Government Office for Science

Foresight

Foresight Flood and Coastal Defence Project 2004 (Updated 2008)

The Flood Cycle:
(courtesy HR Wallingford)

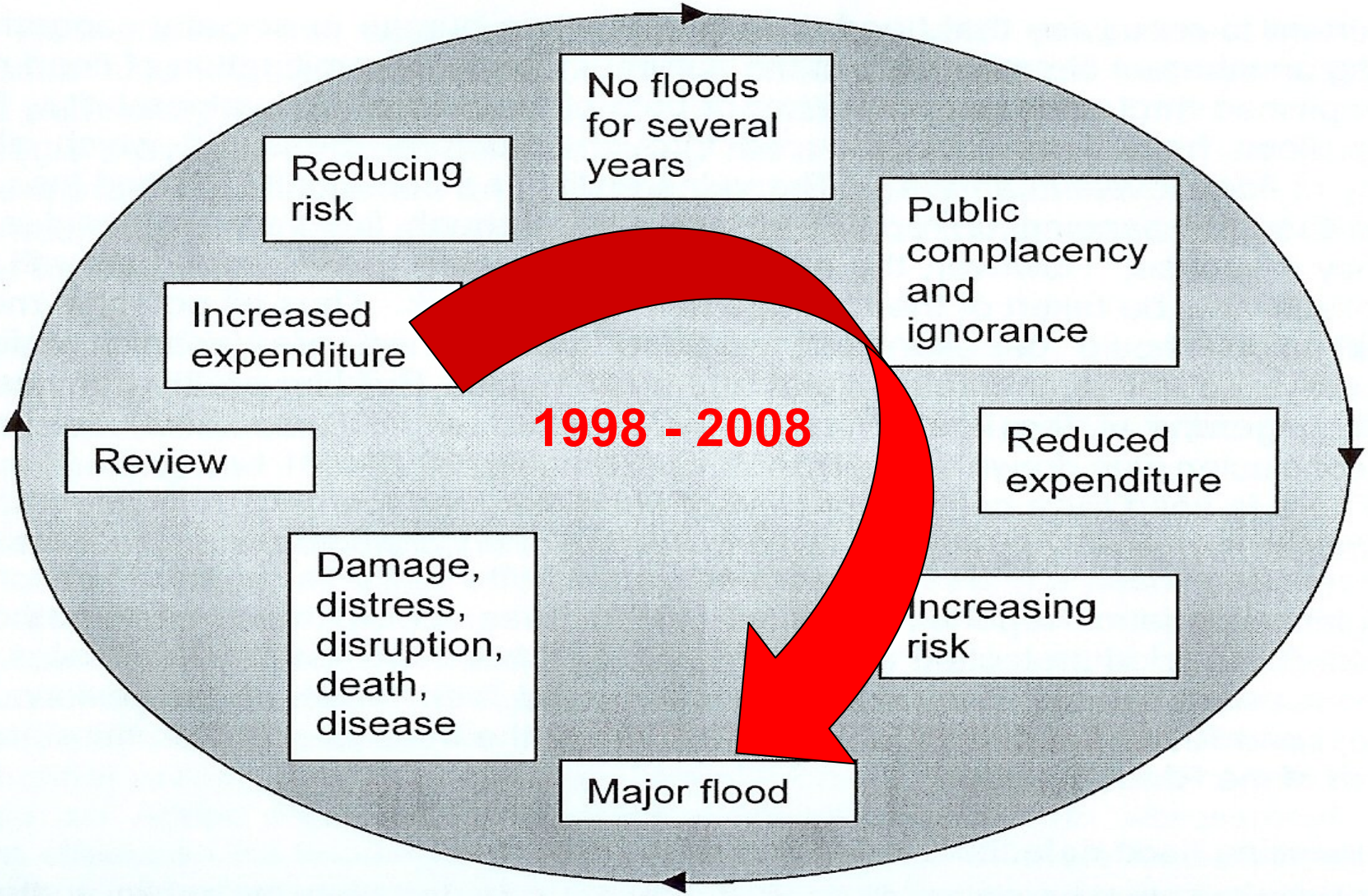
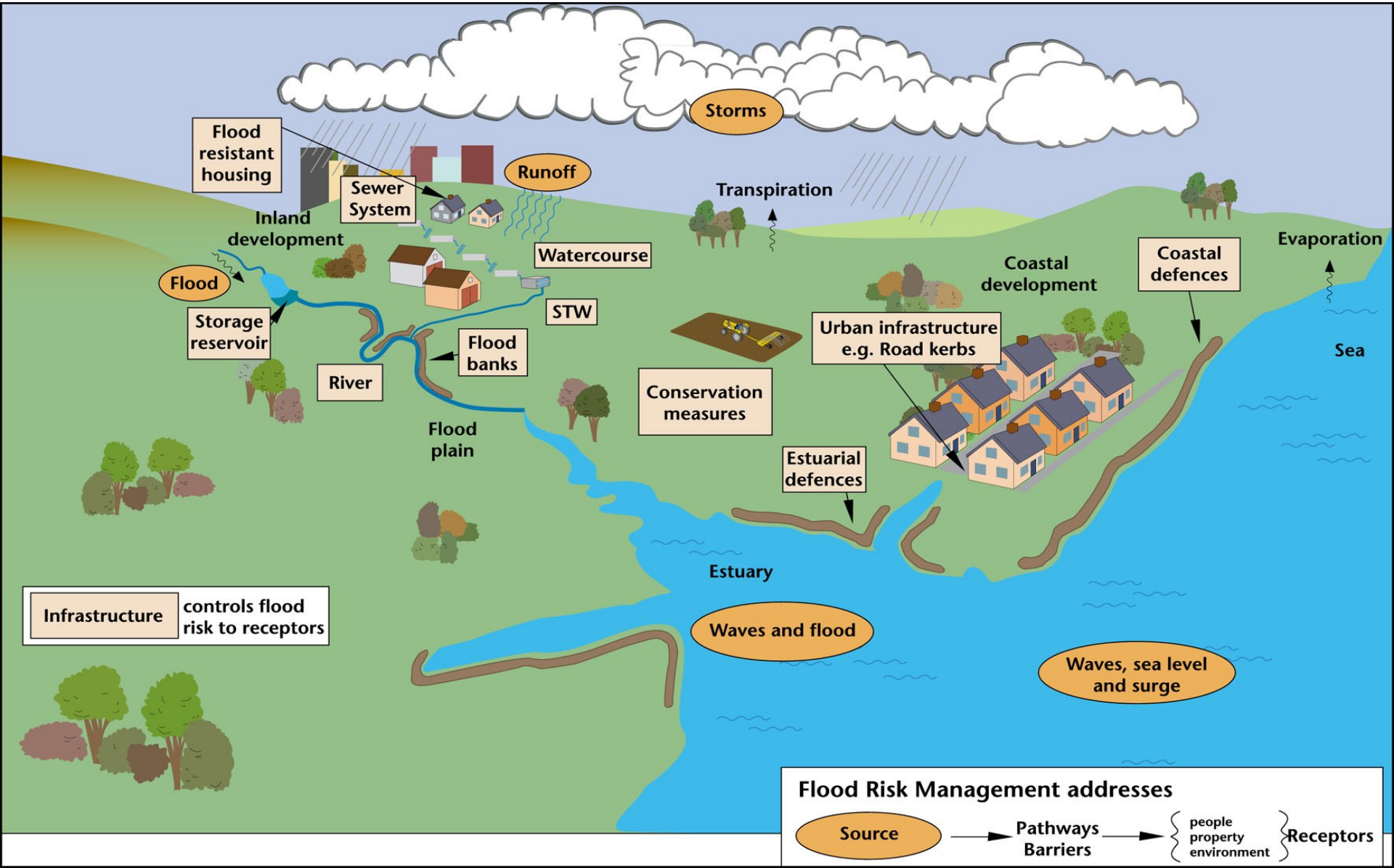
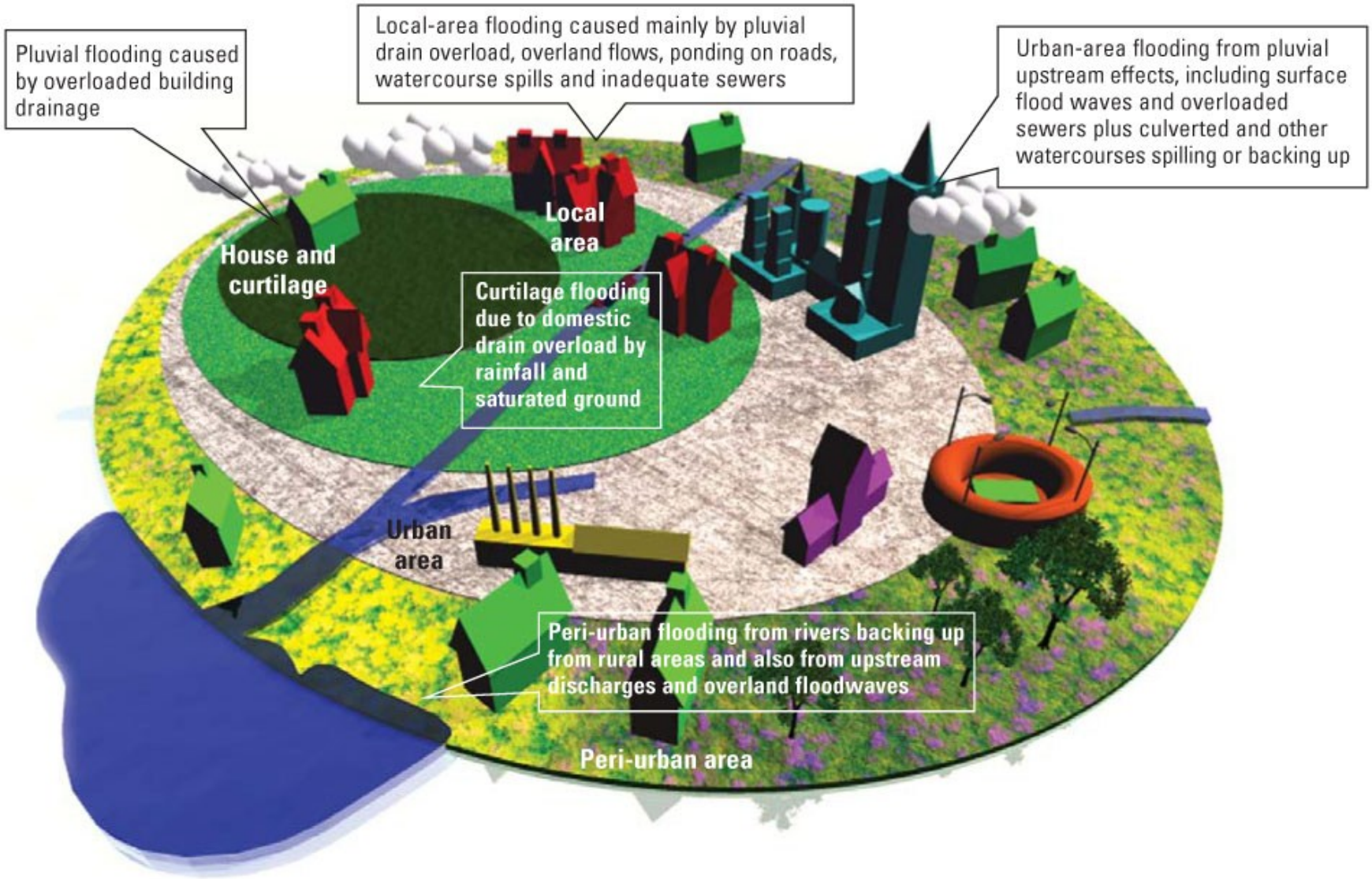


Figure 1 Hypothetical Cycle for Flood Defence Expenditure and Flood Risk

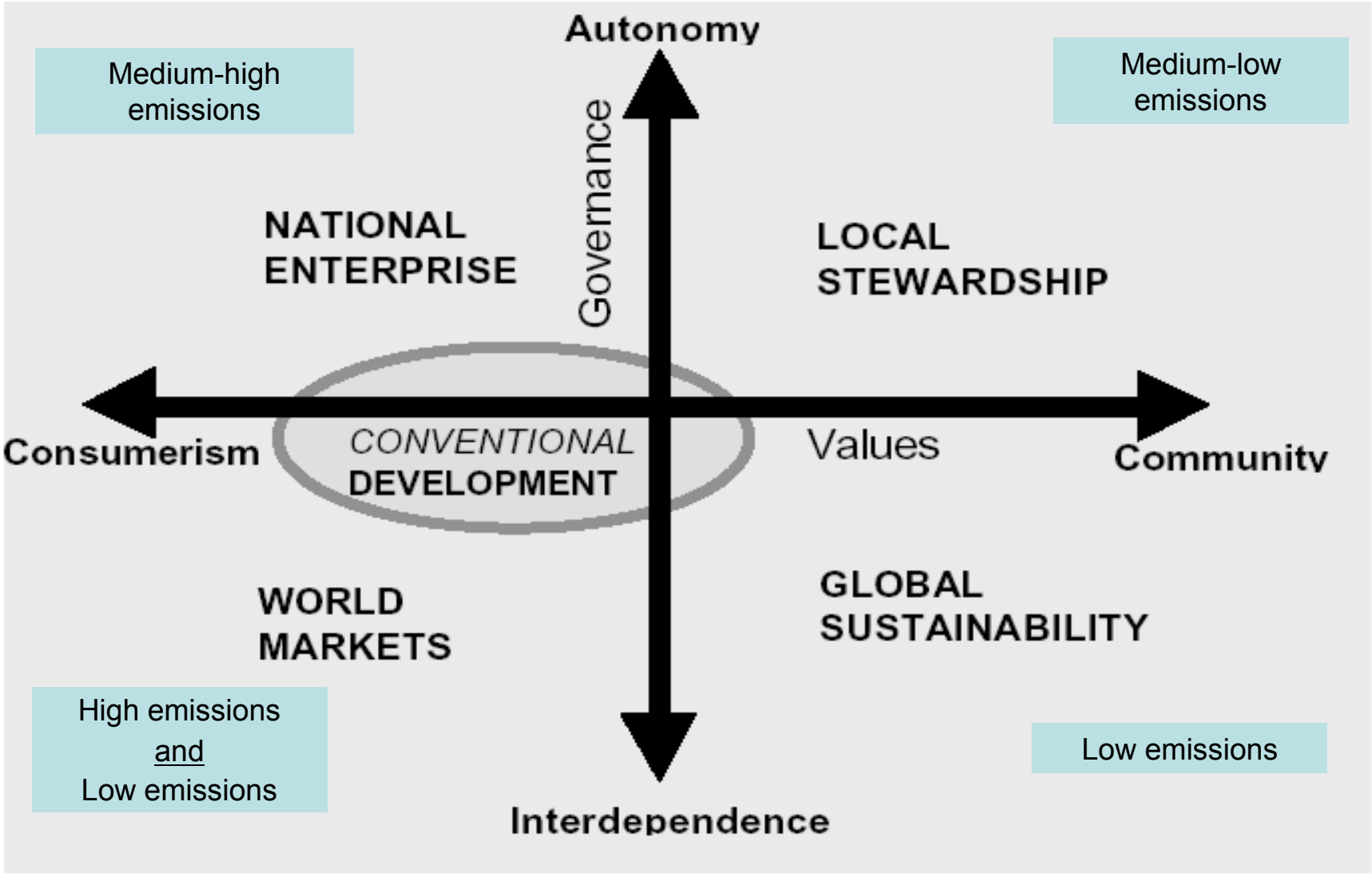
The catchment and coastal flooding system

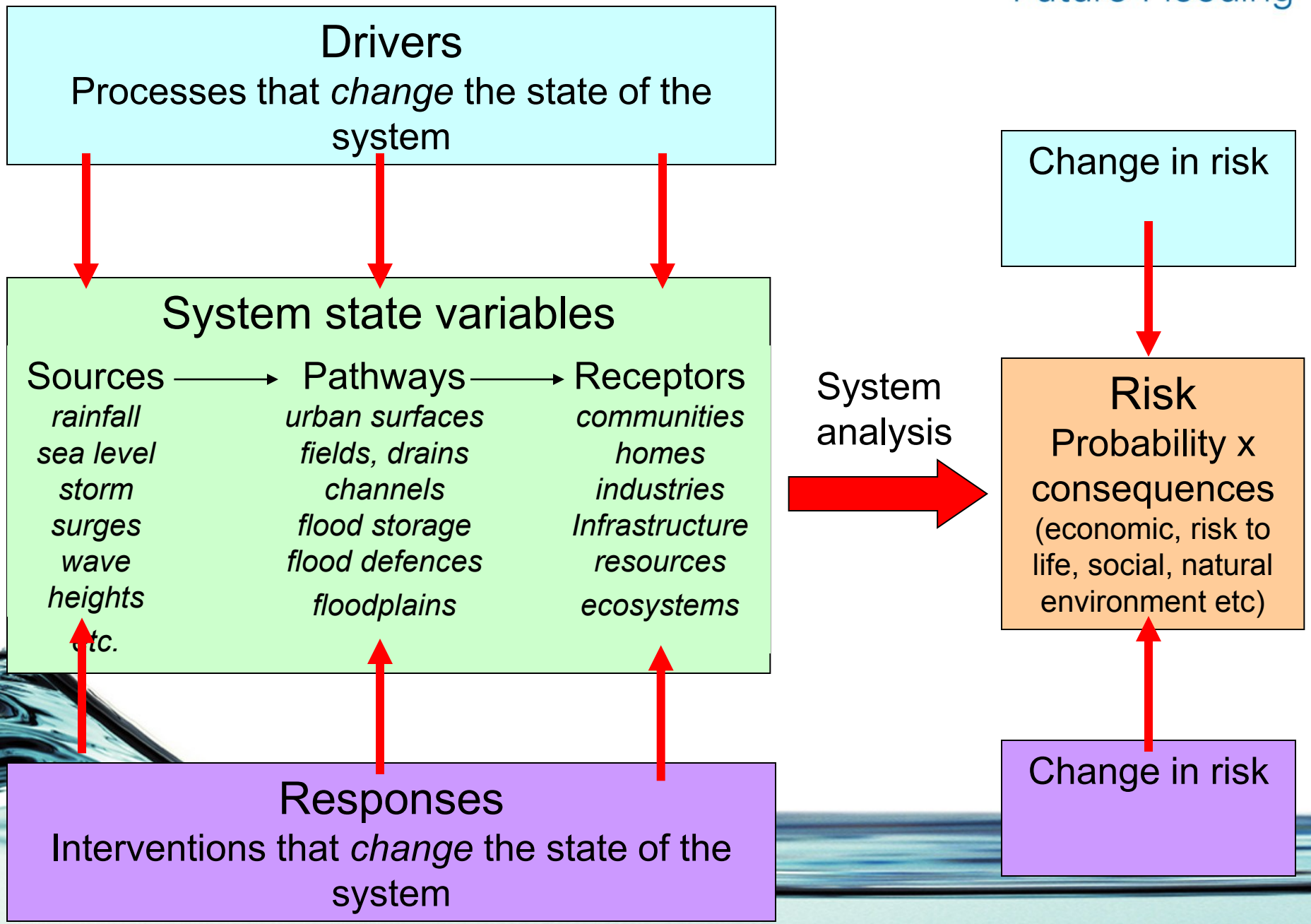


The urban flooding system



Foresight Futures 2020 + UKCIP2002 climate change scenarios




Drivers
Processes that *change* the state of the system
System state variables
Sources
rainfall
sea level
storm surges
wave heights
etc.
Pathways
urban surfaces
fields, drains
channels
flood storage
flood defences
floodplains
Receptors
communities
homes
industries
Infrastructure
resources
ecosystems
Responses
Interventions that *change* the state of the system
System analysis
Risk
Probability x consequences
(economic, risk to life, social, natural environment etc)
Change in risk
Change in risk

Future Flood Risks:
Drivers of River and Coastal Flooding

Drivers of fluvial and coastal flooding		
Driver group	Driver	SPR classification
Climate change	Precipitation	Source
	Temperature	Source
Catchment runoff	Urbanisation	Pathway
	Rural land management	Pathway
	Agricultural impacts	Receptor
Fluvial Systems and Processes	Environmental regulation	Pathway
	River morphology and sediment supply	Pathway
	River vegetation and conveyance	Pathway
Coastal processes	Waves	Source
	Surges	Source
	Relative sea level rise	Source
	Coastal morphology and sediment supply	Pathway
Human behaviour	Stakeholder behaviour	Pathway
	Public attitudes and expectations	Receptor
Socio-economics	Buildings and contents	Receptor
	Urban impacts	Receptor
	Infrastructure impacts	Receptor
	Social impacts	Receptor
	Science, engineering and technology	Receptor

Future Flooding

Drivers of Flood and Coastal Erosion Risk

"… any phenomenon that changes the state of the flooding system…"

Table 2.4b **National ranking of catchment-scale drivers – 2080s**

	World Markets	National Enterprise	Local Stewardship	Global Sustainability
	2080s	2080s	2080s	2080s
1	Social Impacts	Relative Sea Level Rise	Social Impacts	Environmental Regulation
2	Relative Sea Level Rise	Infrastructure Impacts	Relative Sea Level Rise	Relative Sea Level Rise
3	Surges	Surges	Environmental Regulation	Vegetation and Conveyance
4	Infrastructure Impacts	Buildings and Contents	Surges	Social Impacts
5	Buildings and Contents	Coastal Morphology and Sediment Supply	Precipitation	Precipitation
6	Coastal Morphology and Sediment Supply	Social Impacts	River Morphology and Sediment Supply	River Morphology and Sediment Supply
7	Waves	Precipitation	Coastal Morphology and Sediment Supply	Buildings and Contents
8	Precipitation	Urbanisation	Waves	Infrastructure Impacts
9	Stakeholder Behaviour	Waves	Vegetation and Conveyance	Coastal Morphology and Sediment Supply
10	Urbanisation	Urban Impacts	Urban Impacts	Surges
11	Urban Impacts	Rural land Management	Temperature	Urban Impacts
12	Rural land Management	Vegetation and Conveyance	Agriculture Impacts	Waves
13	River Morphology and Sediment Supply	Environmental regulation	Infrastructure Impacts	Temperature
14	Vegetation and Conveyance	River Morphology and Sediment Supply	Buildings and Contents	Agricultural Impacts
15	Temperature	Temperature	Urbanisation	Rural land Management
16	Agriculture Impacts	Agriculture Impacts	Rural land Management	Urbanisation
17	Environmental Regulation	Stakeholder Behaviour	Stakeholder Behaviour	Stakeholder Behaviour

Baseline ranking of river and coastal flood risk drivers

- Socio-economic development
- Climate change
- Infrastructure
- River and Coastal Drivers
- Stakeholder Behaviour
- Environmental Regulation

Legend	Driver Impact Category	Risk Multiplier (M) Range	Colour Code
	High increase	$M \geq 2$	
	Medium increase	$2 > M \geq 1.2$	
	Low impact	$1.2 > M \leq 0.83$	
	Medium decrease	$0.83 \geq M \geq 0.5$	
	High decrease	$M < 0.5$	

Table 2.6b **Uncertainty in catchment-scale drivers ranked by national flood risk – 2080s**

	World Markets	National Enterprise	Local Stewardship	Global Sustainability
	2080s	2080s	2080s	2080s
1	Social Impacts	Relative Sea Level Rise	Social Impacts	Environmental Regulation
2	Relative Sea Level Rise	Infrastructure Impacts	Relative Sea Level Rise	Relative Sea Level Rise
3	Surges	Surges	Environmental Regulation	Vegetation and Conveyance
4	Infrastructure Impacts	Buildings and Contents	Surges	Social Impacts
5	Buildings and Contents	Coastal Morphology and Sediment Supply	Precipitation	Precipitation
6	Coastal Morphology and Sediment Supply	Social Impacts	River Morphology and Sediment Supply	River Morphology and Sediment Supply
7	Waves	Precipitation	Coastal Morphology and Sediment Supply	Buildings and Contents
8	Precipitation	Urbanisation	Waves	Infrastructure Impacts
9	Stakeholder Behaviour	Waves	Vegetation and Conveyance	Coastal Morphology and Sediment Supply
10	Urbanisation	Urban Impacts	Urban Impacts	Surges
11	Urban Impacts	Rural Land Management	Temperature	Urban Impacts
12	Rural Land Management	Vegetation and Conveyance	Agriculture Impacts	Waves
13	River Morphology and Sediment Supply	Environmental Regulation	Infrastructure Impacts	Temperature
14	Vegetation and Conveyance	River Morphology and Sediment Supply	Buildings and Contents	Agriculture Impacts
15	Temperature	Temperature	Urbanisation	Rural Land Management
16	Agriculture Impacts	Agriculture Impacts	Rural Land Management	Urbanisation
17	Environmental Regulation	Stakeholder Behaviour	Stakeholder Behaviour	Stakeholder Behaviour

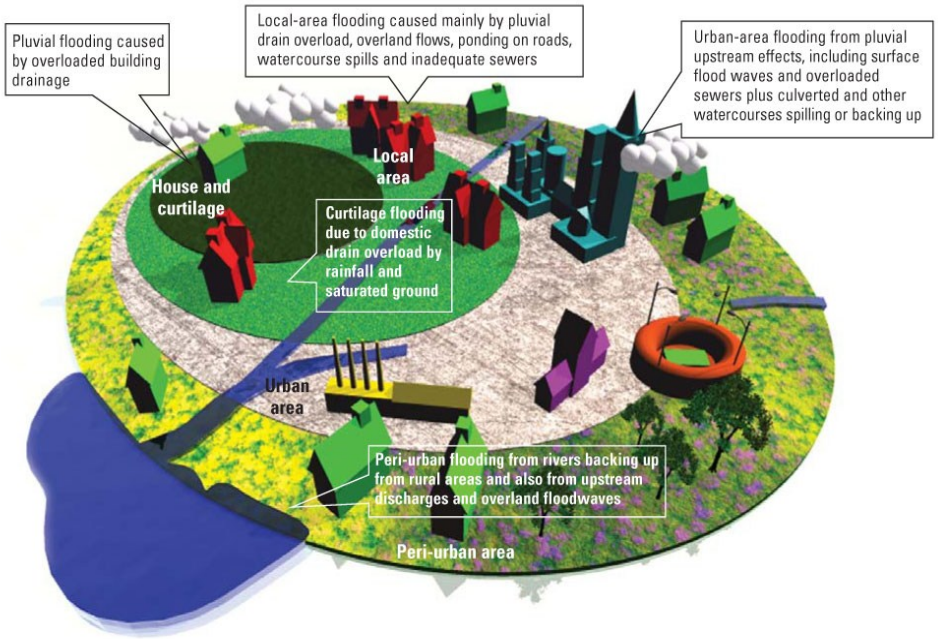
Major uncertainties:

- Relative Sea level rise
- Coastal morphology
- Storm Surges
- Precipitation
- Stakeholder behaviour
- Buildings and contents
- Urbanisation
- Rural land management

Legend	Uncertainty band category	Uncertainty band width (B) (B = ratio of upper to lower bound estimates of flood-risk impact multiplier)	Colour code
	High	B ≥ 3	
	Medium	3 > B ≥ 1.5	
	Low	1.5 > B	

Drivers of urban flood risk

Driver group	Driver	SPR classification
Climate change	Precipitation	Source
Runoff	Urbanisation	Pathway
	Management of Peri-Urban Rural Land	Pathway
Urban conveyance systems and processes	Environmental Management and Regulation	Pathway
	Urban Watercourse Conveyance, Blockage and Sedimentation	Pathway
	Sewer Conveyance, Blockage and Sedimentation	Pathway
	Impact of External Flooding on Intra-urban Drainage Systems	Pathway
	Intra-urban Asset Deterioration	Pathway



Plus:

- Human behaviour
- Urban planning policy

Tables 3.3b **Driver ranking for the 2080s – urban**

	World Markets	National Enterprise	Local Stewardship	Global Sustainability
	2080s	2080s	2080s	2080s
1	Social Impacts	Infrastructure Impacts	Social Impacts	Environmental Management and Regulation
2	Infrastructure Impacts	Stakeholder Behaviour	Environmental Management and Regulation	Social Impacts
3	Buildings and Contents	Buildings and Contents	Stakeholder Behaviour	Precipitation
4	Intra-Urban Asset Deterioration	Social Impacts	Precipitation	Stakeholder Behaviour
5	Sewer Conveyance, Blockage and Sedimentation	Intra-Urban Asset Deterioration	Impact of External Flooding on Intra-Urban Drainage Systems	Buildings and Contents
6	Stakeholder Behaviour	Precipitation	Urbanisation	Infrastructure Impacts
7	Precipitation	Sewer Conveyance, Blockage and Sedimentation	Intra-Urban Asset Deterioration	Urbanisation
8	Urbanisation	Urbanisation	Urban impacts	Intra-Urban Asset Deterioration
9	Urban Watercourse, Conveyance, Blockage and Sedimentation	Urban Impacts	Urban Watercourse Conveyance, Blockage and Sedimentation	Urban Watercourse Conveyance, Blockage and Sedimentation
10	Urban Impacts	Impact of External Flooding on Intra-Urban Drainage Systems	Sewer Conveyance, Blockage and Sedimentation	Sewer Conveyance, Blockage and Sedimentation
11	Impact of External Flooding on Intra-Urban Drainage Systems	Urban Watercourse Conveyance, Blockage and Sedimentation	Management of Peri-Urban Rural Land	Urban Impacts
12	Management of Peri-Urban Rural Land	Management of Peri-Urban Rural Land	Buildings and Contents	Impact of external Flooding on Intra-Urban Drainage Systems
13	Environmental Management and Regulation	Environmental Management and Regulation	Infrastructure Impacts	Management of Peri-Urban Rural Land

Ranking of urban flood risk drivers

- Social Impacts
- Stakeholder Behaviour
- Infrastructure Impacts
- Precipitation
- Asset Deterioration
- Environmental management and regulation

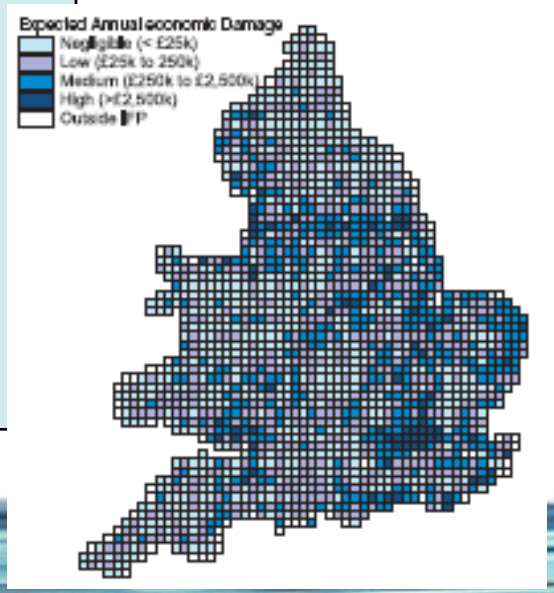
Legend	Driver Impact Category	Risk Multiplier (M) Range	Colour Code
	High Increase	M > 2	
	Medium Increase	2 > M > 1.2	
	Low Impact	1.2 > M < 0.83	
	Medium decrease	0.83 > M > 0.5	
	High decrease	M < 0.5	

Quantitative risk analysis – based on existing data

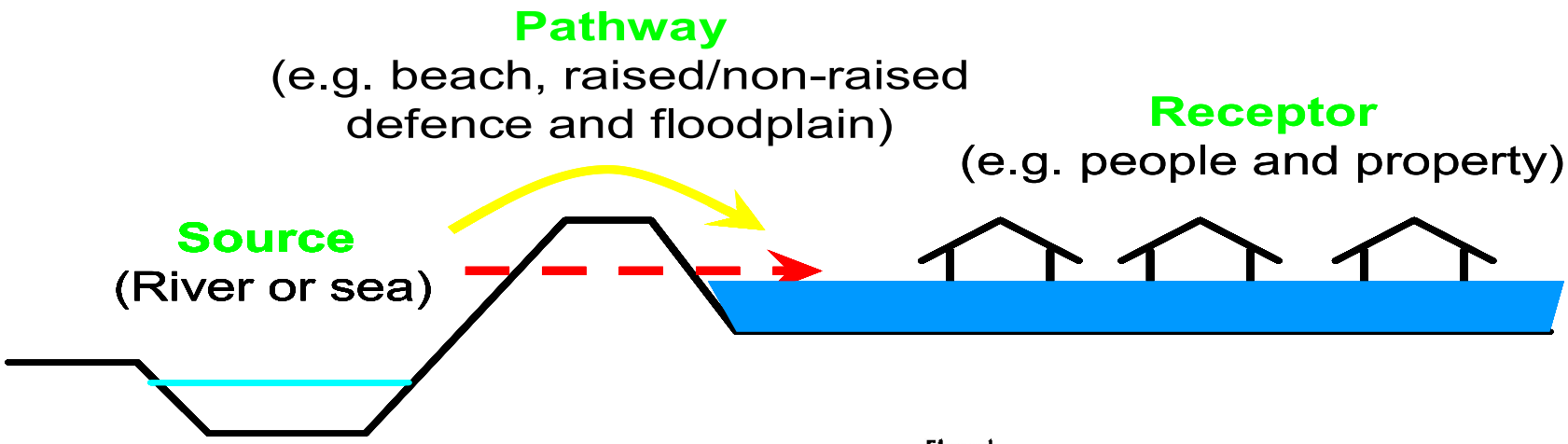
Risk
Assessment
for
Strategic
Planning

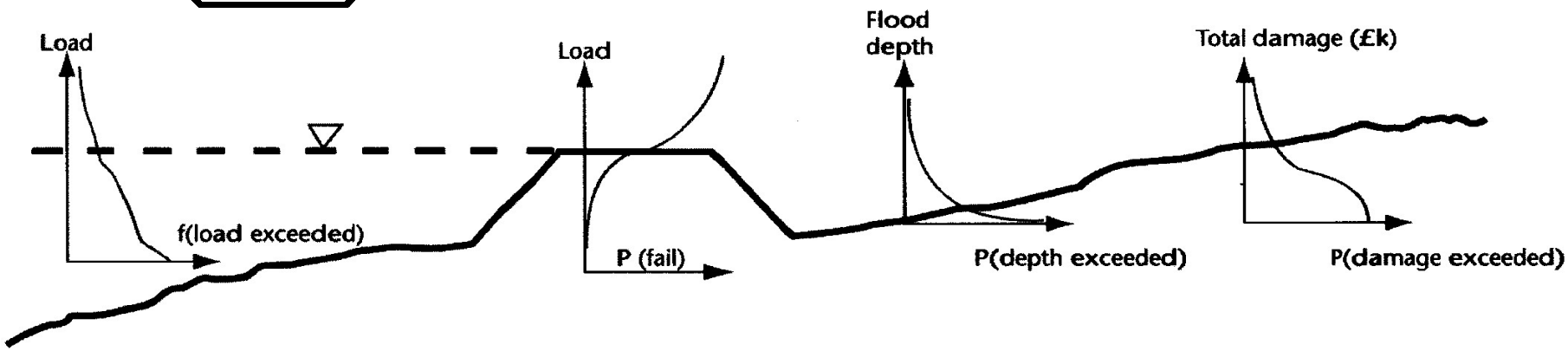
Databases used:

Rivers and coastlines
Floodplain maps
Standard of protection
Condition of defences
Addresses of all properties/people at risk
Depth-damage curves
Social vulnerability
Agricultural land grade



Calculating risk





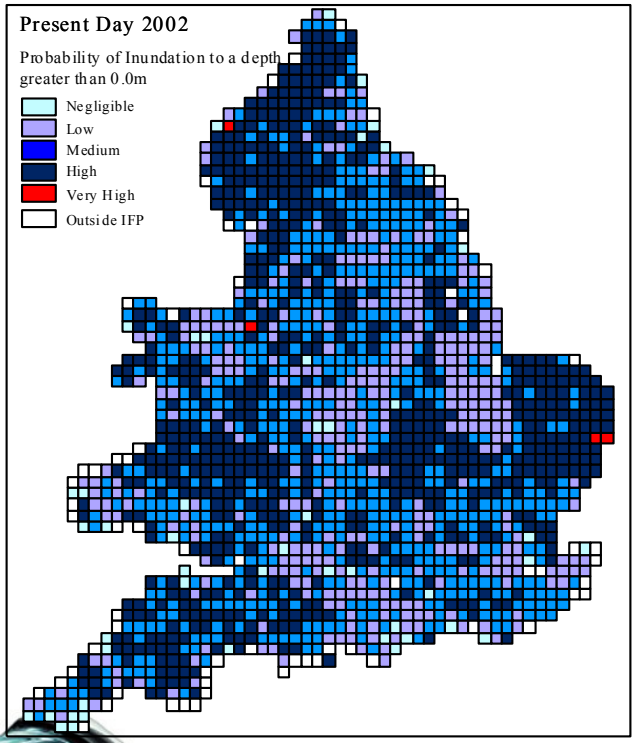
Extreme loads Sources of flooding risk quantified by 'return period', indicating how frequently a particluar load will be exceeded.

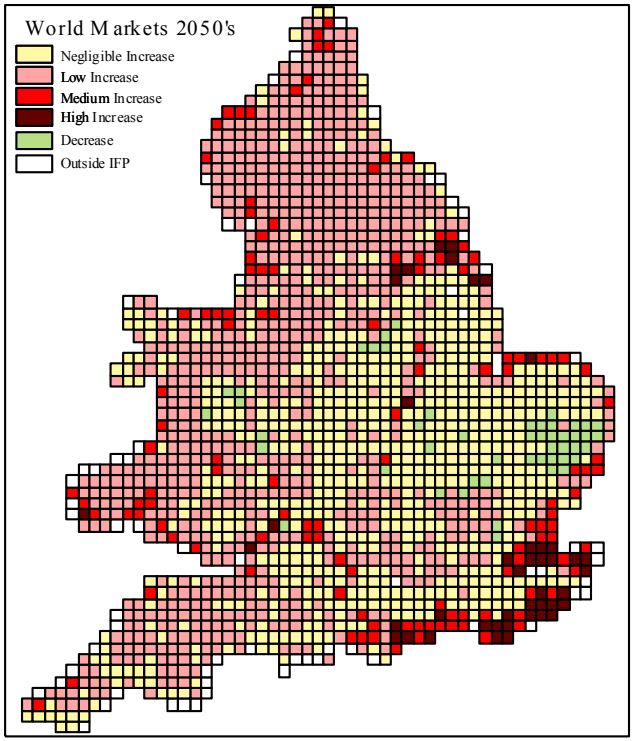
Reliability analysis The performance of flood defence structures and systems shown by a 'fragility curve' - the probability failure with load. These depend on the structure, materials, failure mechanisms and condition.

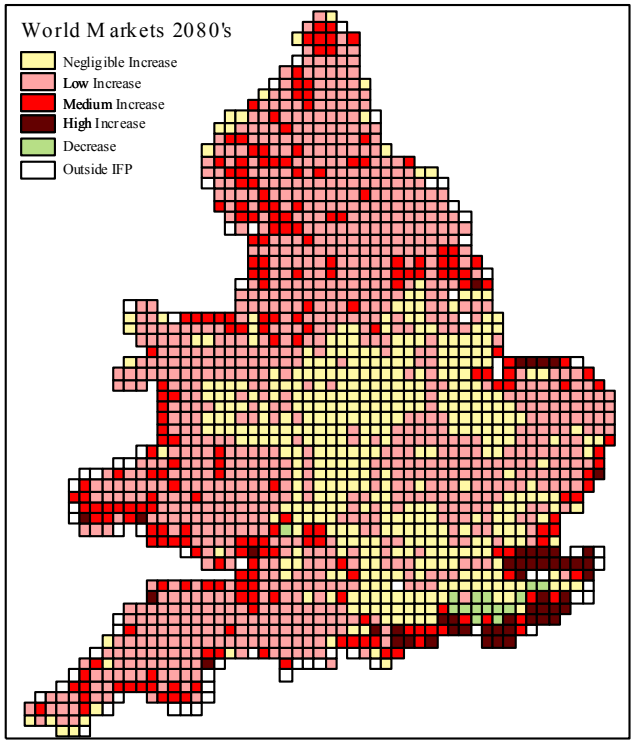
Flood probability The flood extent and depth depend on breach size, overtopping and topography. Flood spreading models are combined with reliability anaylsis to assess depth / probability relationships.

Consequences and risk Flood damage or harm are related to depth. Risk is assessed by the probability that particular damage values are exceeded.

Flood Risk Prediction Maps for 2050s and 2080s

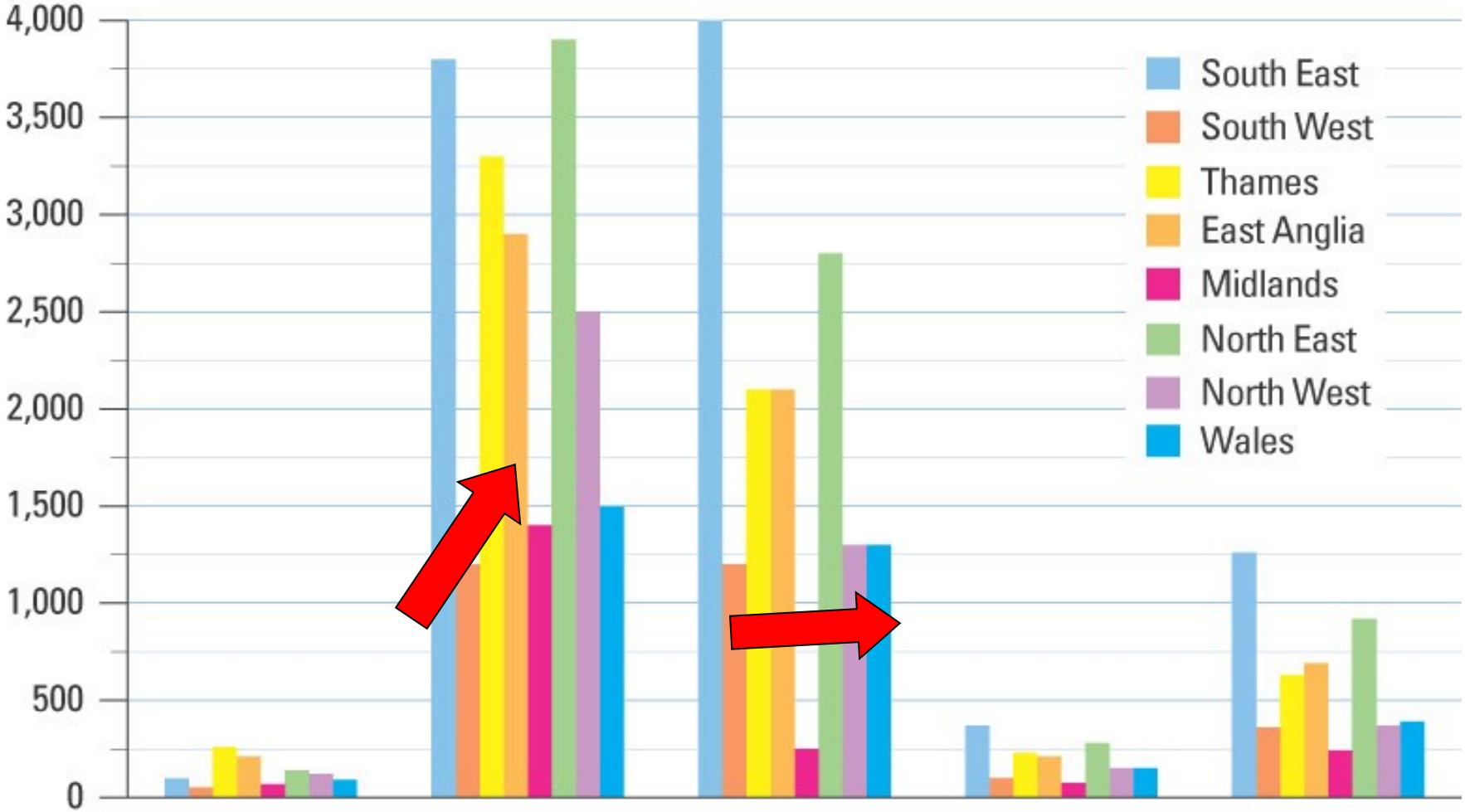




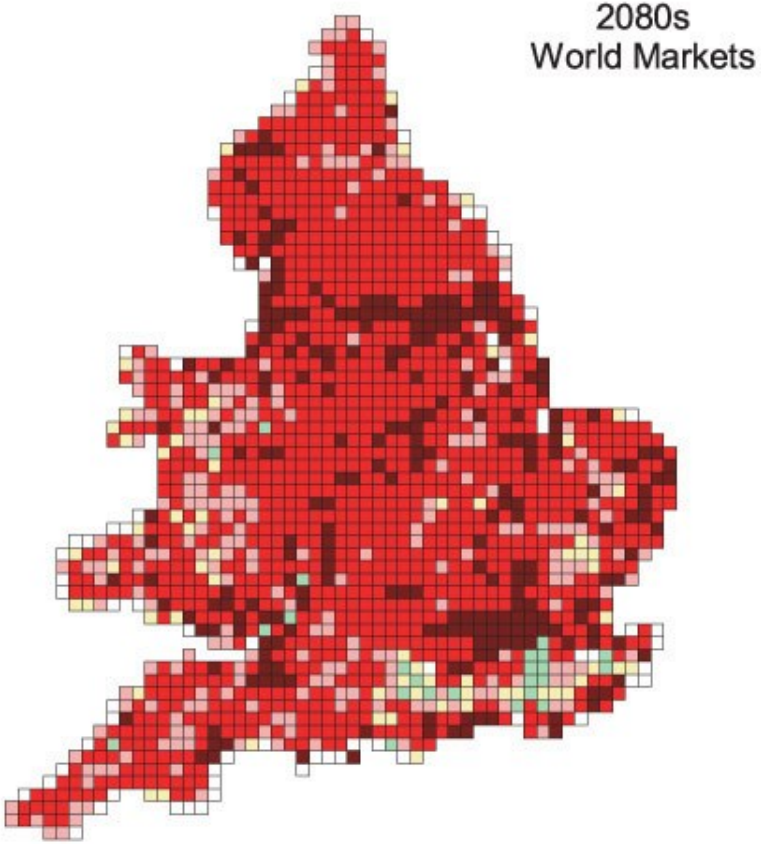


Annual Expected Damages: £ millions (currently ~ £1billion)

Future Flooding



	2000	WM 2080s	NE 2080s	LS 2080s	GS 2080s
Total (£ million)	1,040	20,500	15,050	1,500	4,860



Baseline Conclusions: unless we act:-

- Future flooding will be a very serious threat to the UK.
- It represents a major challenge to government and society.
- Combining the World Markets and Low emissions scenarios reduces future expected annual economic damages by only ~25%.

Responses

Options for managing future flood and coastal erosion risks sustainably

Potential Responses

80 individual responses

Organised into **25** response groups

And **5** response themes

- Reducing urban runoff
- Reducing rural runoff
- Managing flood events
- Managing flood losses
- Engineering and large scale re-alignment or abandonment

Ranking Responses

- River and Coastal Defences
- Land use Planning and Management
- Catchment-wide storage
- Engineered Storage
- River conveyance
- Flood Proofing Buildings
- Pre-flood event measures
- Flood event management

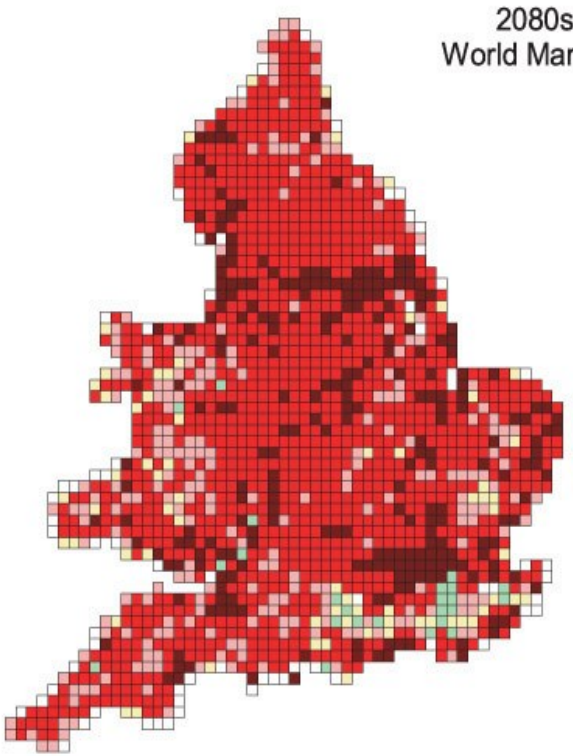
Legend

Colour code	Interpretation
	Major reduction in flood risk (S < 0.7)
	Marked reduction in flood risk (0.7 < S < 0.9)
	Minor reduction in flood risk (0.9 < S < 1.0)
	Ineffective (S = 1)
	Likely to Increase flood risk (S > 1.0)

Responses Groups ranked by potential risk reduction in the 2080s

Rank	World Markets	National Enterprise	Local Stewardship	Global Sustainability
1	River Defences	River Defences	Land Use Planning and Management	Land Use Planning and Management
2	Coastal Defences	Coastal Defences	Flood Proofing Buildings	Catchment-Wide Storage
3	Flood Proofing Buildings	Reduce Coastal Energy	Individual Damage Avoidance	River Defences
4	Reduce Coastal Energy	Realign Coastal Defences	River Defences	Coastal Defences
5	Morphological Coastal Protection	Morphological Coastal Protection	Catchment-Wide Storage	Flood Proofing Buildings
6	Realign Coastal Defences	Coastal Defence Abandonment	Pre-event Measures	Rural Conveyance
7	Real-time Event Management	Flood Proofing Buildings	Real-time Event Management	Realign Coastal Defences
8	River Conveyance	River Conveyance	Engineered Flood Storage	Reduce Coastal Energy
9	Individual Damage Avoidance	Catchment-Wide Storage	Rural Conveyance	Morphological Coastal Protection
10	Pre-event Measures	Land Use Planning and Management	River Conveyance	Engineered Flood Storage
11	Engineered Flood Storage	Engineered Flood Storage	Rural Infiltration	Real-time Event Management
12	Land Use Planning and Management	Real-time Event Management	Manage Urban Runoff	Pre-event Measures
13	Manage Urban Runoff	Pre-event Measures	Flood Water Transfer	Individual Damage Avoidance
14	Flood Water Transfer	Rural Conveyance	Coastal Defences	River Conveyance
15	Catchment-Wide Storage	Rural Infiltration	Realign Coastal Defences	Rural Infiltration
16	Rural Conveyance	Individual Damage Avoidance	Morphological Coastal Protection	Manage Urban Runoff
17	Rural Infiltration	Manage Urban Runoff	Reduce Coastal Energy	Flood Water Transfer
18		Flood Water Transfer	Coastal Defence Abandonment	

Take home messages:



- No single response can manage down future flood risks alone
- Over reliance on structural defences doubles the cost of keeping risk are current levels
- There are feasible and sustainable responses that are affordable - if implemented through Integrated Flood Risk Management.
- But we must act *now* in developing new policies to allow non-structural measures to be effective in time.

and then came summer 2007……..

Floods force thousands from homes

Thousands of people have been forced to leave their homes amid severe flooding across England and Wales that is now believed to have claimed four lives.

Hundreds of families in Lincolnshire, South Yorkshire, Nottinghamshire and Shropshire have been moved to safety.

In Worcestershire police searching for a missing motorist ha

June and July 2007

Flood crisis grows as rivers rise

The flooding crisis in central and western England continues with thousands of homes losing water and electricity supplies.

Flood water threatens the town of Upton-upon-Severn

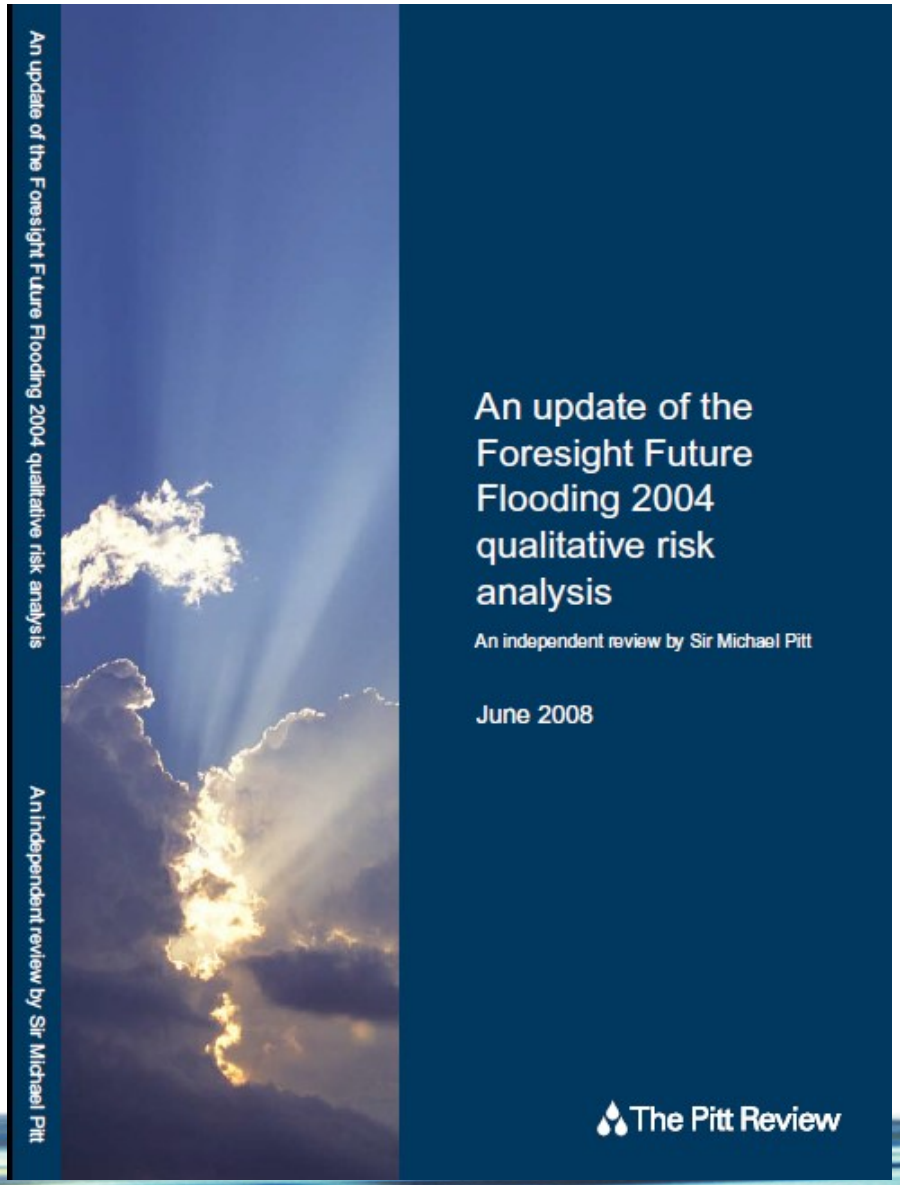
OPEN Enlarge Image

Up to 350,000 people in Gloucestershire will be left without running water by Monday evening, as the Severn and Thames rivers threaten to overflow.

The Environment Agency said water levels on both rivers had exceeded those of devastating floods in 1947.

2008 - Government request Flood Foresight Update

1. Revisit Climate Change and Socio-economic Scenarios.
2. Reassess Drivers and Responses.
3. Repeat high-level, evidence-based, qualitative analysis.
4. Take up new data and insights including Pitt Review.
5. Consider the economic, social and environmental risks associated with coincident flooding.



Has it worked?

Yes - Uptake of Flood Foresight led to a paradigm shift in UK FRM Policy and Practice:

Politicians, Planners and Decision Makers ***listen*** and ***act*** when messages are clear and are supported by the best science and engineering analyses available.

Evidence?