



## UK fragility curve developments

Jonathan Simm, Jim Murphy (AECOM). Greg Frank (Costello)

1. Context setting
2. Hierarchical approach (National to local scale)
3. Further developments

# Context setting

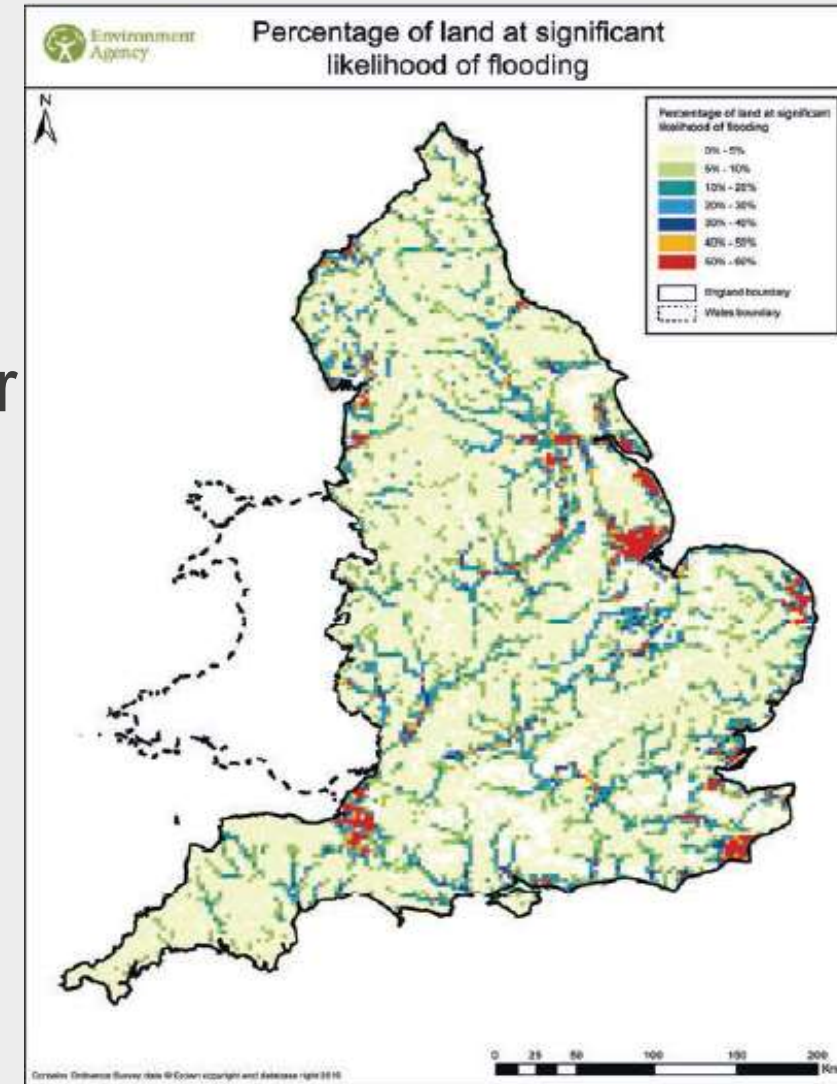


Country or state	Population (million)	Land area (‘000 miles <sup>2</sup> )	Population per mile <sup>2</sup>
USA	323	3806	85
Arizona	7.0	114	61
Texas	27.9	269	103
California	39.2	164	240
Florida	20.6	59	350
North Carolina	10.2	54	190
Virginia	8.1	43	190
England	55.0	50	1,100

# Flood defences in England

Approx 9000 km of raised flood defences,  
i.e. levees and flood walls  
(National Strategy, 2011)

- Defences reduce chance of flooding for many of the 2.4m households at risk of fluvial & coastal flooding, e.g. in winter floods 2013/14:
  - 11,000 properties flooded
  - 1.4m properties protected

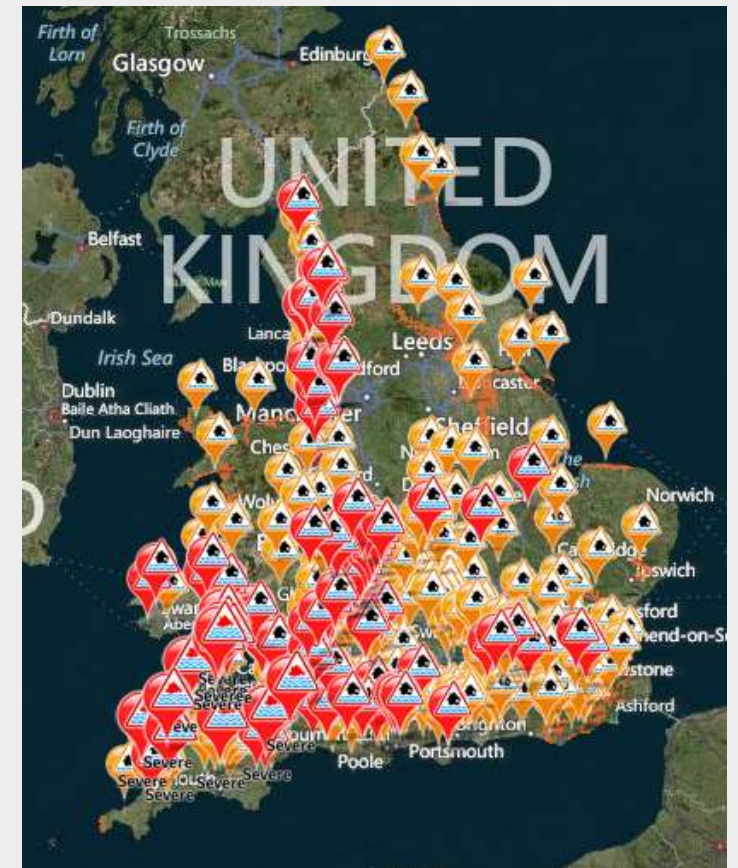




# UK - a history of flooding

Over last 20 years, major flood events in:

- 1998 – 2000 – 2002 – 2005 – 2007 – 2012 – 2013/14 – 2015/16



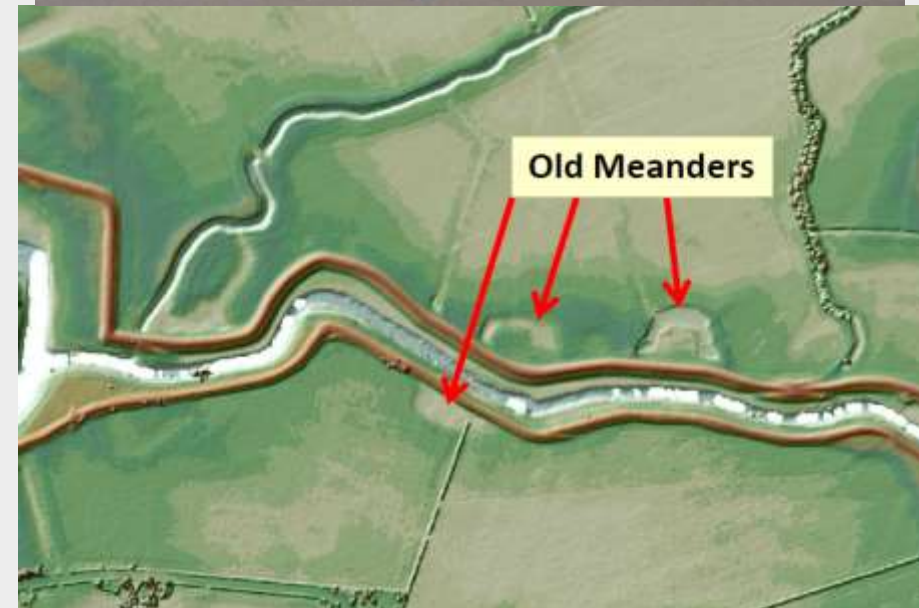
# 10-15 years of severe floods: a significant number of failures, primarily in low risk areas



Croston  
2016

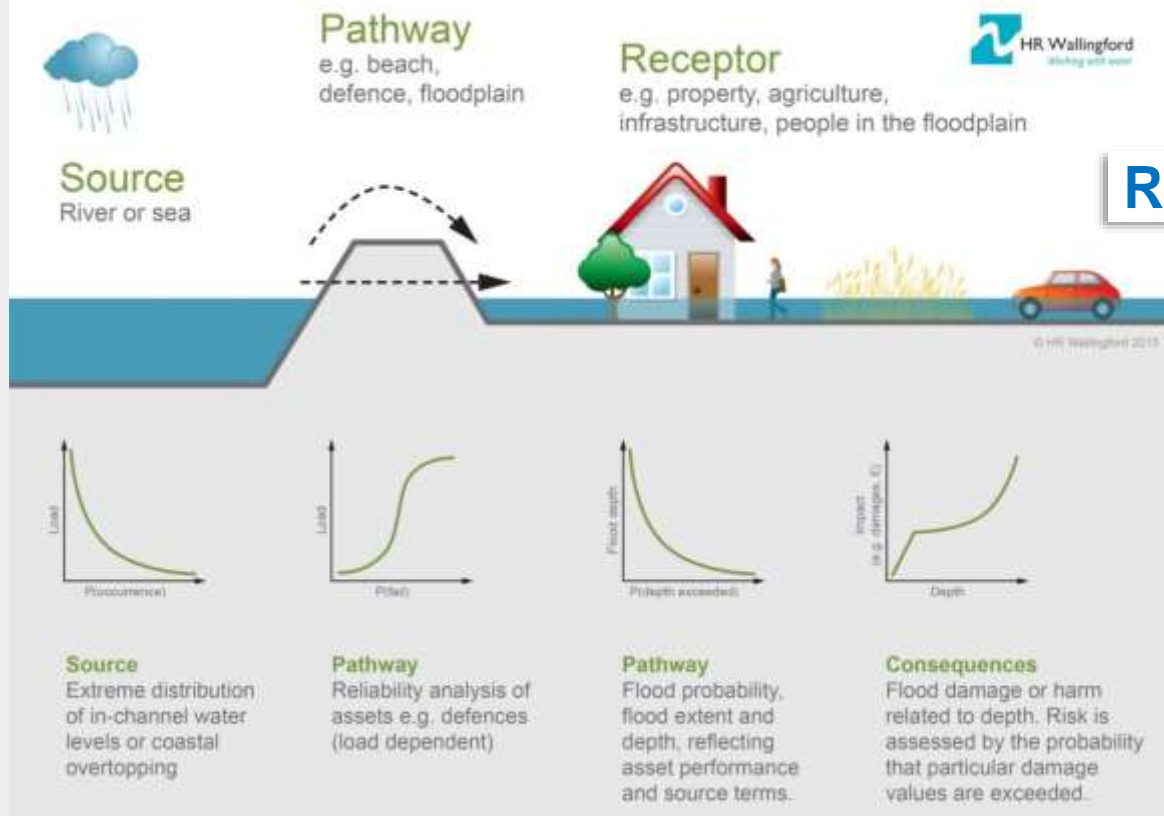


River  
Torne  
2007

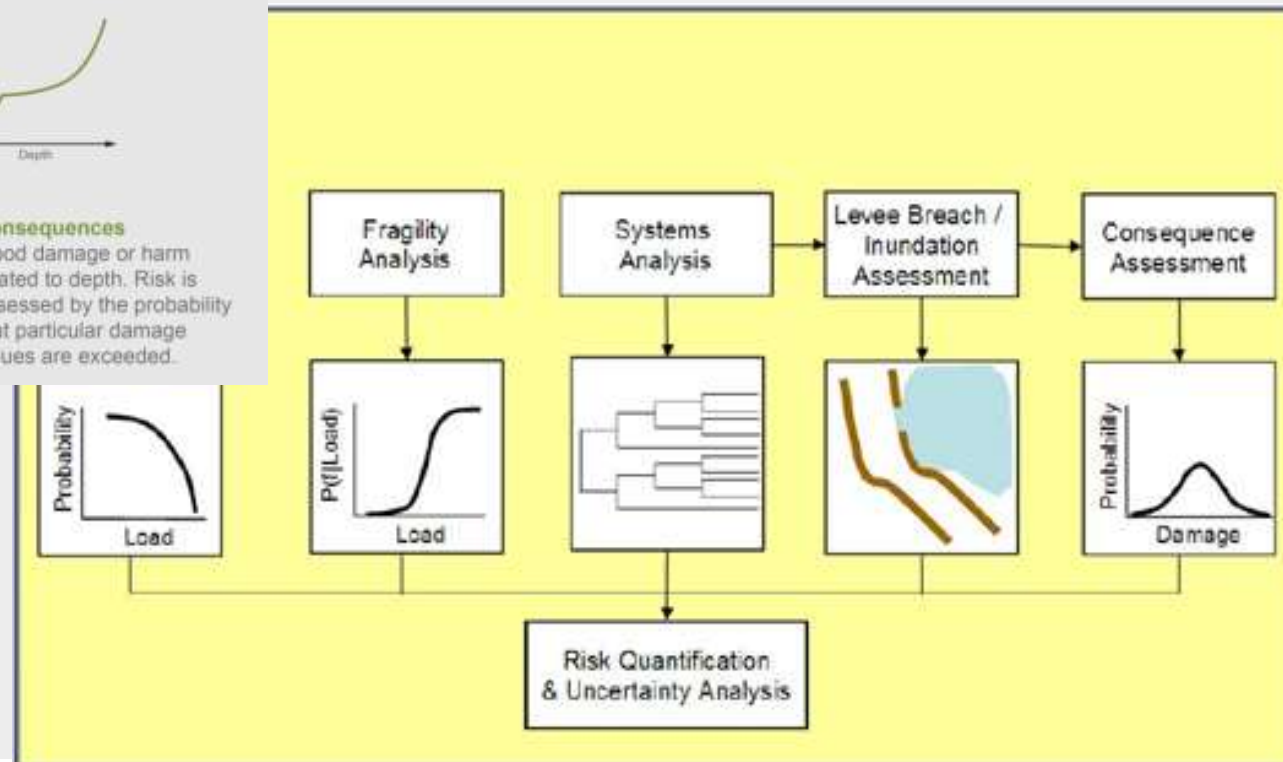




# Full flood risk system modelling



$$\text{Risk} = f(\text{probability and consequence})$$

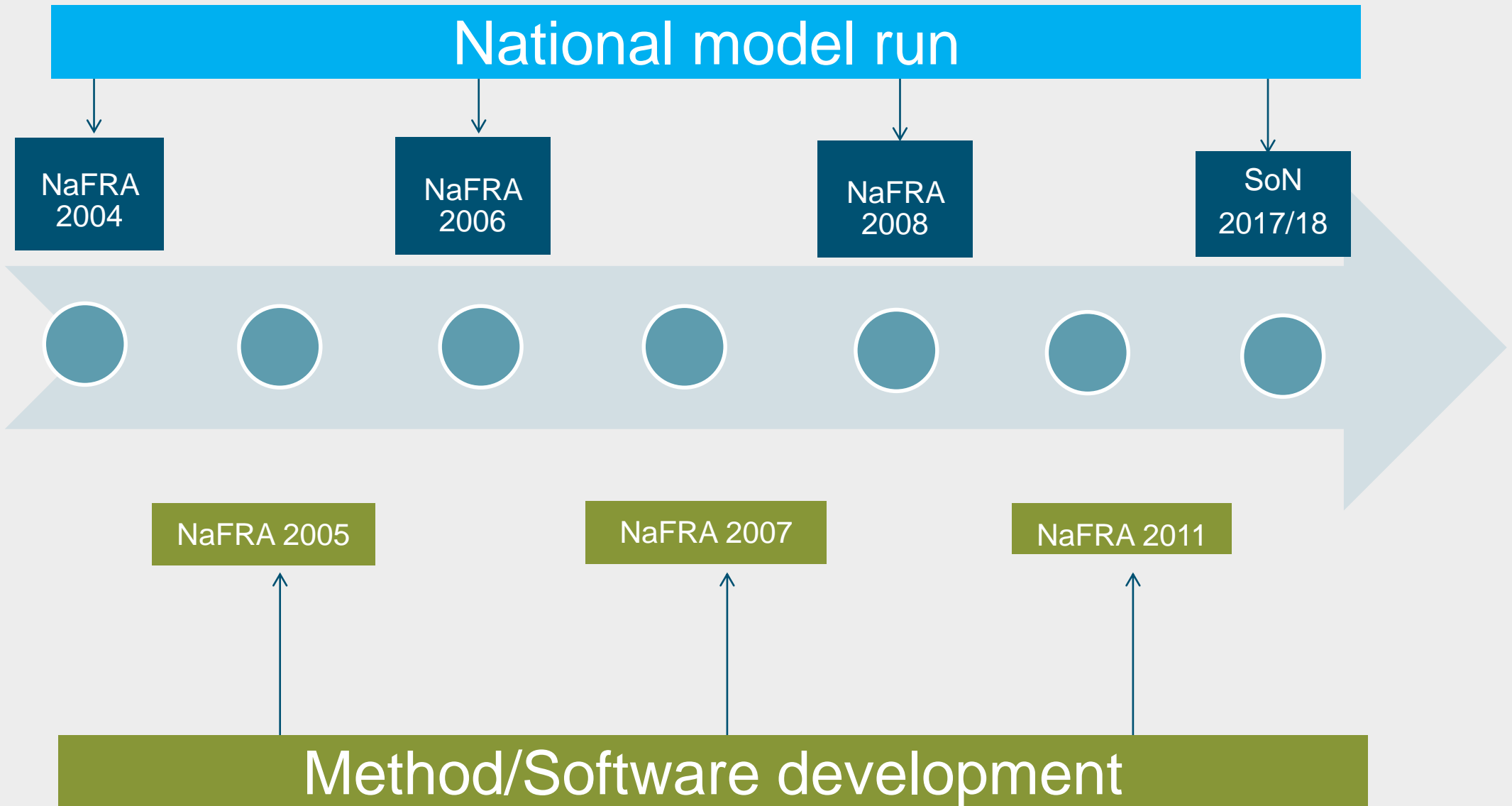


**National Research Council (2013)**

“Levees and the National Flood Insurance Program Improving Policies and Practices”



# National Flood Risk Analysis (NaFRA)



# Outputs - probability of flooding

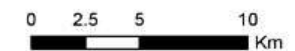
2115

## Humber Estuary

Strategy modelling - Maintain 2115

November 2010

### Probability of flooding





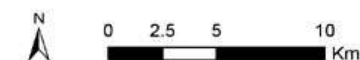
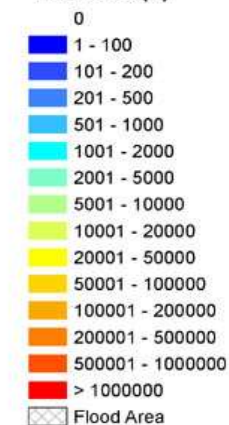
2115

## Humber Estuary

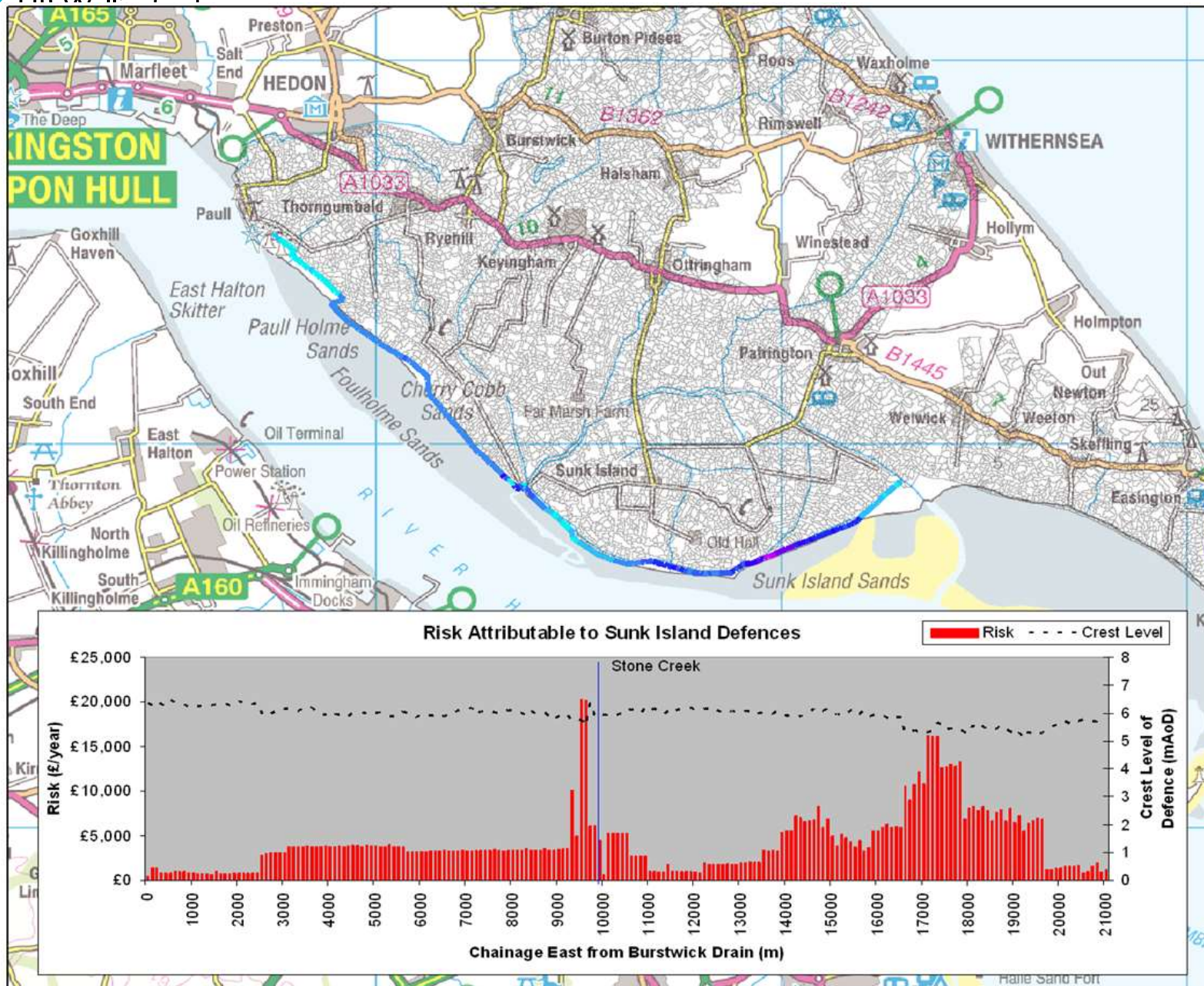
Strategy modelling - Maintain 2115

November 2010

### Total Risk (£)

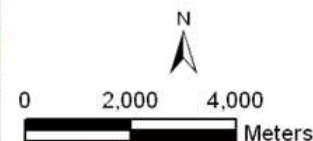






## Sunk Island Flood Risk Evaluation

Legend  
Defence Risk Histogram

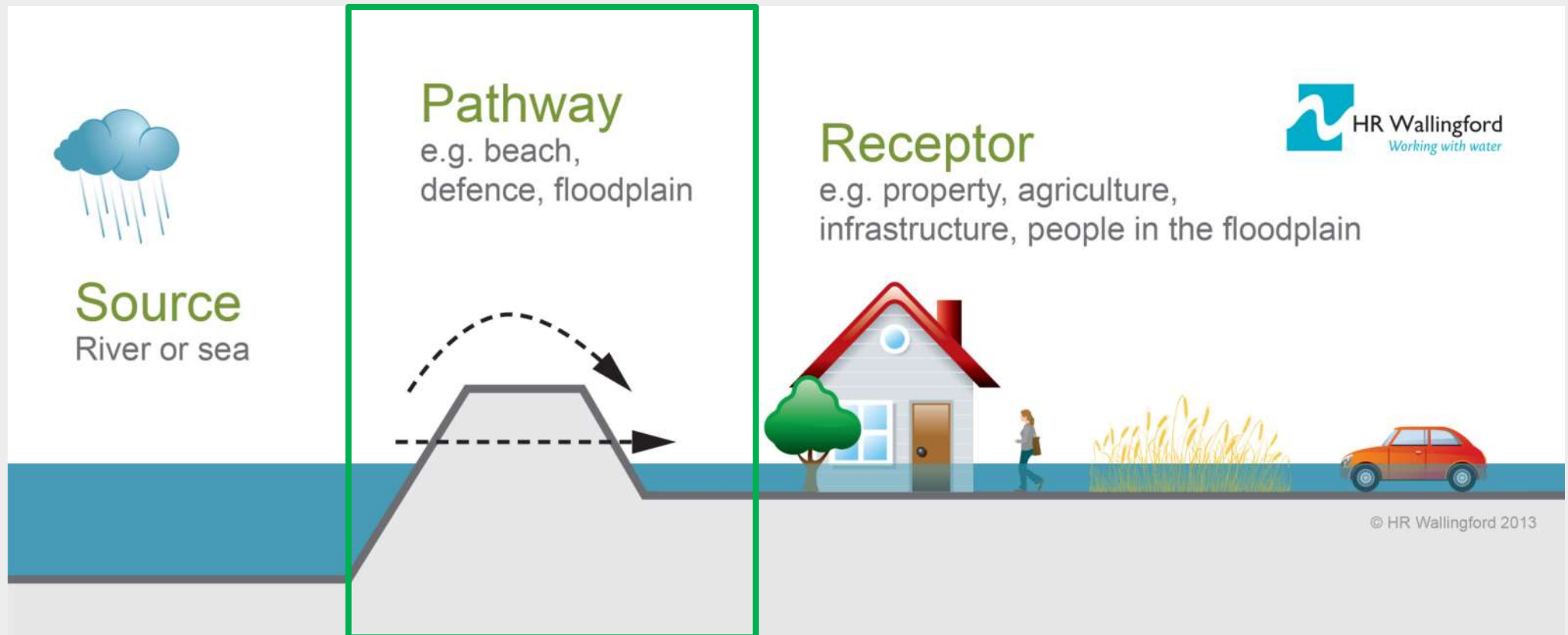


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# Representation of levee performance important for flood risk systems analysis



# Fragility curve fundamentals

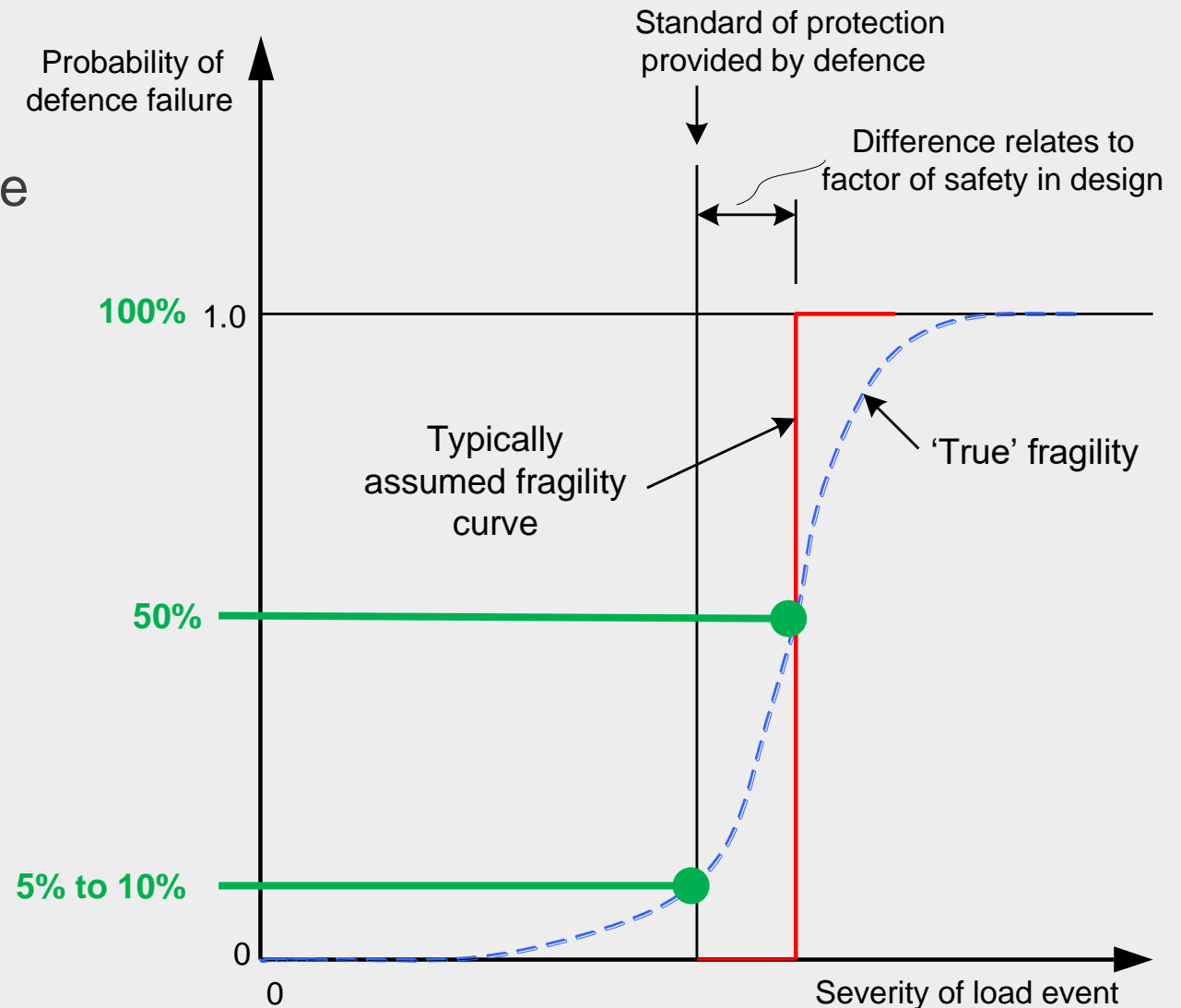
## The Fragility method

A fragility curve is a curve which expresses the probability of failure of a defence as a function of the loading

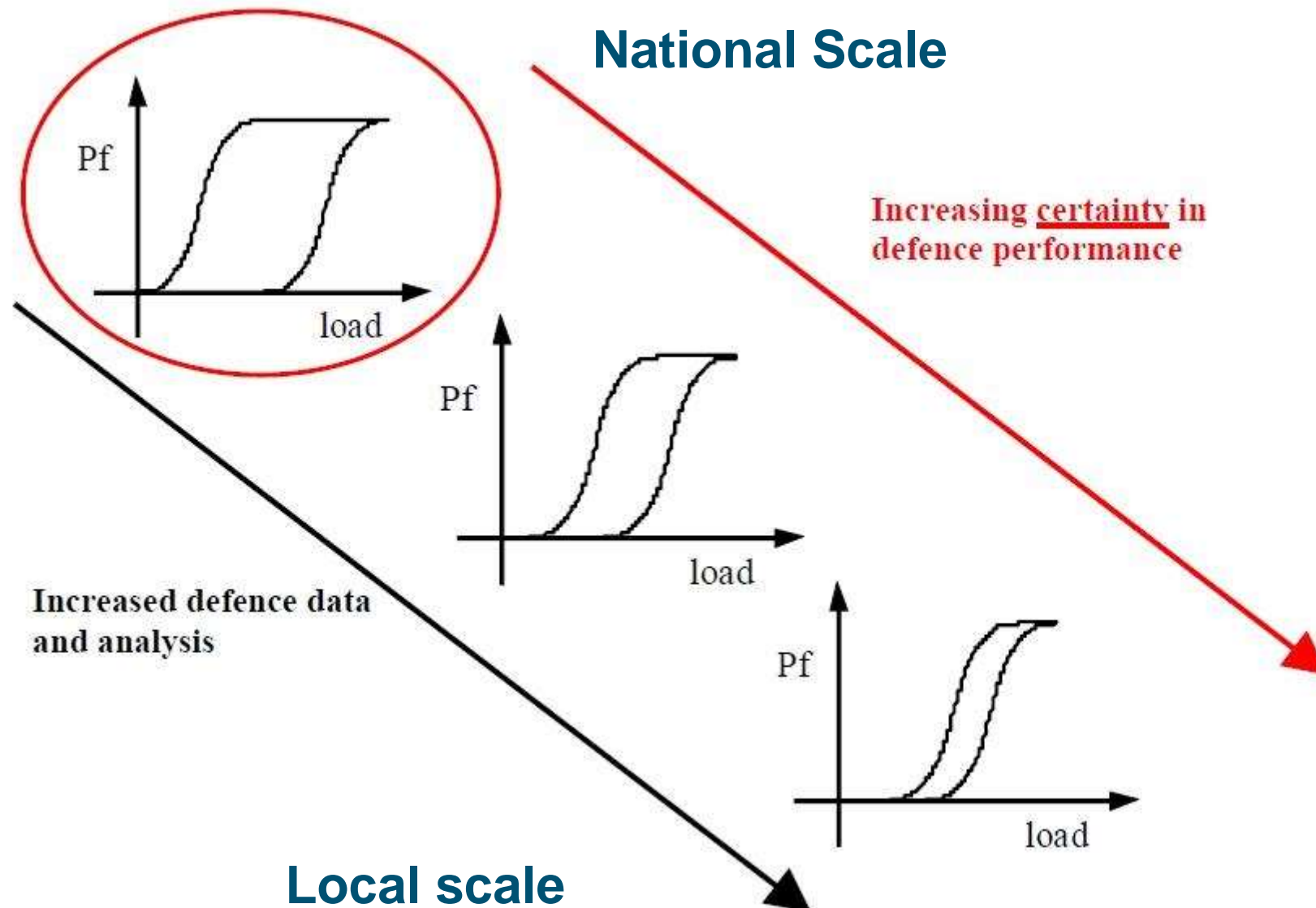
$$Z(\text{reliability}) = R(\text{strength}) - S(\text{loading})$$

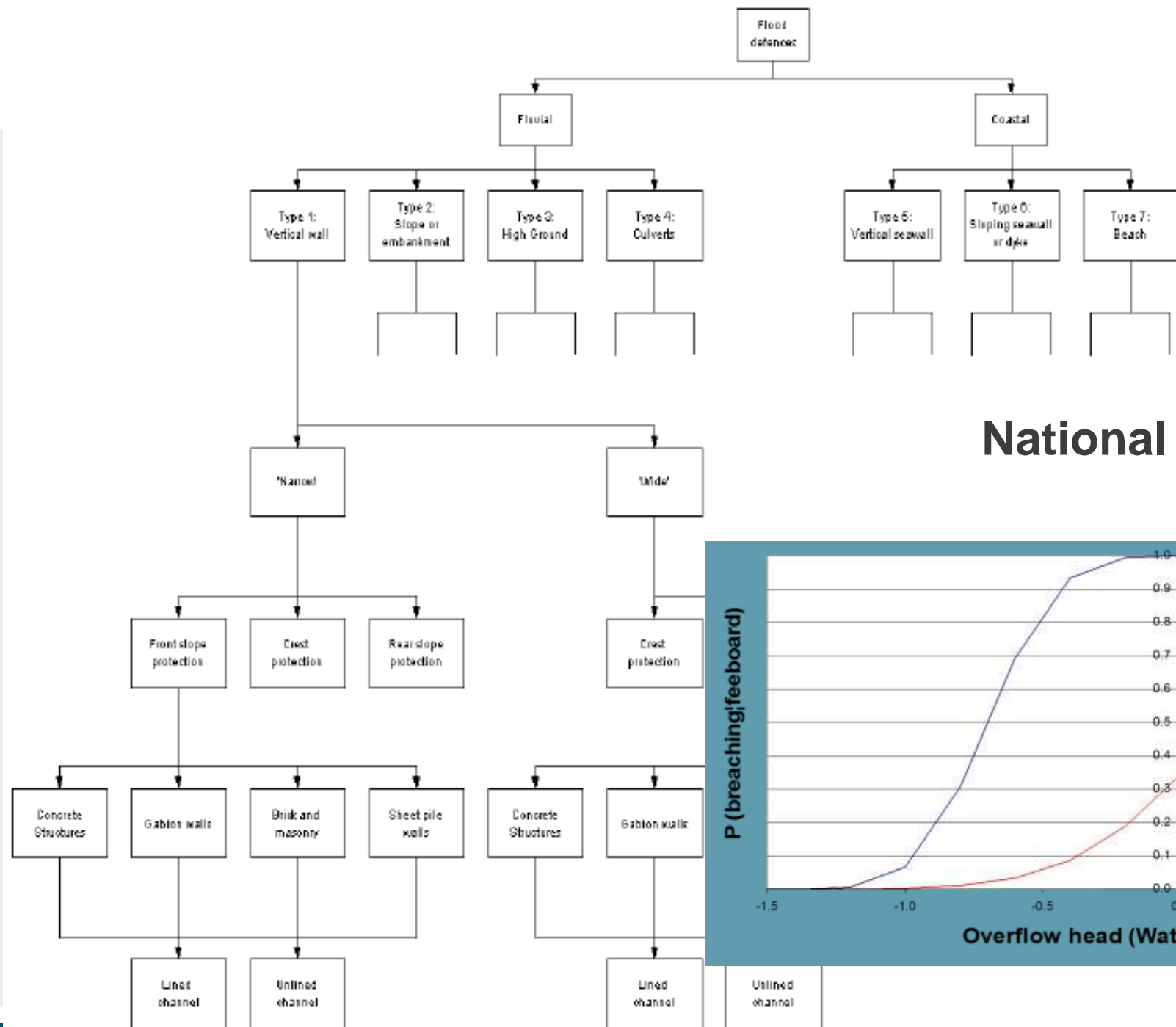
### KEY POINT:

- Probability of failure:
  - for  $|\text{load} > \text{design load}| < 100\%$
  - for  $|\text{load} < \text{design load}| > 0\%$

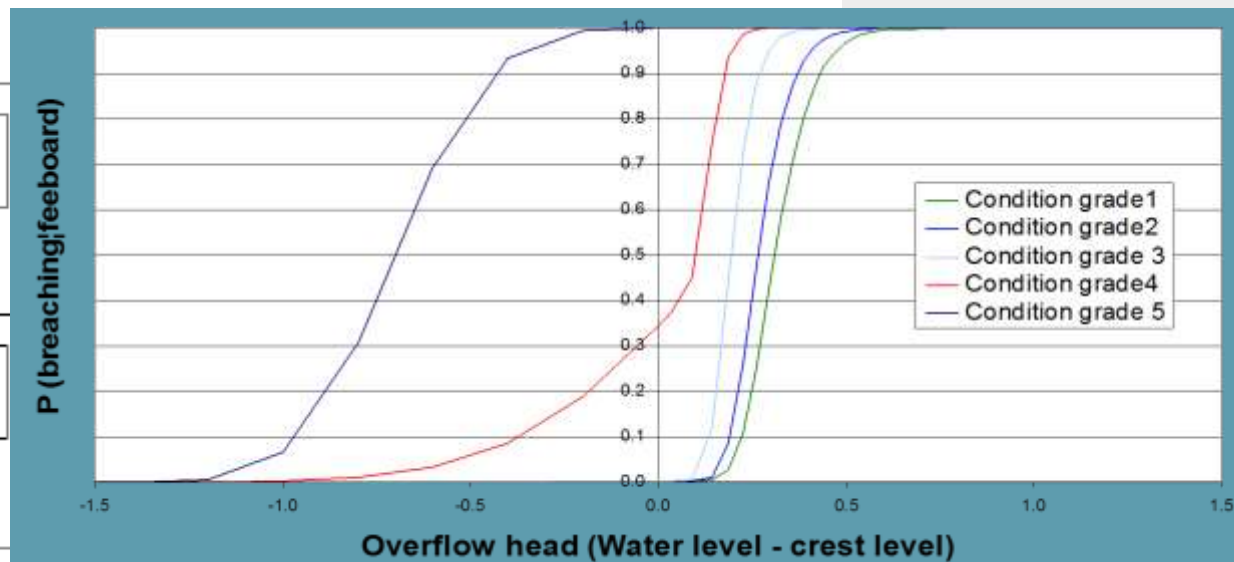


# Improving fragility curve science





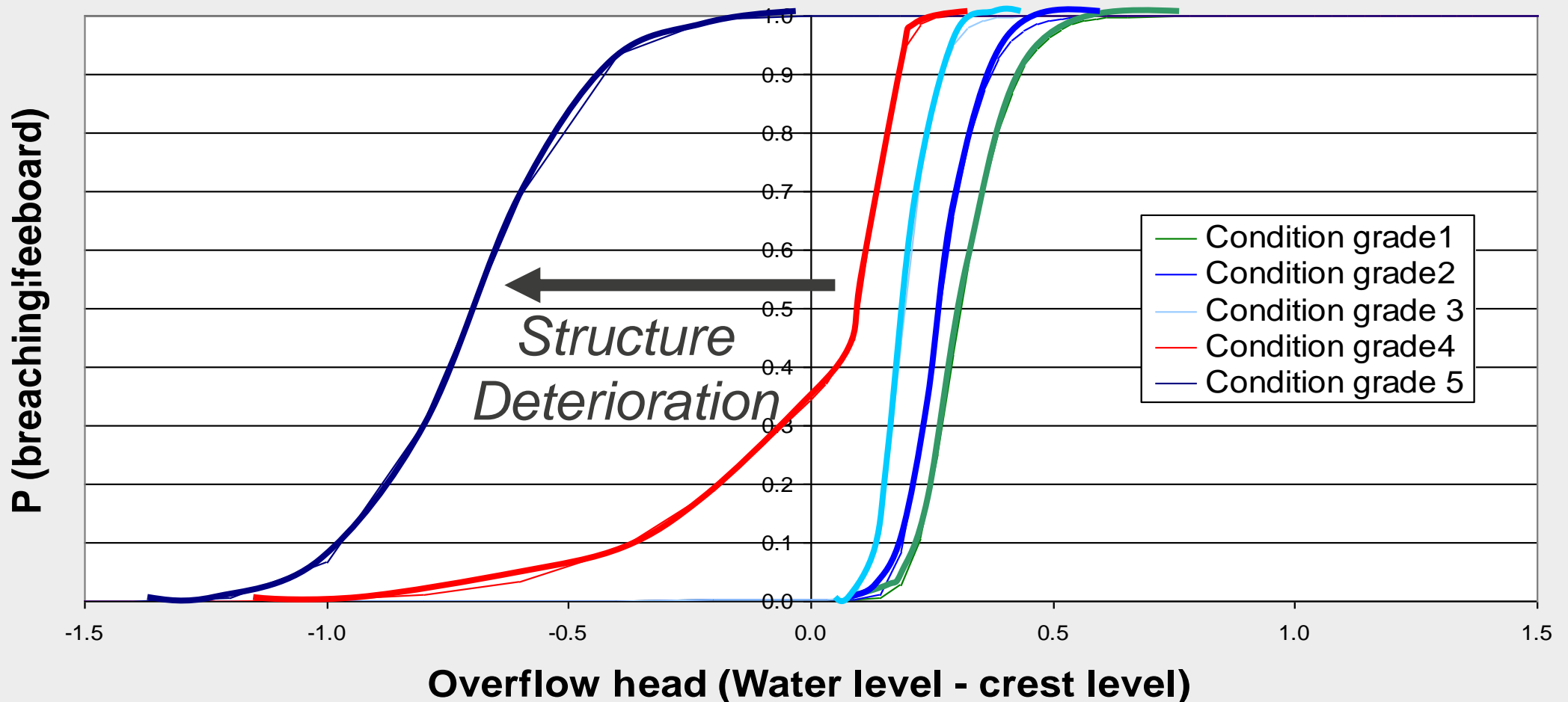
## National Generic Curves



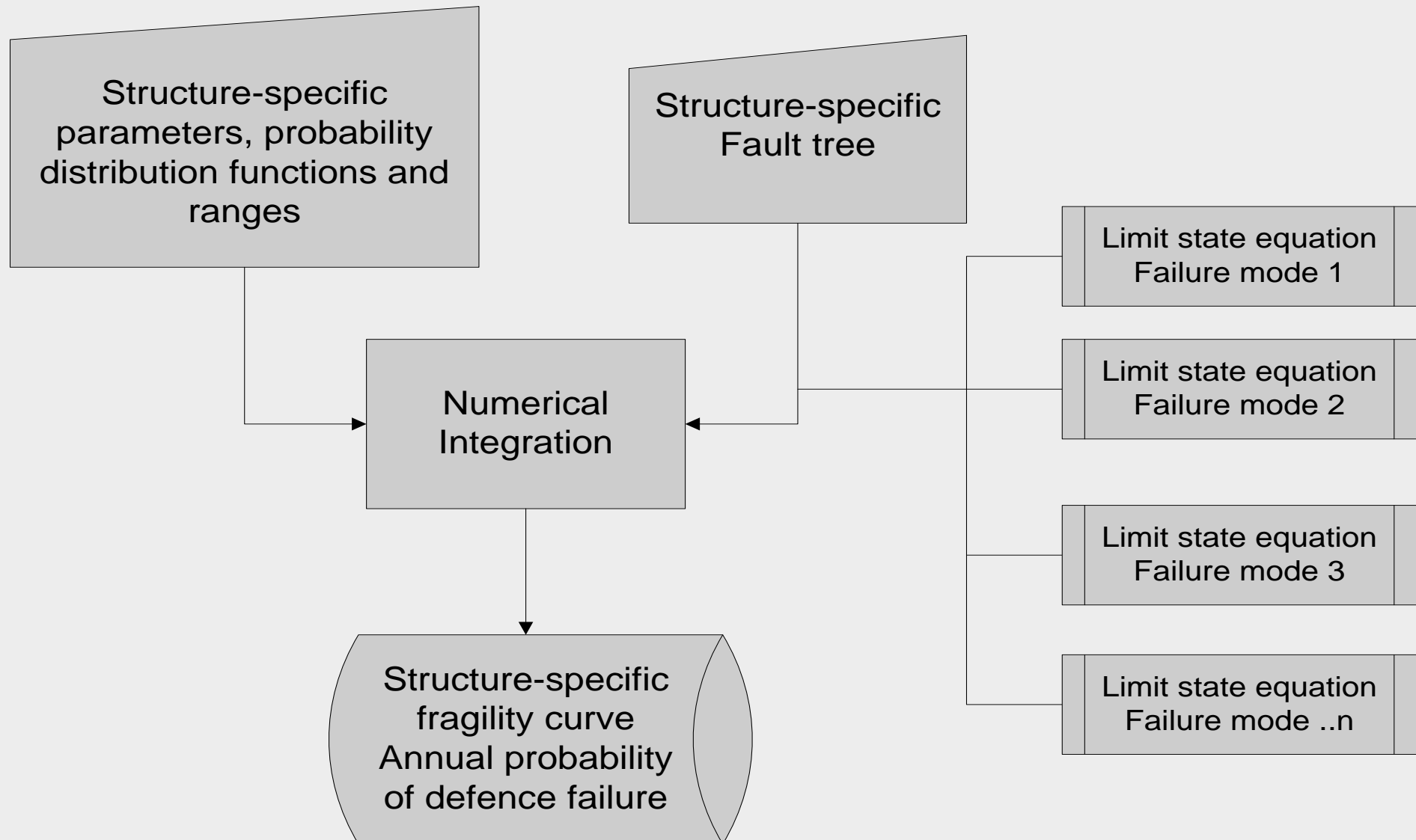


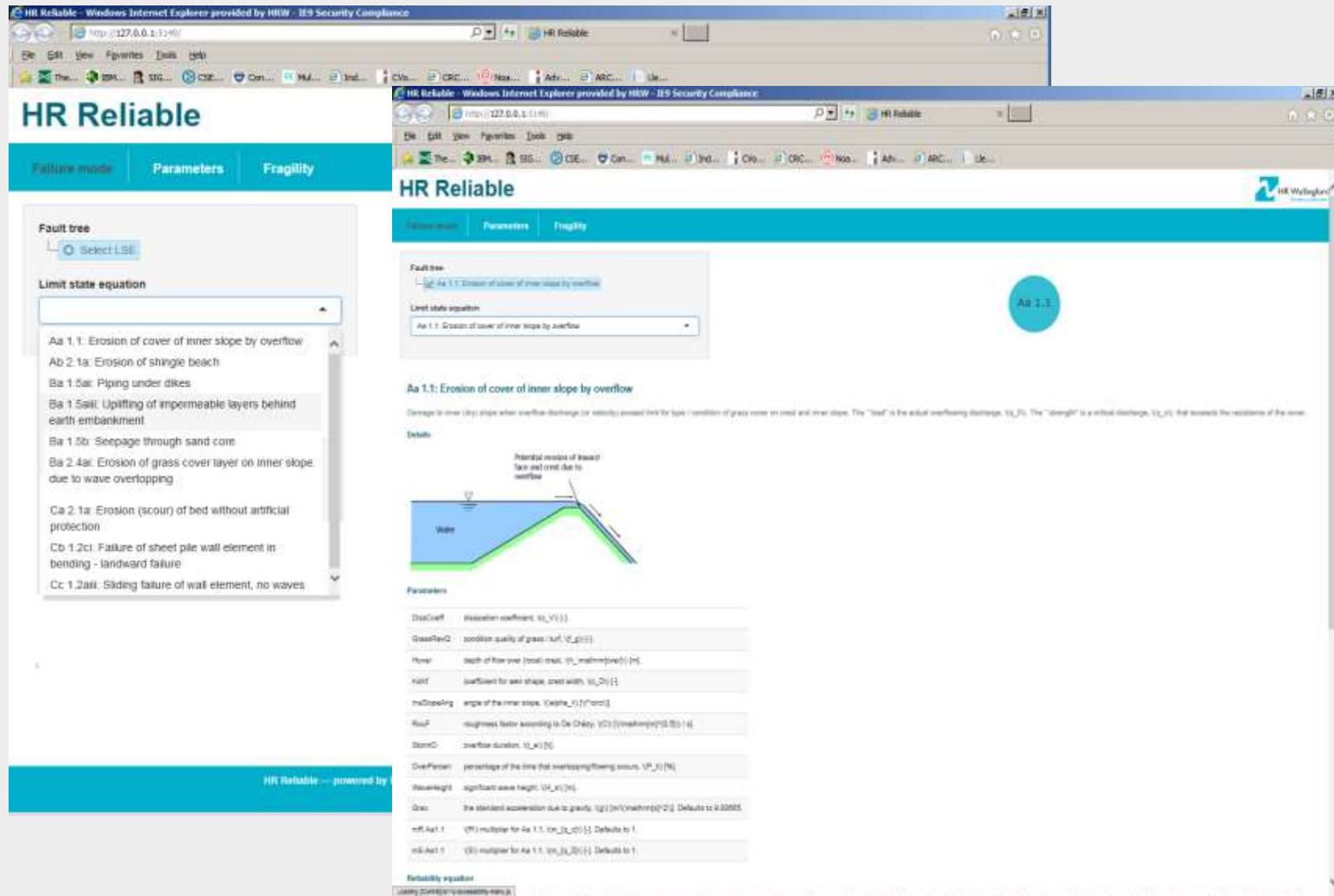
# Typical generic fragility curves

- Linked to visual condition grade
- Capture reduction in performance as levee deteriorates



# Site-specific analysis: HR Reliable components

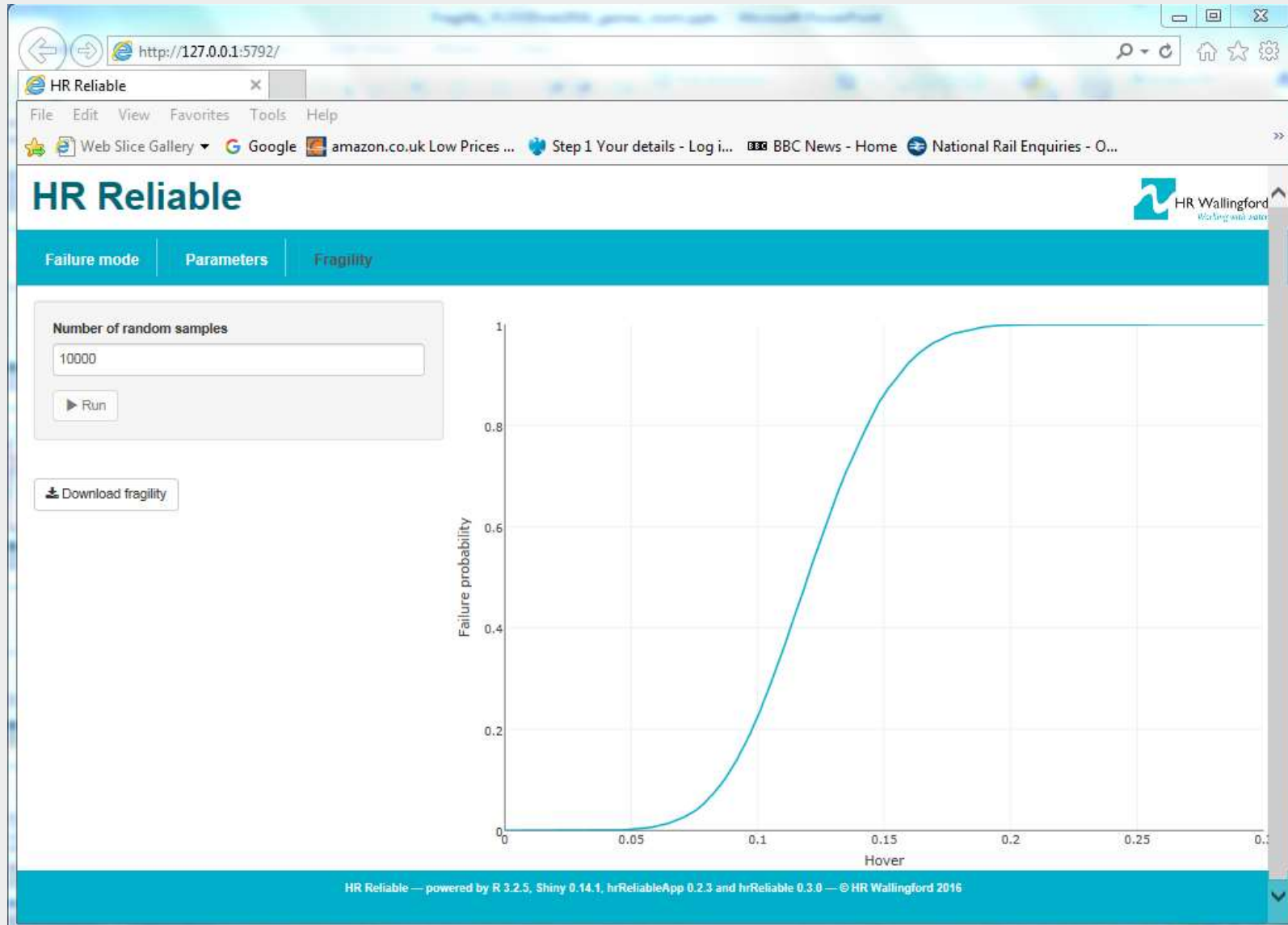




The screenshot displays the HR Reliable software interface, which is a web-based application for assessing the reliability of coastal structures. The interface is divided into several sections:

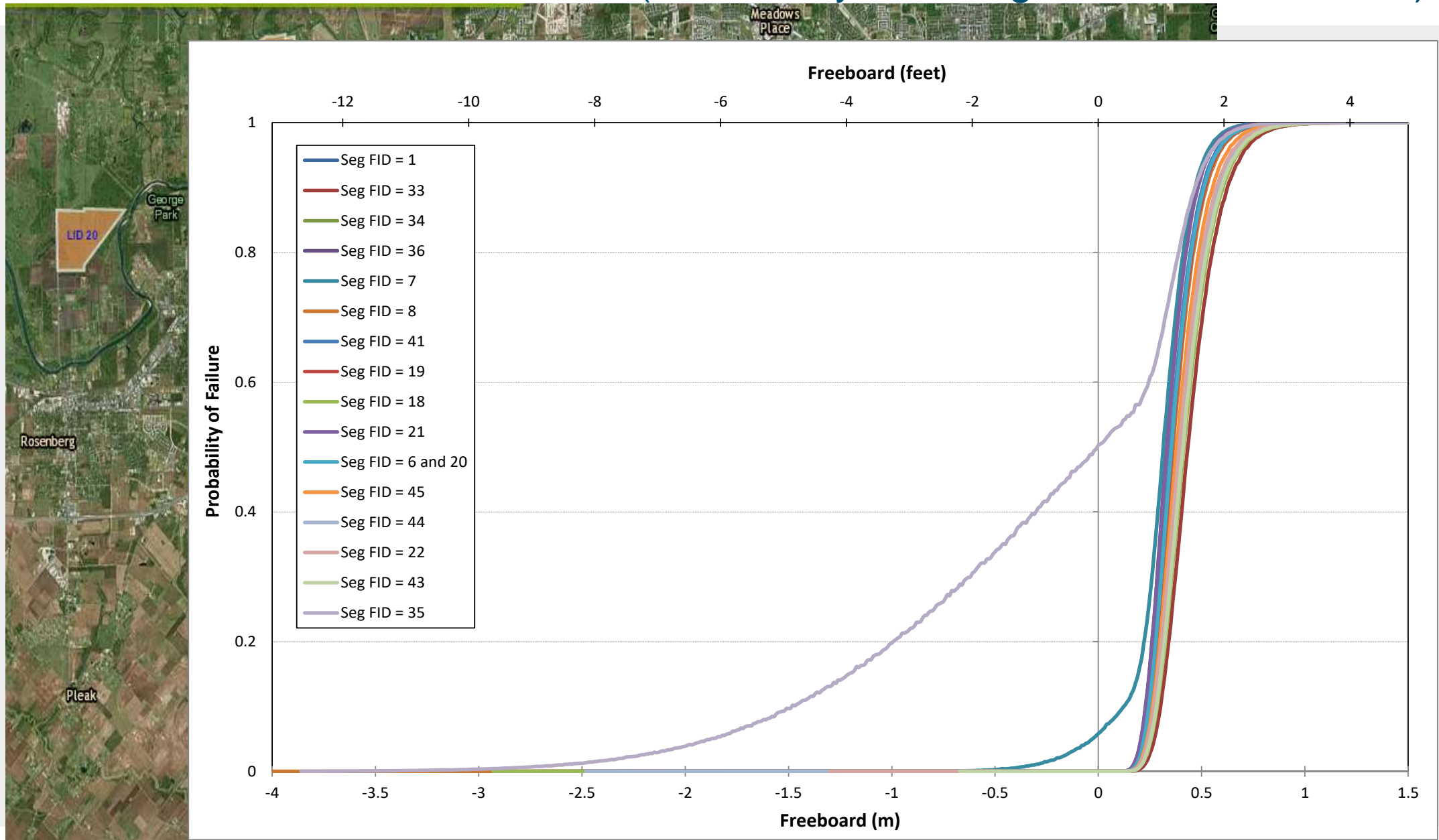
- Header:** The top of the page features the HR Wallingford logo and the text "HR Reliable".
- Navigation:** A horizontal menu bar contains three tabs: "Failure mode", "Parameters", and "Fragility".
- Fault tree:** On the left side, a "Fault tree" section lists various failure modes. A "Select LSE" button is present. The list includes:
  - Aa 1.1: Erosion of cover of inner slope by overflow
  - Ab 2.1a: Erosion of shingle beach
  - Ba 1.5a: Piping under dikes
  - Ba 1.5a.ii: Uplifting of impermeable layers behind earth embankment
  - Ba 1.5b: Seepage through sand core
  - Ba 2.4a: Erosion of grass cover layer on inner slope due to wave overtopping
  - Ca 2.1a: Erosion (scour) of bed without artificial protection
  - Cb 1.2c: Failure of sheet pile wall element in bending - landward failure
  - Cc 1.2a.ii: Sliding failure of wall element, no waves
- Limit state equation:** A dropdown menu is shown, currently displaying "Aa 1.1: Erosion of cover of inner slope by overflow".
- Details:** The main content area displays the details for the selected failure mode, "Aa 1.1: Erosion of cover of inner slope by overflow". It includes a diagram of a coastal profile showing the inner slope and the potential erosion of the cover layer. The diagram is labeled "Potential erosion of inner slope and crest due to overflow".
- Parameters:** A table lists the parameters used in the reliability equation, including:
  - DisCoeff: Dissipation coefficient,  $10^{-1}$
  - GrassRev2: condition quality of grass / turf,  $10^{-1}$
  - Hyet: depth of flow over (crest) crest,  $10^{-1}$
  - Kult: coefficient for wave shape, crest width,  $10^{-1}$
  - IntDrooping: angle of the inner slope,  $10^{-1}$
  - RuP: roughness factor according to De Chely,  $10^{-1}$
  - StormC: overflow duration,  $10^{-1}$
  - OverPercent: percentage of the time that overtopping flows occur,  $10^{-1}$
  - WaveHeight: significant wave height,  $10^{-1}$
  - Gra: the standard acceleration due to gravity,  $10^{-1}$
  - mFAct 1:  $10^{-1}$  multiplier for Aa 1.1,  $10^{-1}$
  - mFAct 5:  $10^{-1}$  multiplier for Aa 1.1,  $10^{-1}$
- Reliability equation:** A section at the bottom of the interface, currently displaying "Loading parameters is necessary to run".

# HR Reliable fragility curve






# Full site specific assessments (LID2 analysis – Sugarland, Houston, TX)



# Next steps (1): Dealing with Transitions



**WP 3: Reliability of Urban Flood Defences**

**Structure Transitions**

Date: September 2012

Report Number: WP03-01-12-10

Version Number: 4\_0\_P02

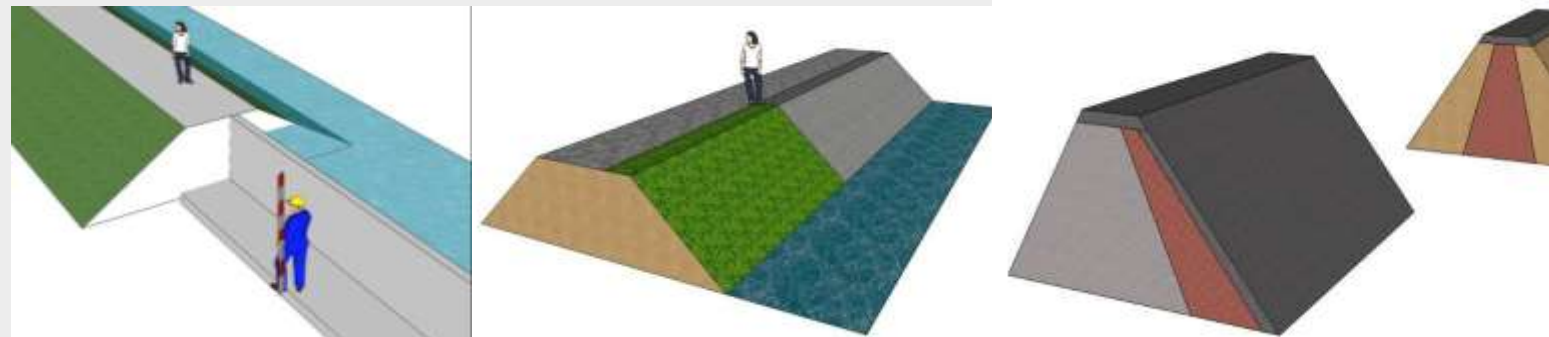
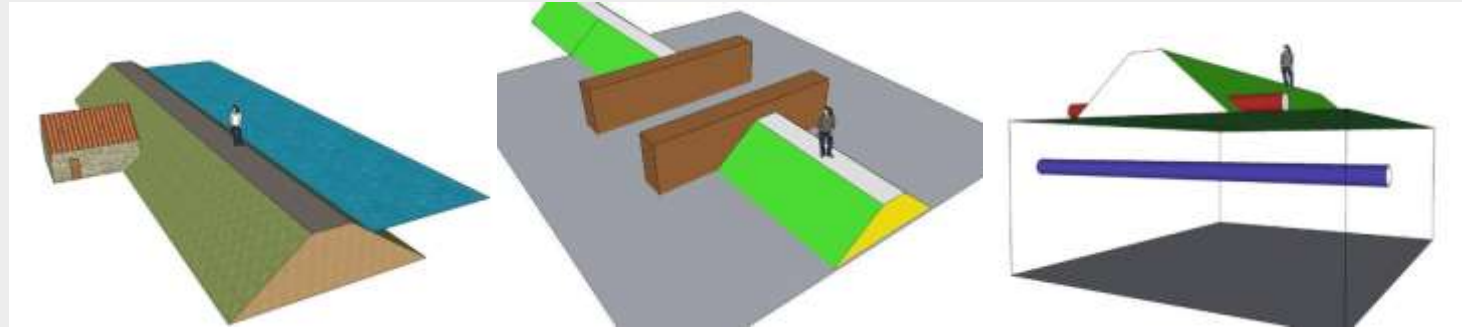
Task Leader: Irstea

FloodProBE is co-funded by the European Community  
Seventh Framework Programme for European Research and  
Technological Development (2009-2013)  
FloodProBE addresses "Technologies for Improved Safety of the Built  
Environment in Relation to Flood Events"  
Start date: November 2009, duration: 4 Years

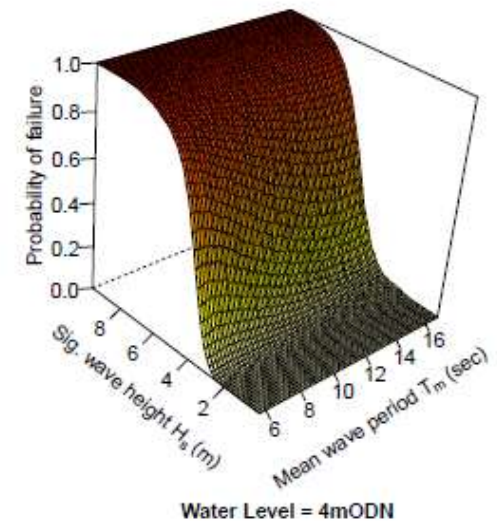
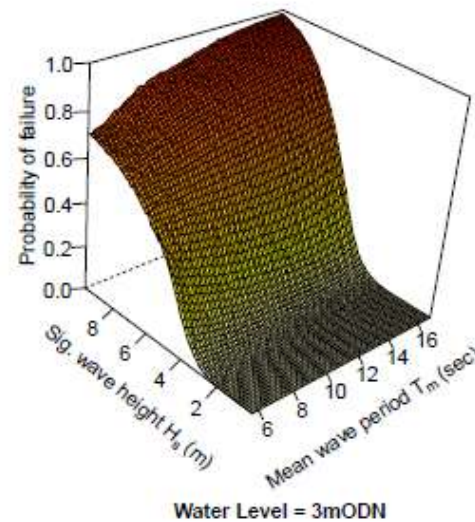
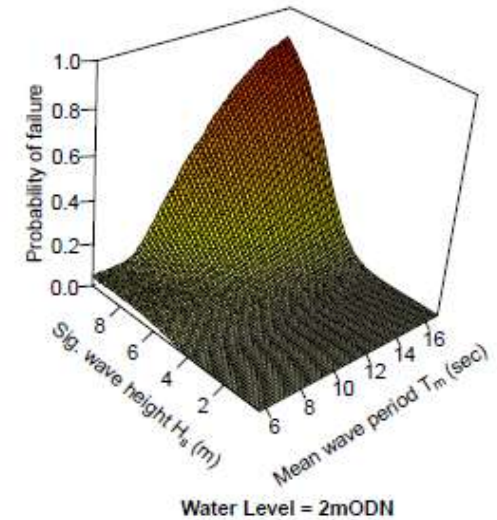
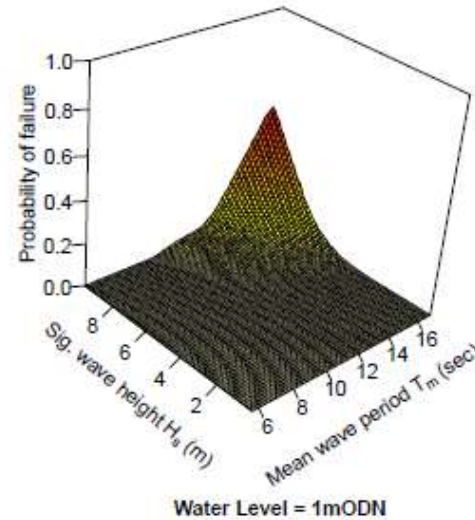
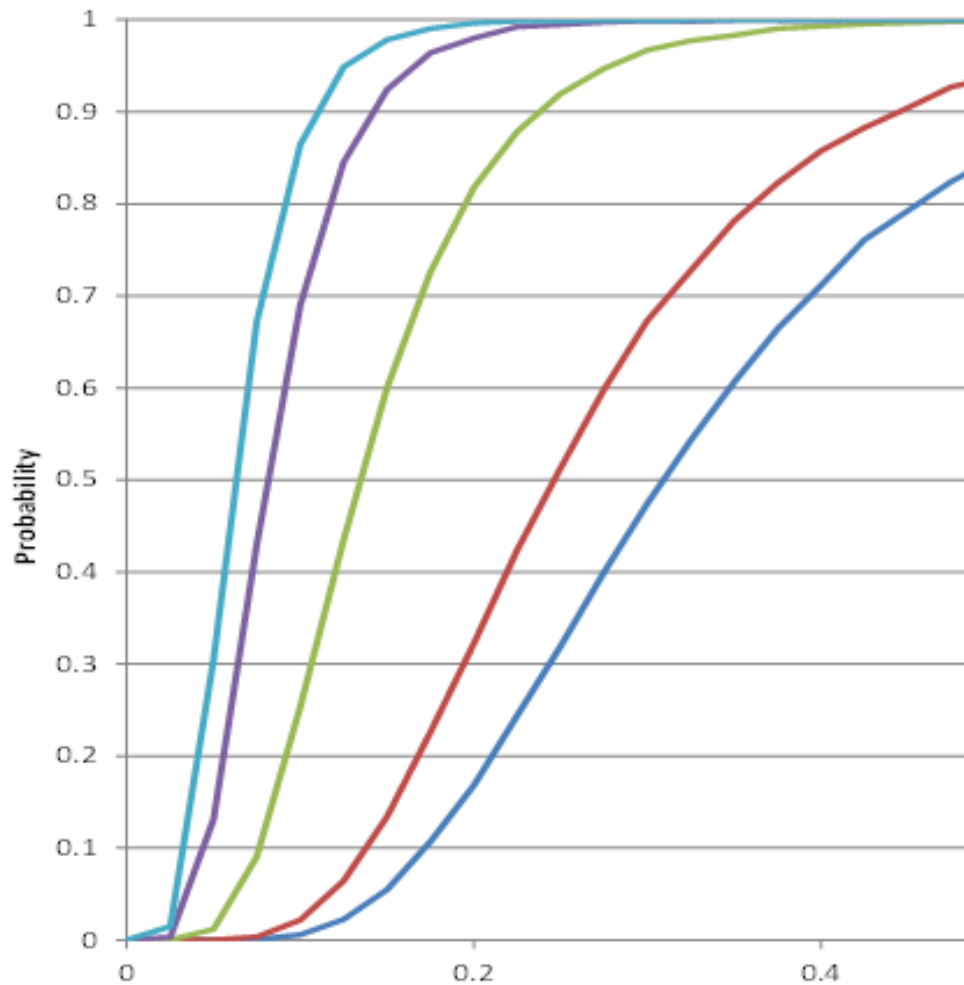
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Co-ordinator: Deltare, Netherlands    Grant Agreement No: 245401    Project website: [www.floodprobe.eu](http://www.floodprobe.eu)



# Next steps (2): introducing multi-variate fragility for coastal levees





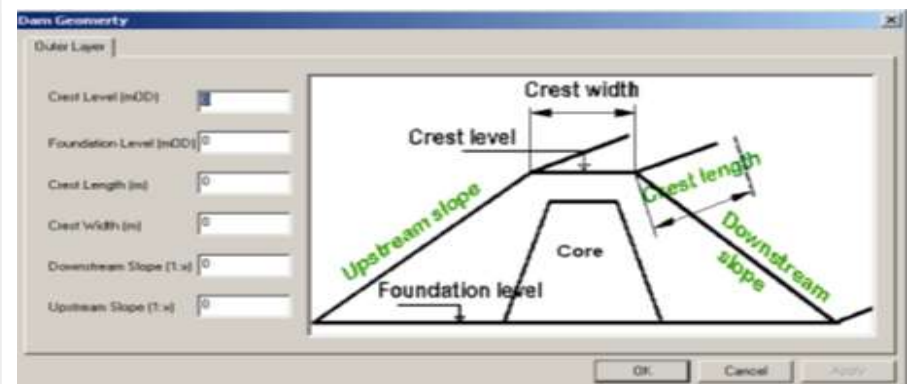
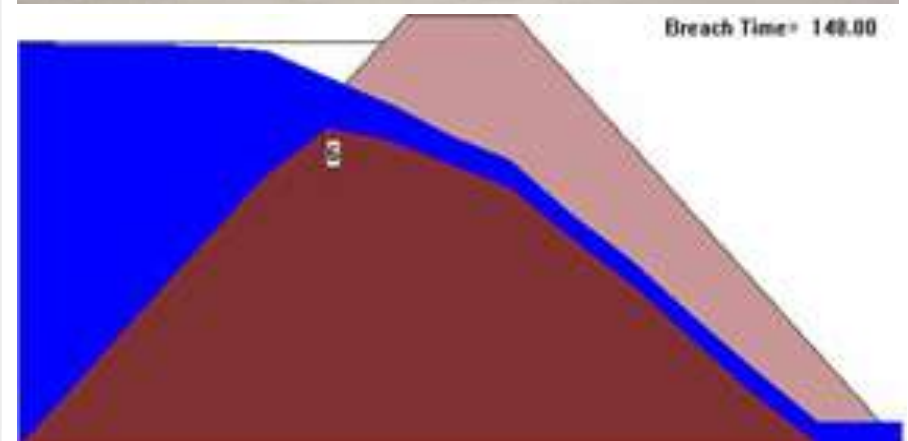
# Next steps (3): dealing (properly) with time-dependent failure mechanisms

Event tree type thinking needed in thinking about breach:

- Dynamic breach growth e.g. EMBREA
- Rapid assessment breach e.g. AREBA

## Features

- Homogeneous or composite structures
- Option for grass/rock surface protection
- Overtopping or piping initiation
- Surface erosion or headcut progression
- Variable erodibility





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Thanks and any questions?

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