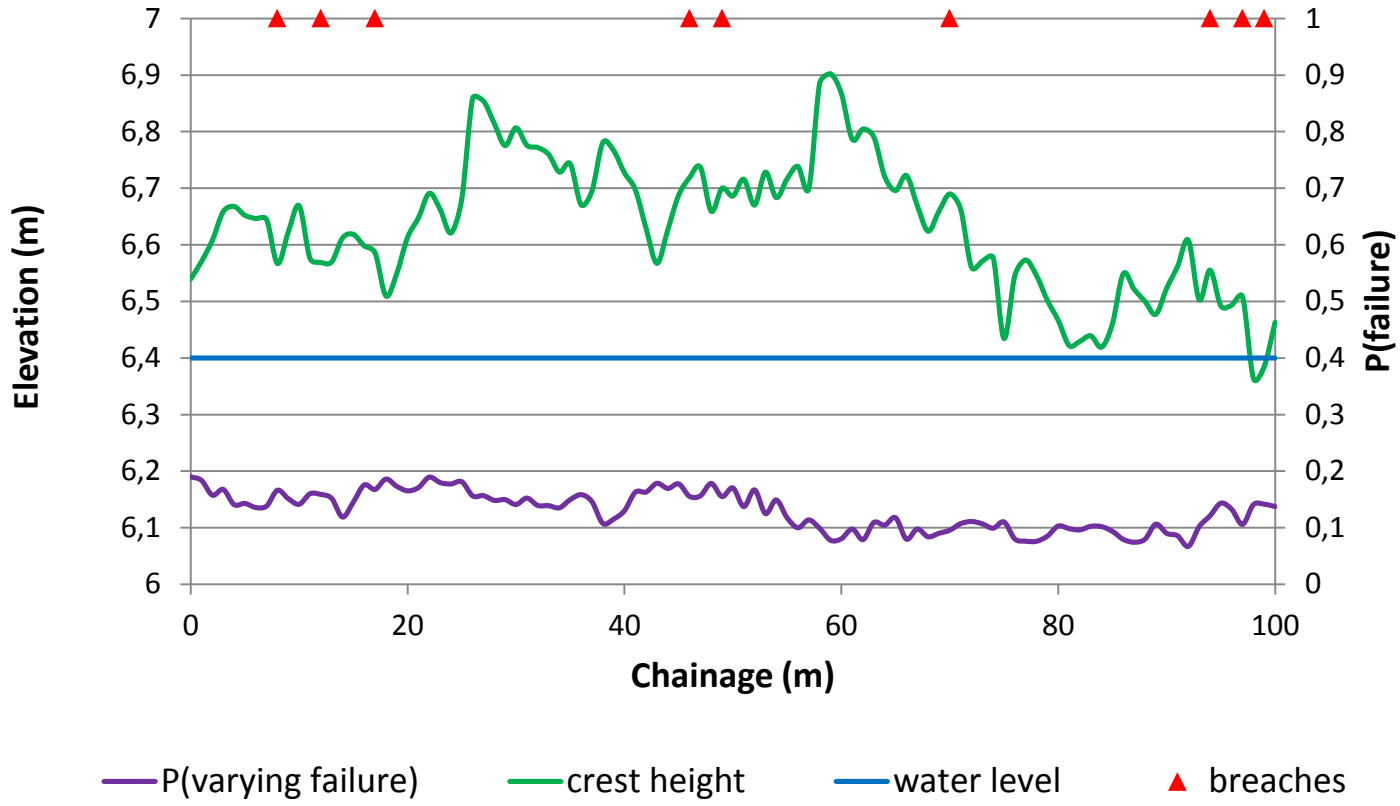
- **Initiation**
  - Fragility curves
  - Type
  - Condition
  - Sequencing



Fragility curve from Hall et al (2003)

Photos from FLOODsite

Sampling breaches



Autocorrelation function for strength =

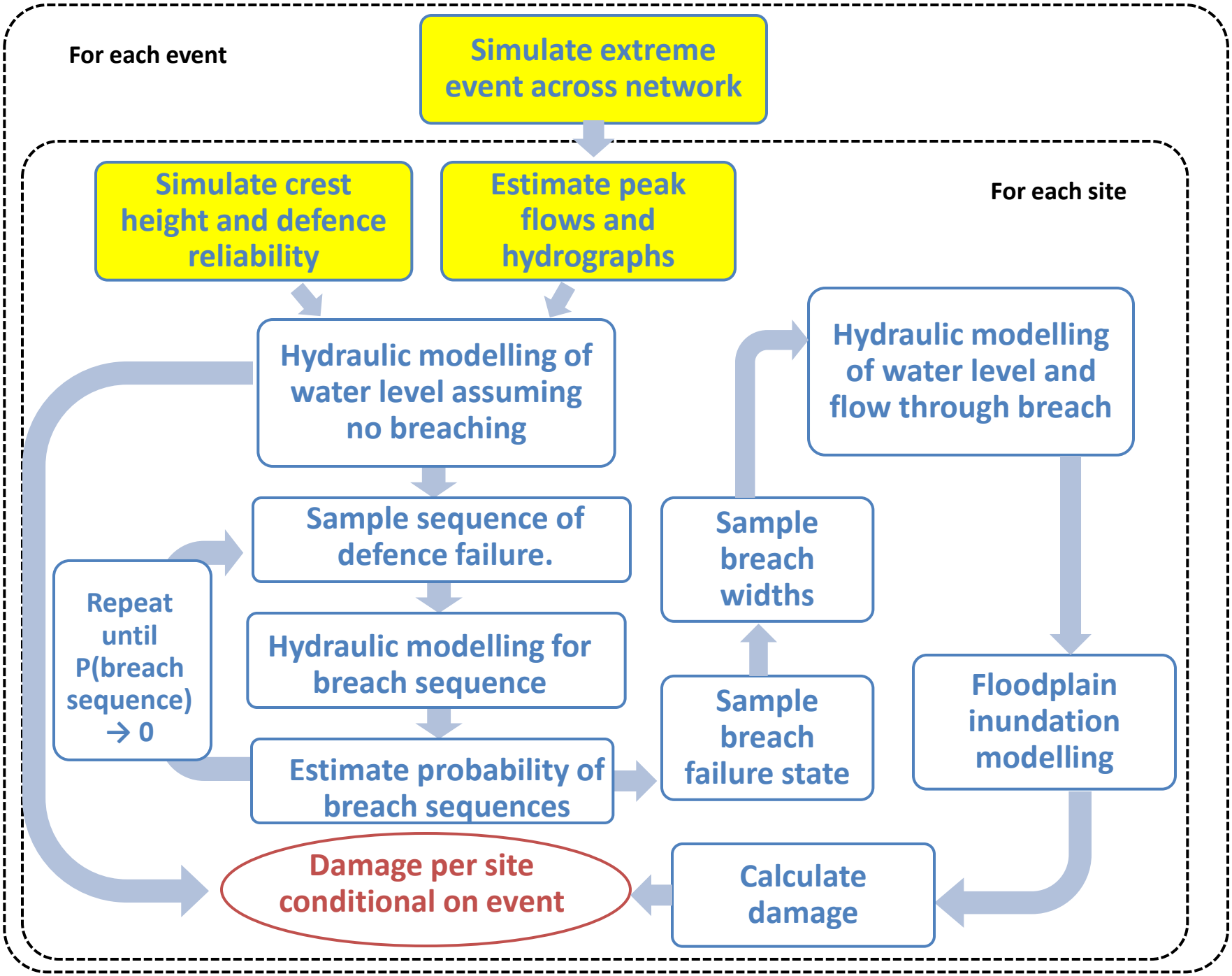
***f* (defence type, age, condition)**

Breach widths

- **Growth Rate**
  - Materials
  - Floodplain type
  - Amount of water
  - Sequencing

- **Max width**

Case study	Observed values	Assumed values	Source
Elbe	20m to 200m Median 20m	Log normal width mean of 64m	De Kok and Grossmann 2010
Lower Rhine		Width 100 – 400m	Apel et al 2004
Lower Rhine		Width 50 - 150m	Kamrath et al 2006
UK RASP method		Function of load and defence length	Hall et all 2003
Netherlands	Largest 520m wide and 36m deep		Muir-Wood and Bateman 2005
River Po		Normal Width: 100m - 300m Depth: 0.5m - 4m	Govi and Turitto 2000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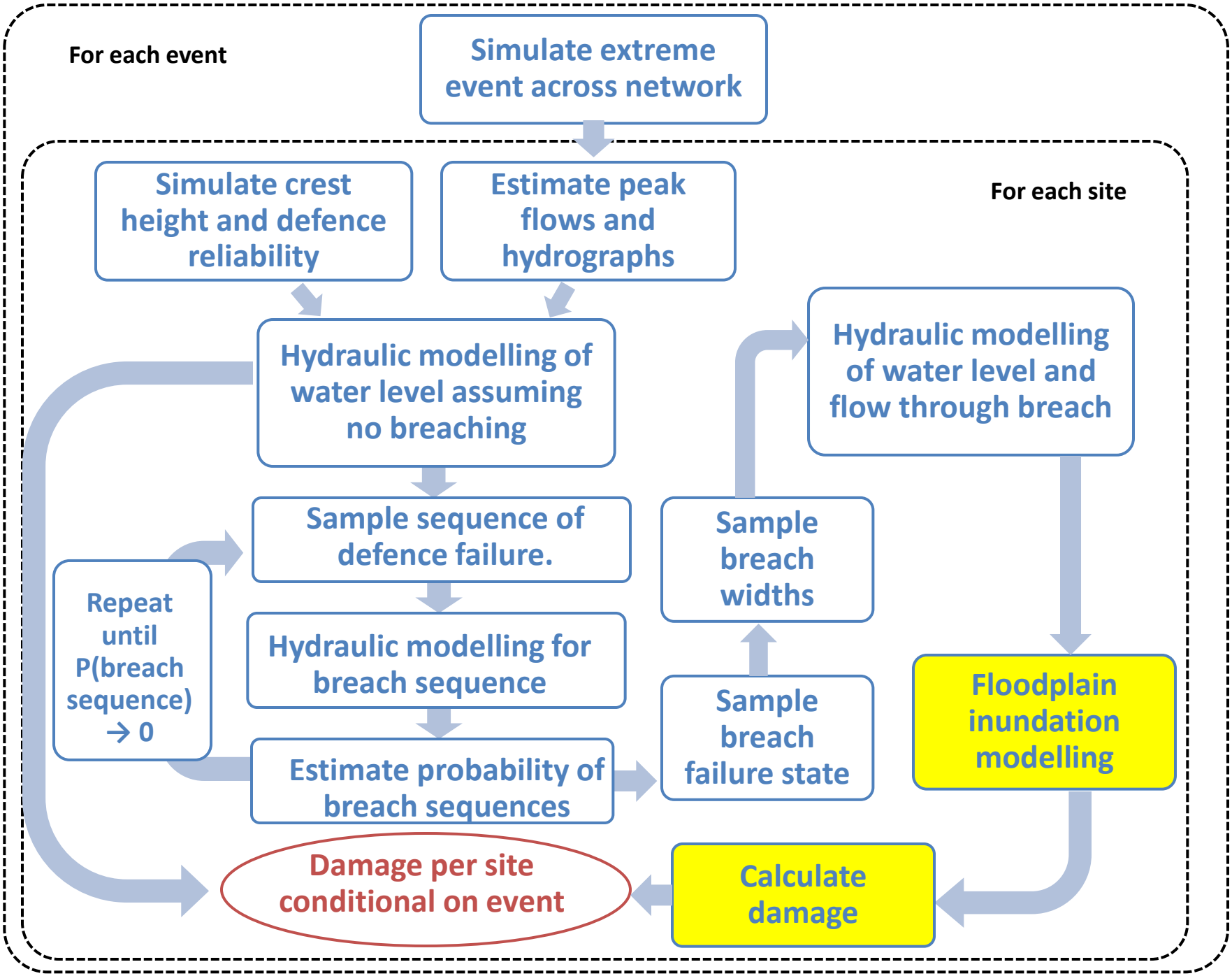
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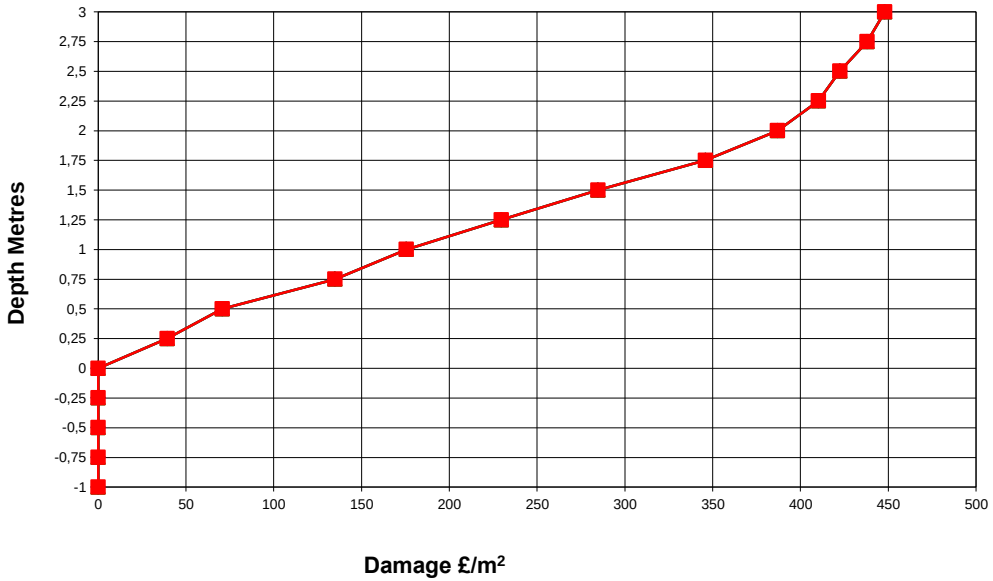
Damage

- Raster based floodplain inundation model
  - ➡ depths
- Depth-damage curves
  - ➡ damage



Penning-Roswell et al (2006)

Risk

Risk = Probability x Consequence

$$P(I_{max,i,j} | F_{i,j} | OT_{i,j}, B_{i,j}, BW_{i,j} | L_{j,i}, C_{i,j}, R_{i,j} | Q_{i,j} | X_i)$$

$I_{max,i,j}$ = maximum inundation depth across site j for event i

Risk

Risk = Probability x Consequence

$$P(I_{max,i,j} | F_{i,j} | OT_{i,j}, B_{i,j}, BW_{i,j} | L_{j,i}, C_{i,j}, R_{i,j} | Q_{i,j} | X_i)$$

$F_{i,j}$ = Flow over or through defence

$) = f$(type, $\text{erial}, L_{i,j}$)

$P(B_{i,j}) = f(C_{i,j}, L_{i,j}, R_{i,j}, OT_{i,j})$

Risk

Risk = Probability x Consequence

$$P(I_{max,i,j} | F_{i,j} | OT_{i,j}, B_{i,j}, BW_{i,j} | L_{j,i}, C_{i,j}, R_{i,j} | Q_{i,j} | X_i)$$

$Q_{i,j}$ = Inflow to hydraulic model

$P(L_i) = f(\text{upstream breaches}, Q_{i,j})$

Conclusions

- **Integrated system model**
- **Detail nested in national scale**
- **Consider risk load**
  - If modelling of flood defences is poor how much impact does this have?
  - Which areas could flood at the same time / where are we over exposed?
- **Future...**
  - Sensitivity testing
  - Resilience measurers

Thank you

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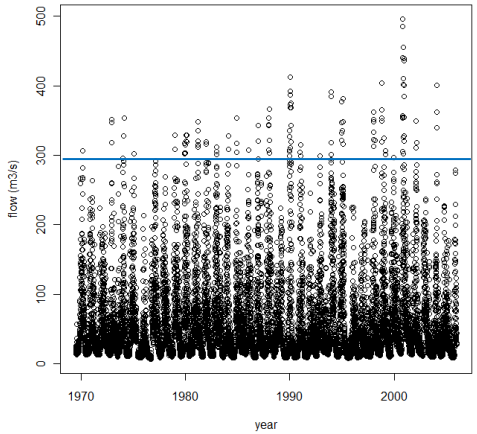
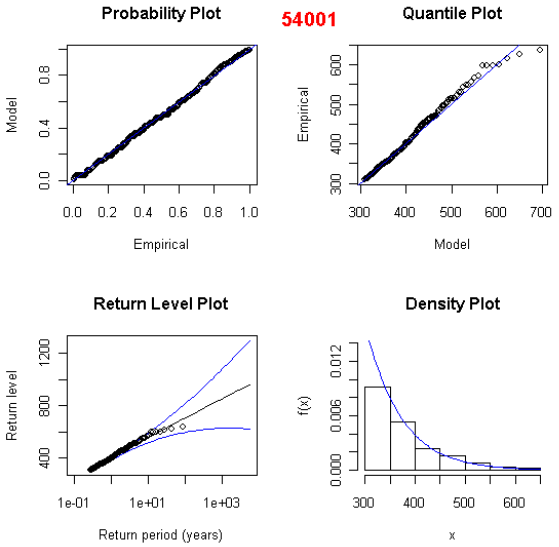
Modelling extreme events (2)

1. Extreme data at conditional gauge

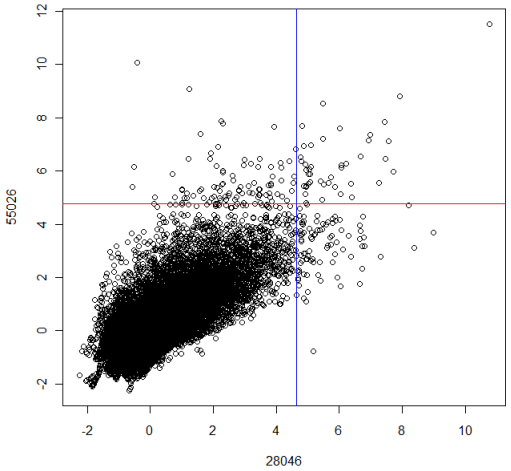


Fit Generalised Pareto

- Shape (β)
- Scale (ε)
- threshold



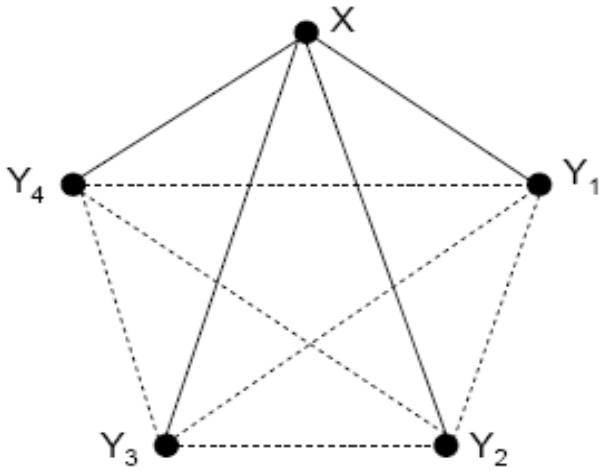
2. Extreme dependence between gauges



Fit dependence model

$$\boldsymbol{Y} = \boldsymbol{a}(x) + \boldsymbol{b}(x)\boldsymbol{Z}$$

Solid lines: parametric
Dashed lines: nonparametric (residuals)



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