# *Infrastructure management*

***A summary of the research and its outcomes***

Flood Risk Management Research Dissemination Event
FRMRC-NHRI Exchange Event
Guangdong, 30 November 2011


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**www.floodrisk.org.uk**

**EPSRC Grant: EP/FP202511/1**

# Outline

- **Infrastructure management research**
  - The motivation
  - The science
- **Where next…**

# A world wide challenge

Effective and efficient infrastructure management presents many problems:

- Flood control **systems are complex** combinations of levees, pumps, dams, channels etc
- **Future change** – climate, deterioration and land use influence risk
- **Budgets are limited** – requiring prioritisation and is required

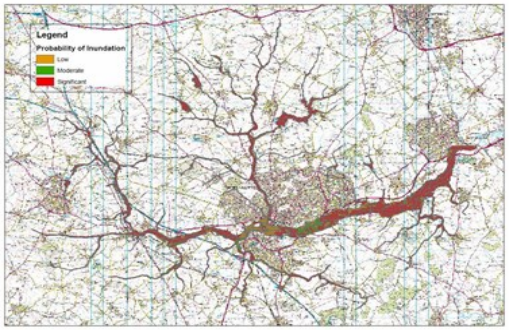
  ($2.2 trillion to fix, US – Steve Stockton, £20 billion sunk investment, England and Wales)

FRMRC flood risk management research consortium

# Some difficult science questions….

## A range of spatial and temporal scales of interest

All (national) Systems




One Flood Risk Management System

One Asset

**What are the national…**

- Hot spots?
- Investment need?
- How might these change ?

**How will the system...**

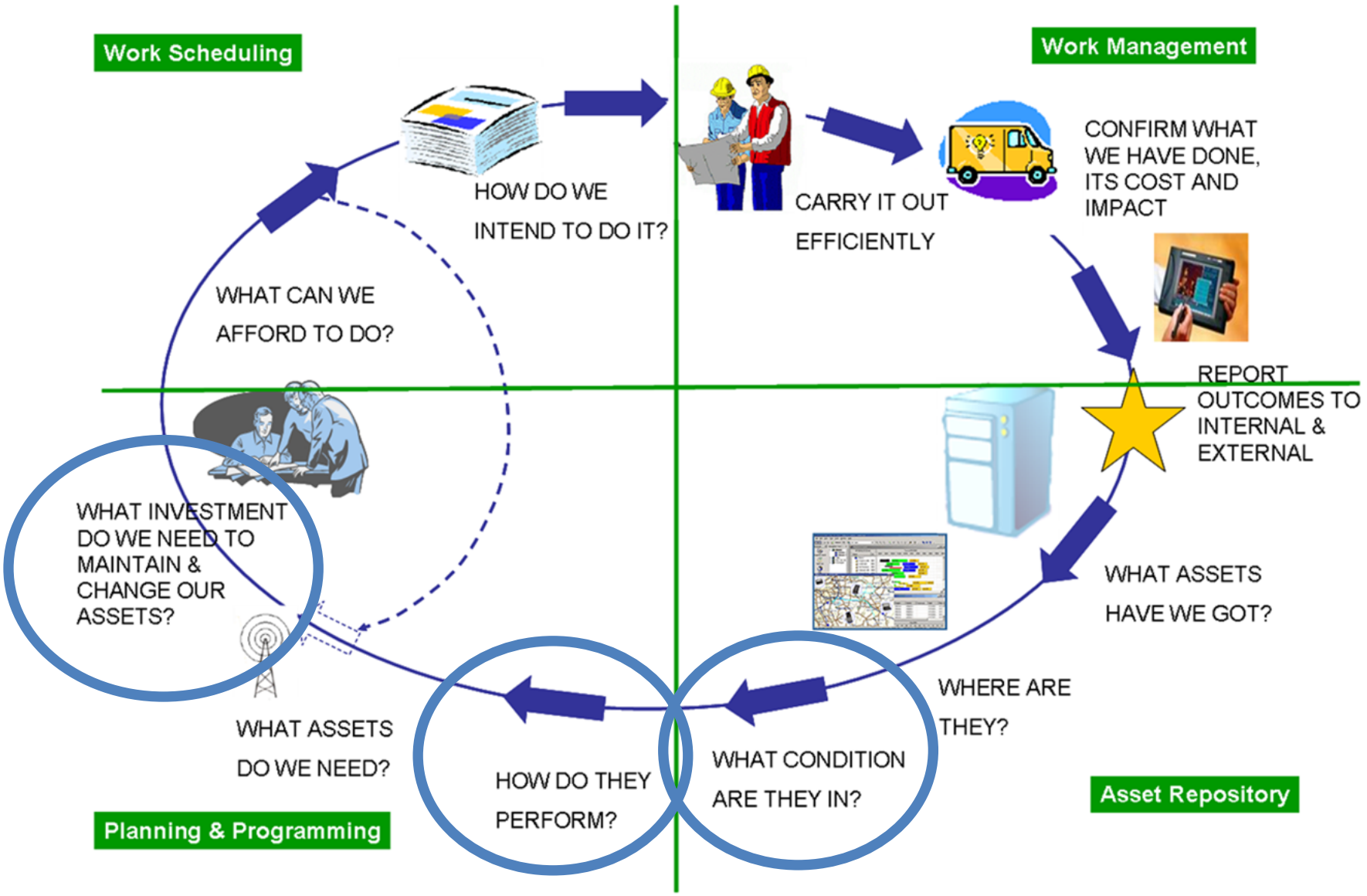
- Perform now and in the future?
- Which assets contribute most to risk?

**How will an asset…**

- Perform under load or on demand?
- Improve or deteriorate with/without action?

FRMRC flood risk management research consortium

# A clear role in supporting practice…..



# The science

1. **Inspection** - integrating visual inspection and remote sensed data in the condition assessment process (WP4.2)
2. **Individual asset performance** – Understanding underground/above ground gully connections (WP3.3), blockage potential (WP4.1), breach growth (WP4.4)
3. **Asset system performance** – Integrating coastal and flood risk analysis and the dynamic performance beach\cliff assets (WP4.3)
4. **Decision support** – Identifying optimum asset management (WP 1.7/WP 4.5)

# Linking visual and remote sensed data (WP4.2)

## The aim

- To develop an approach to condition assessment that **supplements** purely **visual inspection** with routine **quantified measurement** (without significant cost increases).


The Condition Inspection Manual, Environment Agency, UK



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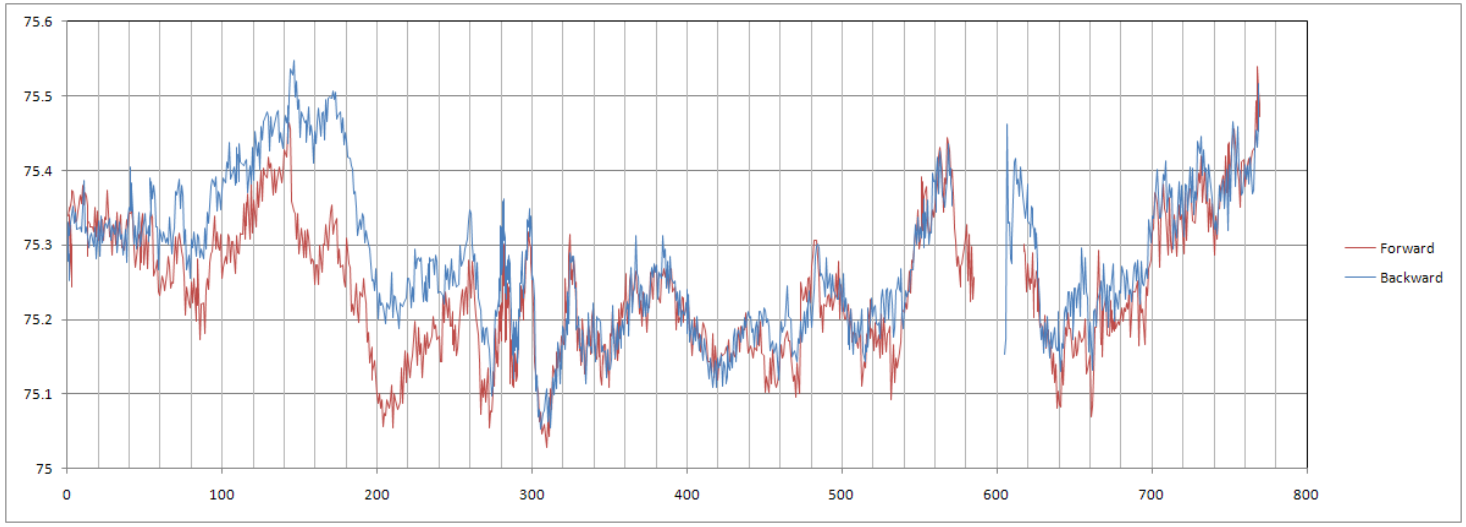
# Linking visual and remote sensed data (WP4.2)

## Routinely quantified movement in the levee crest

Utilizing Kinematic GPS as part of the visual inspection



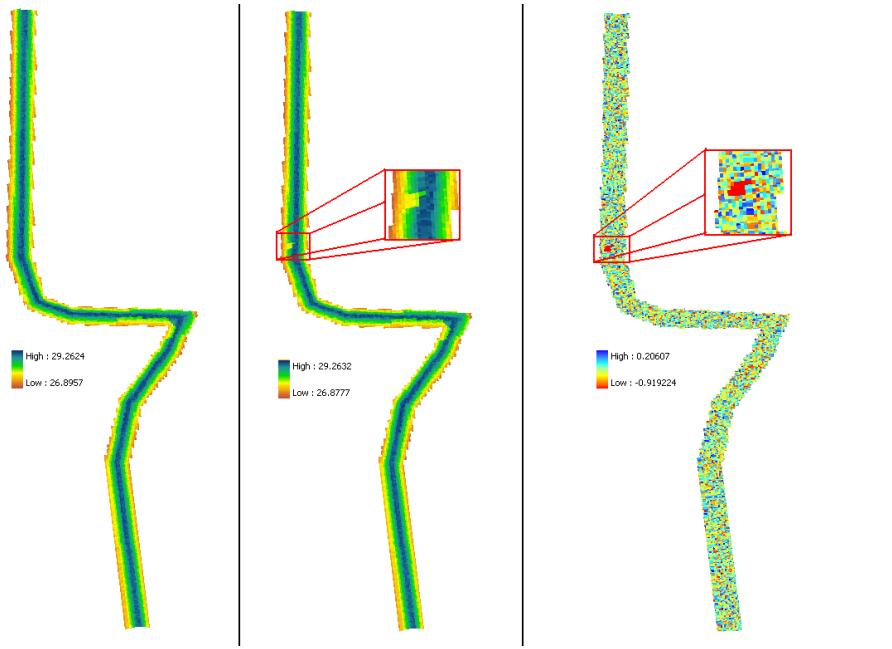

**(max diff 0.24m)**

**Data Collection System (GPS in a back pack)**

# Linking visual and remote sensed data (WP4.2)

## Can LiDAR be better used to identify surface movement in levees?

Simulation to explore required accuracy to support asset inspection




No slip | With slip | Post processed to highlight slip

## Can simple measures help?

What inspection aids make a real difference?

**Summary Report** – linking supporting technologies and methodologies to their use in condition monitoring

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# Gully performance (WP3.3)

Inflow Q=?

Outflow Q=?




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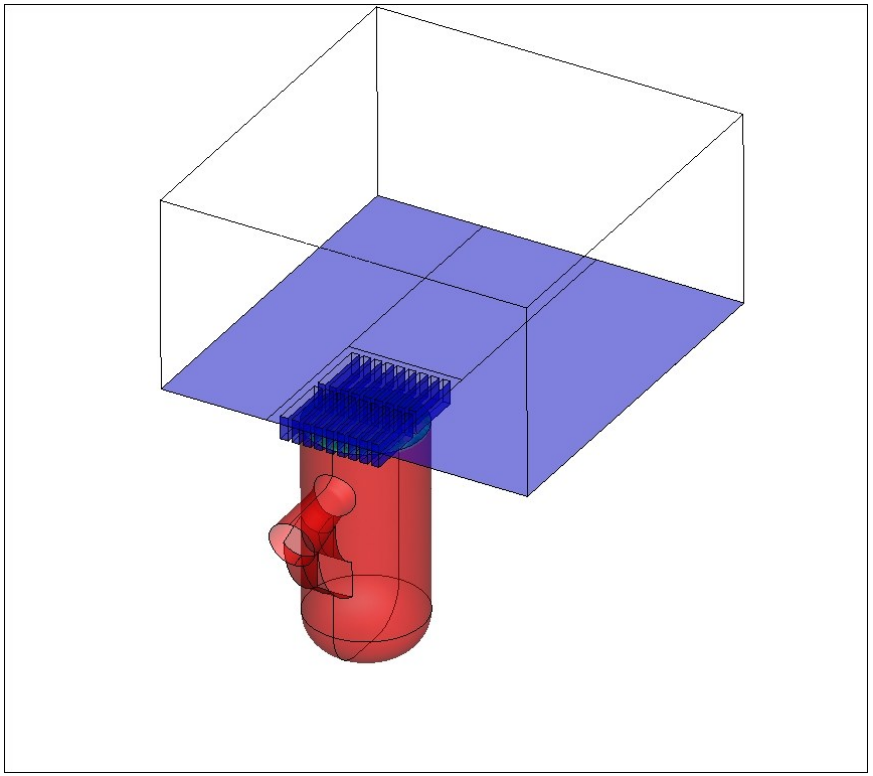
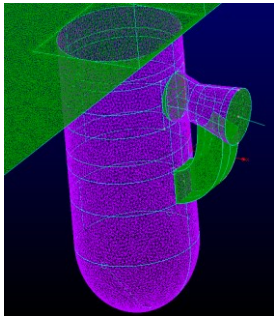
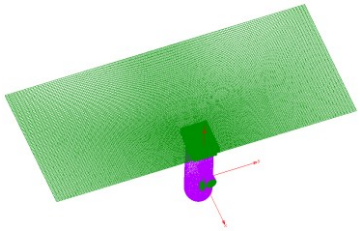
# Gully performance (WP3.3)



**Phyiscal modelling**



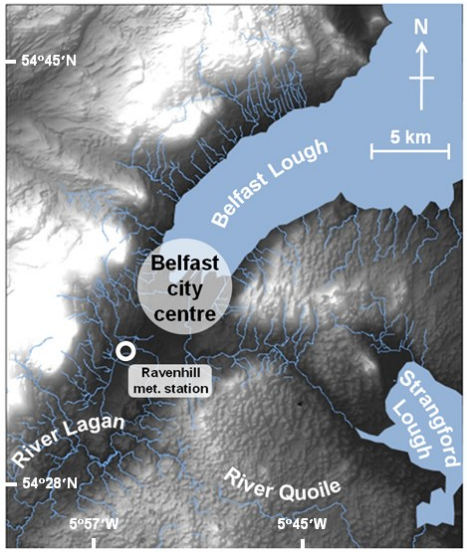


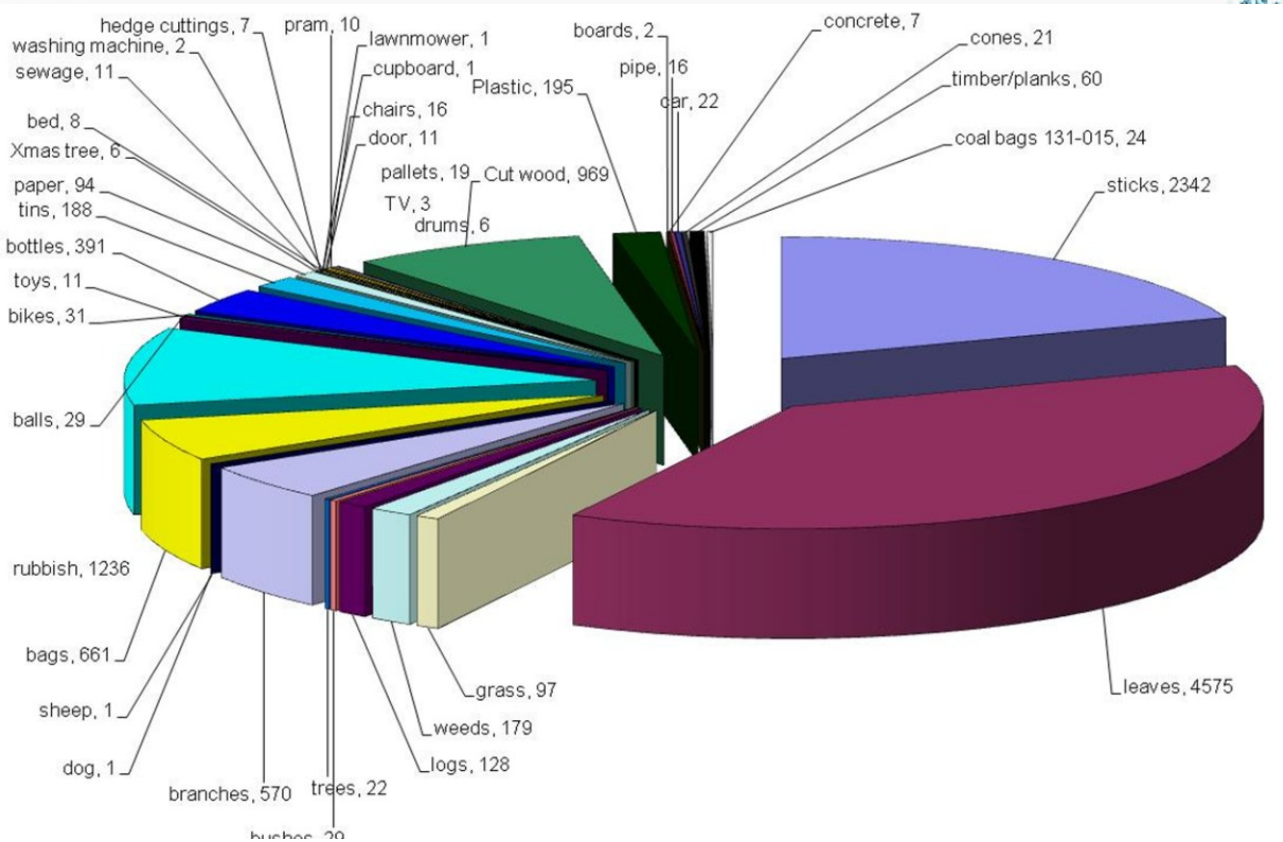
**3D simulation**

# Potential debris blockage structures (WP4.1)

**Improve understanding of:**

- The ***rate*** at which debris arrives at structures
  - related to flow regime
- The ***probability*** of a blockage occurring
  - related to upstream driving variables
- The ***extent*** of any blockage - area 'blinded'
  - Related to screen properties




$P_d / Sa_b = f$

- channel
- flow
- (screen)
- landuse
- social dep.

→ **predictive equations**

Data driven analysis – Case study from Belfast



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# Breach – rapid methods for assessment (WP 4.4)

## The aim

- What would happen if a levee breached?
- How might the breach grow?
- What volume and how fast would the inflow be?

## Currently

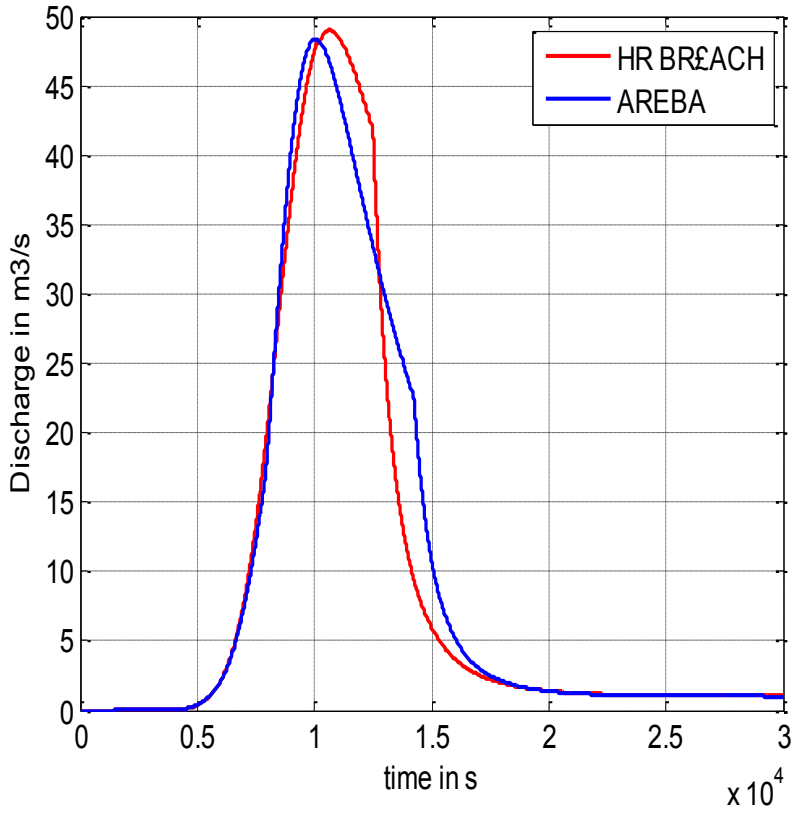
- Breach models are either, highly simplified, or complex to run requiring significant data.


- FRMRC utilised information from field study collected through (www.floodsite.net and www.impact.net)

# Breach size – rapid methods for assessment (WP 4.4)

## New in FRMRC (AREBA)

- Simple, fast to run but credible
- Analytical equations used to solve
  - Surface erosion
  - Headcut
  - Piping
- Embankments only



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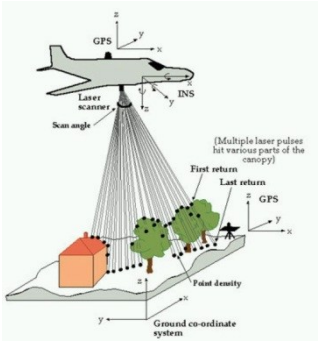
4. **Decision support** – Identifying robust strategies and seeking optimum asset intervention strategies in complex systems under climate change (WP1.7/4.5)

# Optimisation of strategies under uncertainty

Engineers face a doubt as to which action to take:

- **Where?** – Improvement to which asset would yield the greatest risk reduction?
- **When?** - Is action required now, or can investment be postponed?
- **How?** – What standard is appropriate, should land be secured for future widening / construction ?

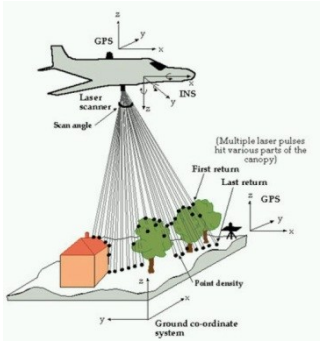


# Infrastructure planning (WP1.7)

Infrastructure planning decisions can be supported by:

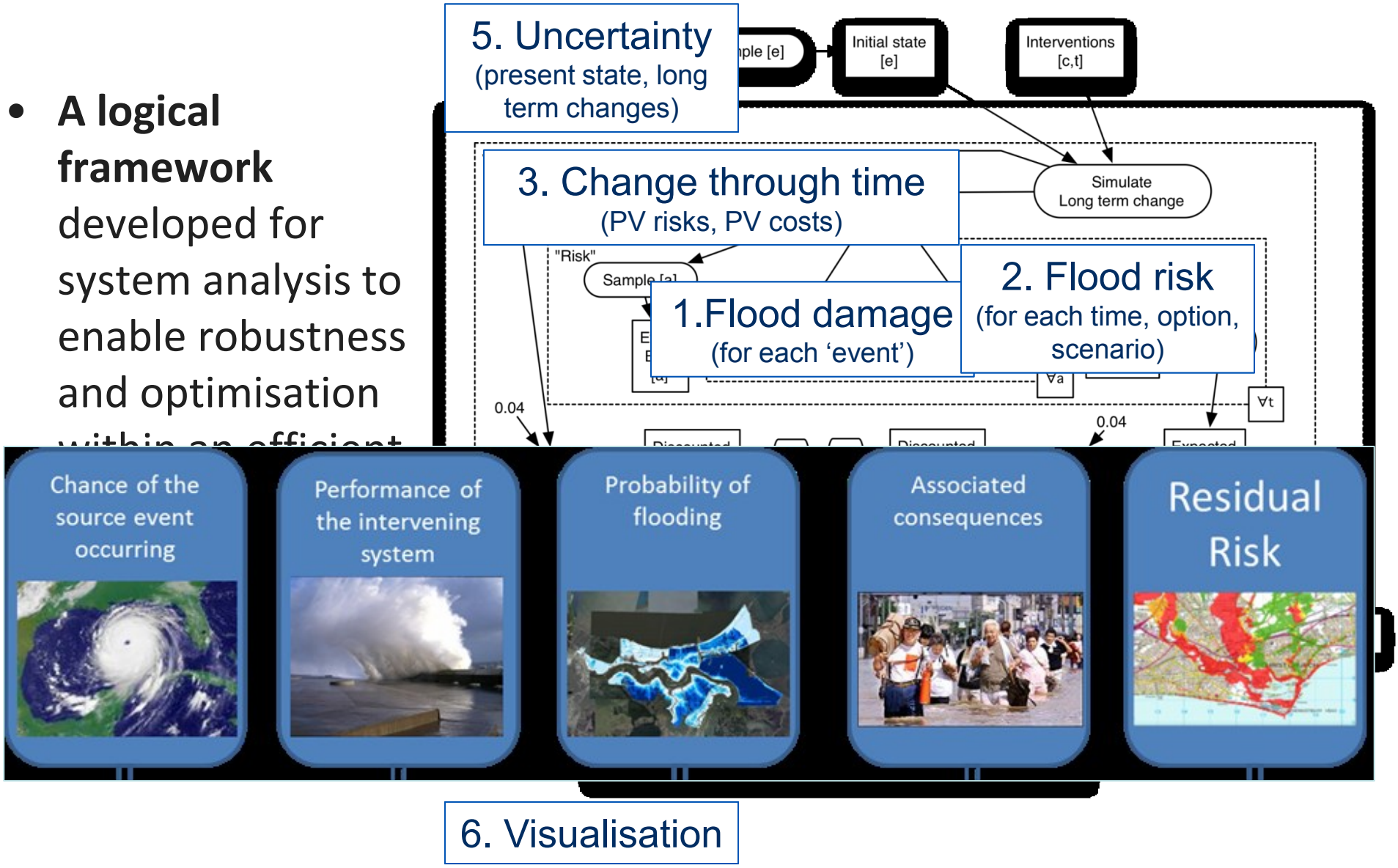
**Quantified flood risk analysis and option exploration**

- … for a series of infrastructure options
- … which may be implemented at various times in the future
- … whose cost is state-dependent
- … under conditions of long term change
- … in order to generate aggregate performance metrics which are used to compare options
- … and identify solutions that are *optimal*, *robust*…



# Framework of analysis (WP1.7)

- **A logical framework** developed for system analysis to enable robustness and optimisation within an efficient



# Optimisation of investment strategies (WP4.5)

## Challenge

- To loop through this process many times to identity an optimal flood risk management strategy (taking account of uncertainty in future climate change)

**Case study on the River Dodder**

Total: 158 defences group in a small number of reaches

**Legend**

- High Ground
- B&M vertical wall
- Turf Embankment



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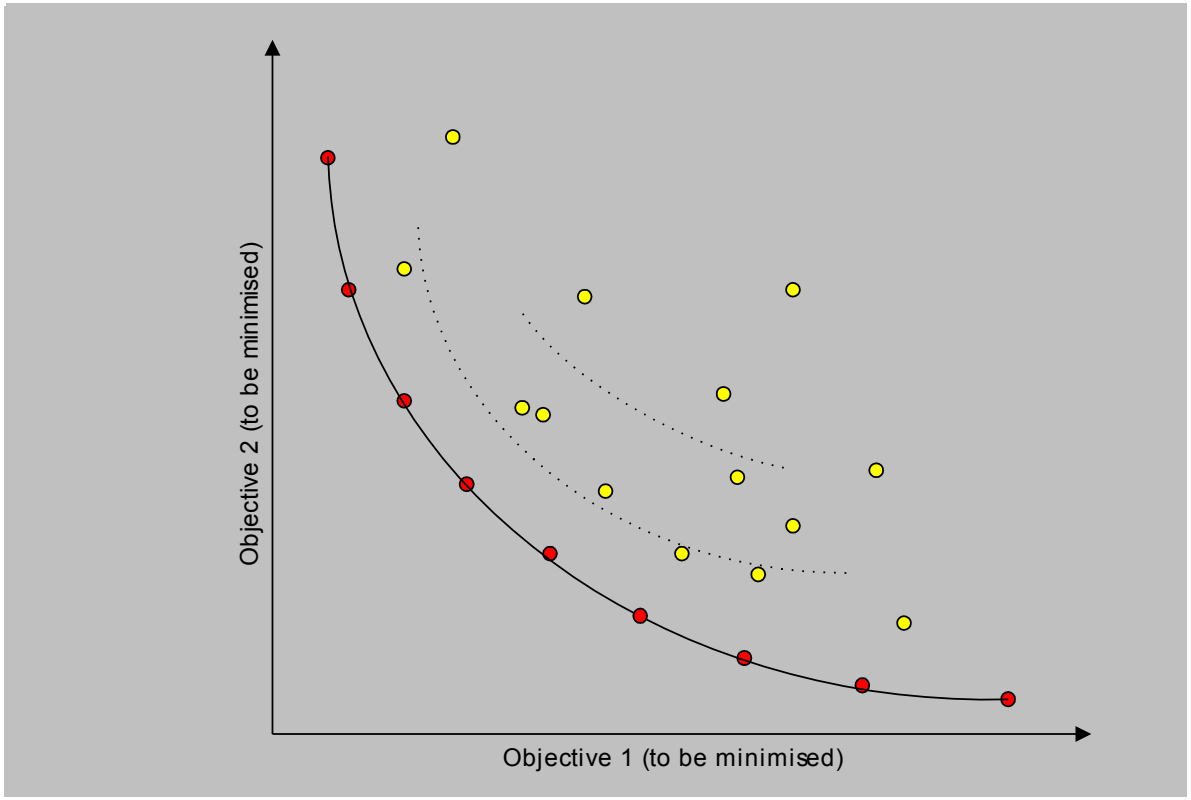
# Multiobjective Optimisation - The Pareto Front

## Optimisation

- Possible interventions strategies automatically generated using a GA.
- Performance of each assessed against given criteria (e.g. cost and benefits)
- Invariably a set of optimal solutions is discovered (i.e. a **Pareto set**)



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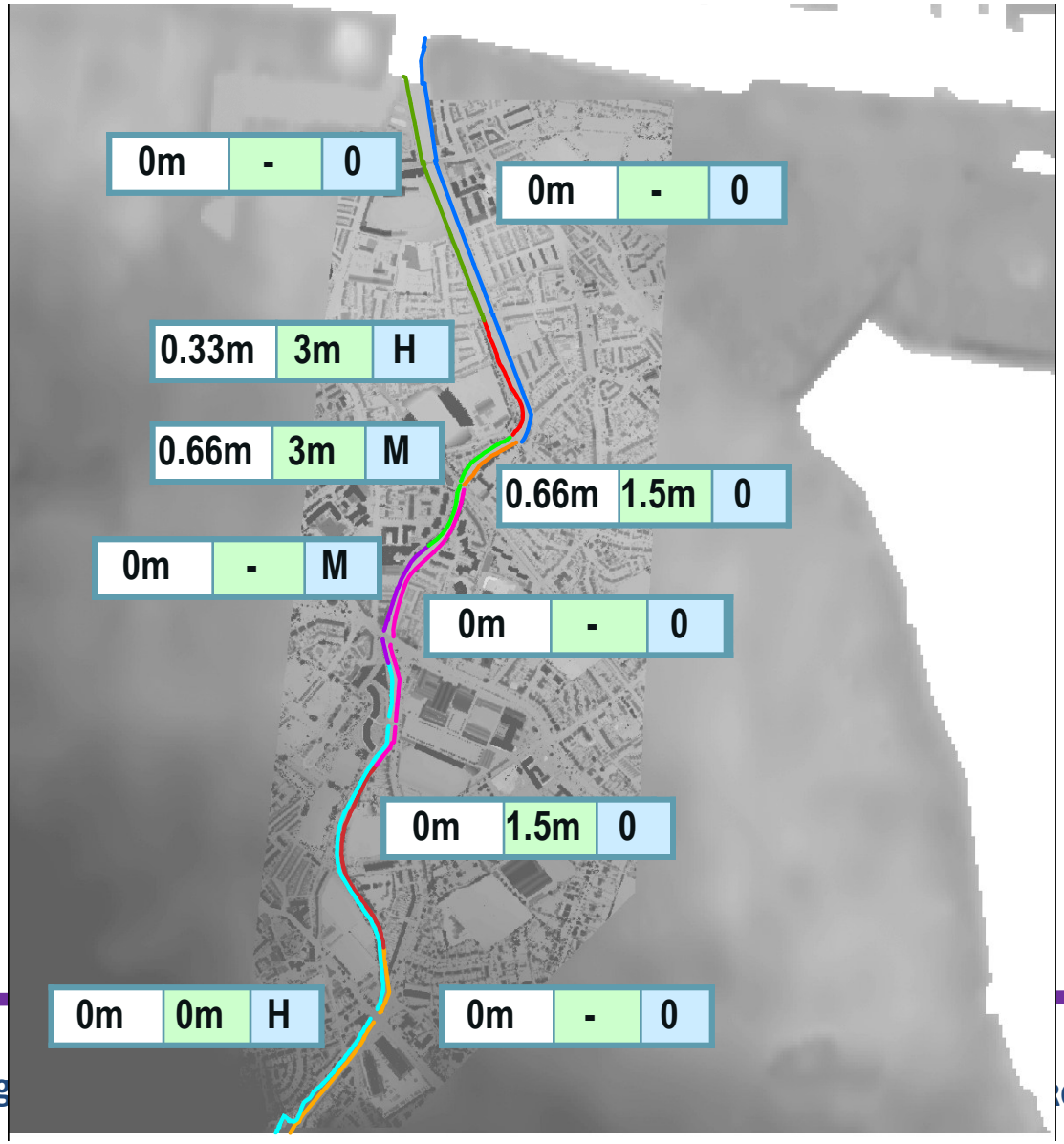
# Optimisation of investment strategies (WP4.5)

## The results

- Strategy with the highest Net Present Value (NPV)



# Where next…

Promoting linkage with researcher and practitioners to aim future development and take-up

Much is already finding its way into practice:

- UK – Through TE2100
- USA – USACE (comparing approaches in St Paul)
- China – GIWP / WWF

# Some key outputs

**Books**

Thomas Telford Book

**Flood defence infrastructure management and design** – Due for release Spring Next year (edited Sayers)

**CIRIA TN**

II – Culvert Blockage, Visual inspection methods

**Papers**

Many journal papers and conference papers

**Tools**

Proof of concept – e.g. AREBA, optimisation methods, risk analysis frameworks (www.refame.org)

**Data**

Base datasets in blockage (plus various model runs).

**Practitioner and specific outreach events**

Advances in asset management – A workshop for practitioners (4 Oct 2011)

Science of asset management - A workshop for international scientific exchange (9th Dec 2011)

Exchange workshops in Australia (SWP4), **China,** Ireland and Scotland

# Work package leaders

1. **W.P4.1 Flood risks associated with debris at structures**
   - The University of Nottingham and Herriot Watt University, working with HR Wallingford, JBA and Royal Haskoning
2. **WP4.2 Performance based inspection of flood defences**
   - The University of Nottingham, working with Dr Mervyn Bramley (independent) and HR Wallingford
3. **WP4.3 Integration of coastal flood and erosion risk models**
   - HR Wallingford, working with Halcrow, and co-workshops with SWP2
4. **WP4.4 Breach size – rapid methods for assessment**
   - Oxford University working with HR Wallingford- linked with SWP2
5. **WP 4.5 Optimisation of investment strategies**
   - HR Wallingford and Royal Haskoning
6. **WP 3.3 Gully performance – connecting above and below ground system**
   - Universities of Exeter and Sheffield
7. **Computer support for infrastructure planning decisions**
   - Universities of Newcastle and Oxford



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# Funders

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- **Department of Environment, Food and Rural Affairs/Environment Agency Joint Research Programme**
- **United Kingdom Water Industry Research**
- **Office of Public Works Dublin**
- **Northern Ireland Rivers Agency**

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# Further information

**See the Website**
www.floodrisk.org.uk

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**Acknowledges** (see following slides for details)
- Work package researchers
- Steering Group Members
- Funders