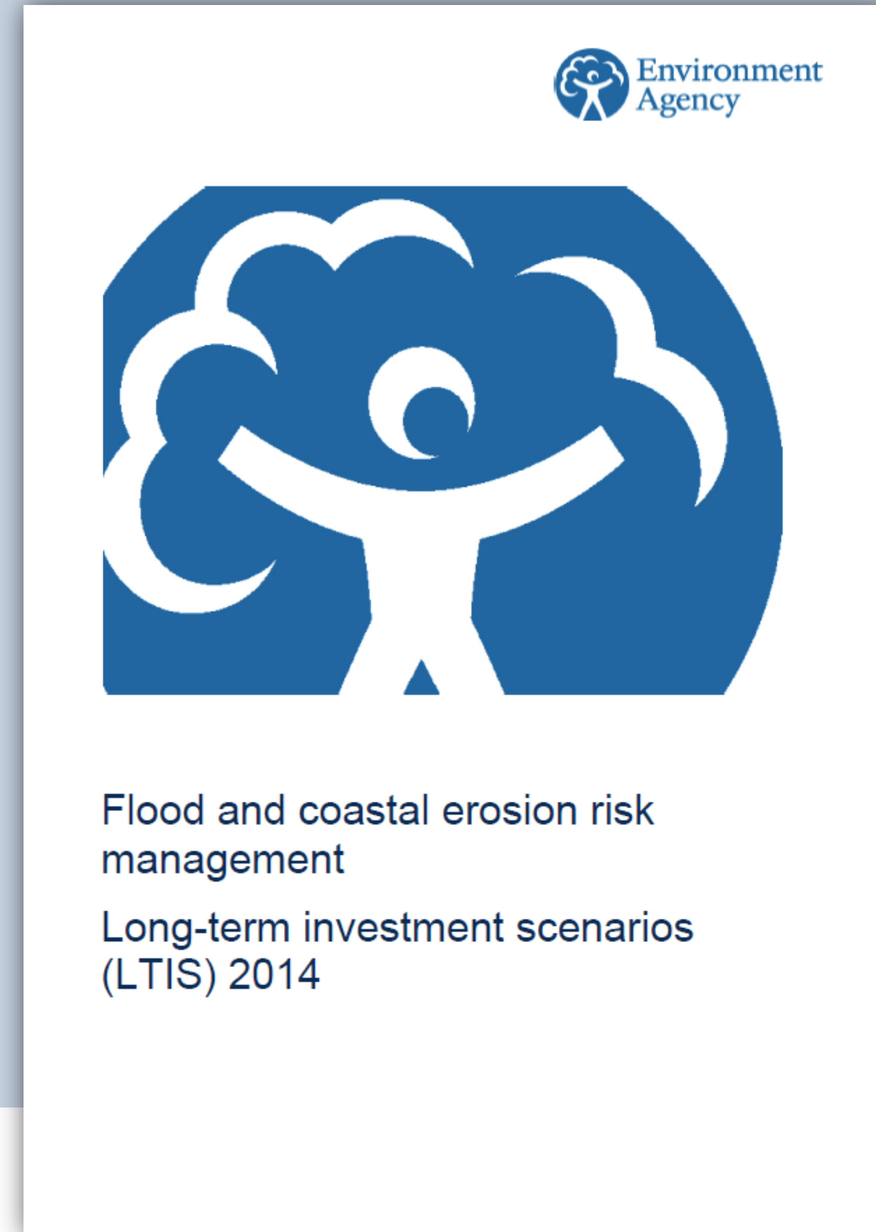
Environmental *Change* Institute

Long term investment strategy – An independent review of the 2014 assessment

Jim Hall

Environment Agency Long Term Investment Scenarios



Environment Agency

Flood and coastal erosion risk management

Long-term investment scenarios (LTIS) 2014

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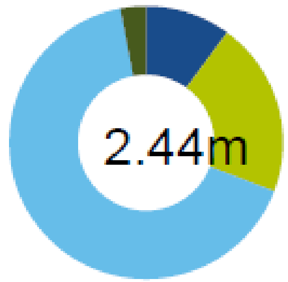
What LTIS has achieved

- A scientific and economic basis for resource allocation
- More complex than any equivalent assessment worldwide
- Based on a legacy of flood risk assessment research, dating back at least to 2002

Noteworthy achievements

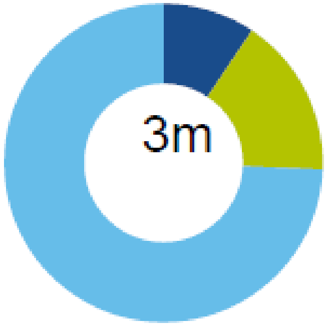
- A national flood risk assessment model has been combined with a deterioration model, scenario assumptions and economic appraisal in 3000 flood systems.
- This has been integrated in to a national optimisation of investment, comparing risks and costs.
- The study takes a long term perspective and integrates current investment plans with longer term scenarios
- Surface water flooding has been considered alongside river and coastal flooding.
- The major sensitivities (in the effect of climate change, floodplain development and the underlying risk estimate) have been analysed to explore and demonstrate the robustness of the results to uncertainties and assumptions.

Flooding from rivers and the sea



High Medium Low Very Low

Surface water flooding

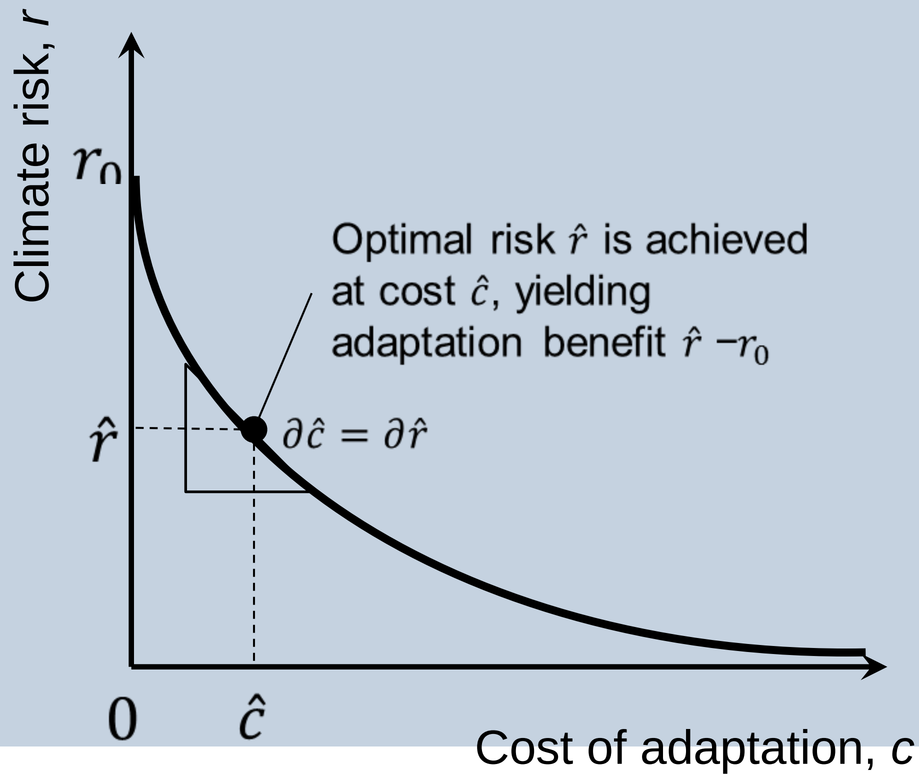


High Medium Low

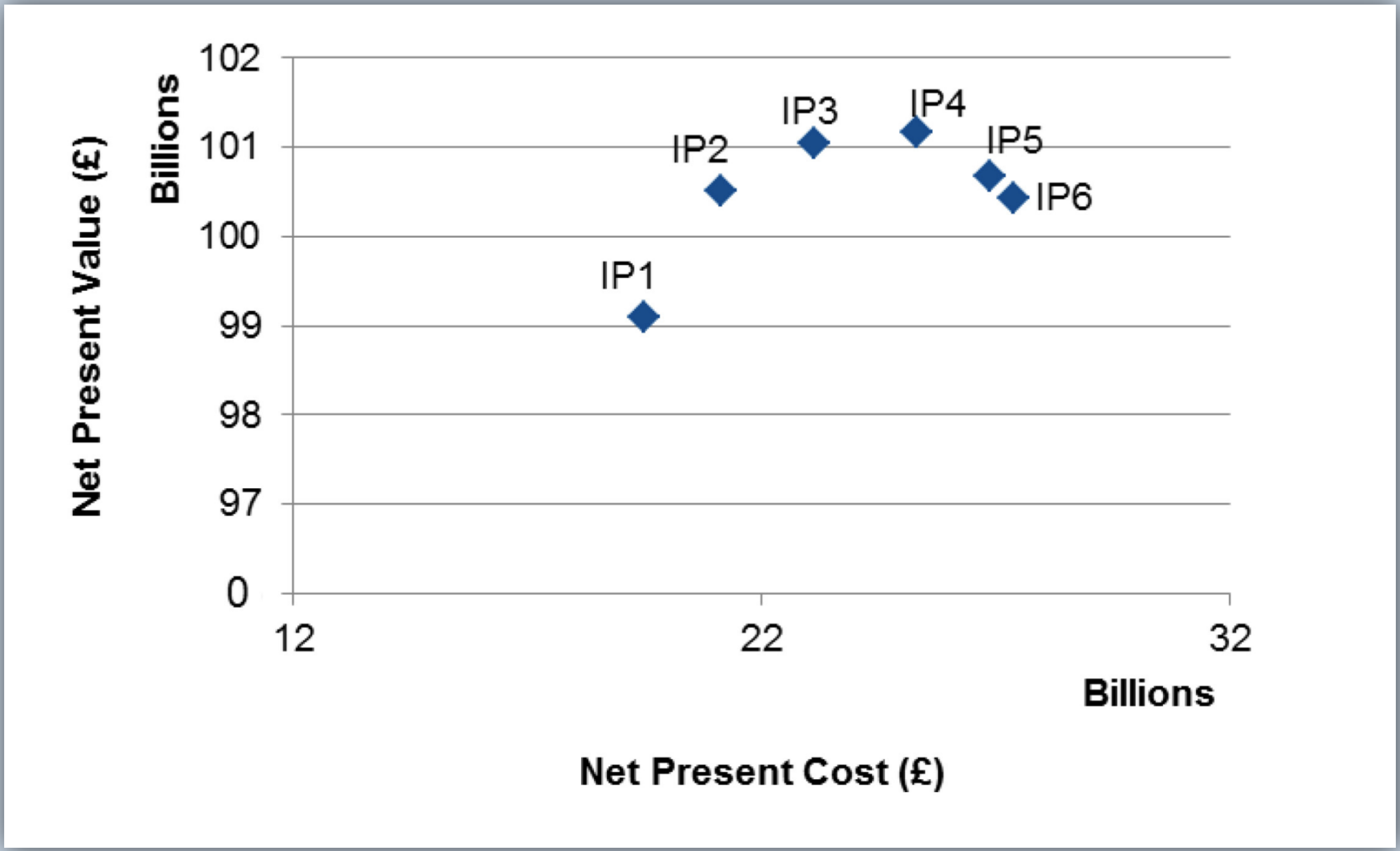
Table 1 Properties at risk from flooding

	Rivers and the sea (thousands) From National Flood Risk Assessment (NaFRA)		Surface water (thousands) From flood map for surface water	
	Residential	Non-residential	Residential	Non-residential
High	153,000	91,000	209,000	73,000
Medium	350,000	153,000	388,000	102,000
Low	1,274,000	329,000	1,809,000	423,000
Very low	72,000	21,000	Not assessed	Not assessed
Total	1,849,000	594,000	2,406,000	598,000

Optimising future expenditure



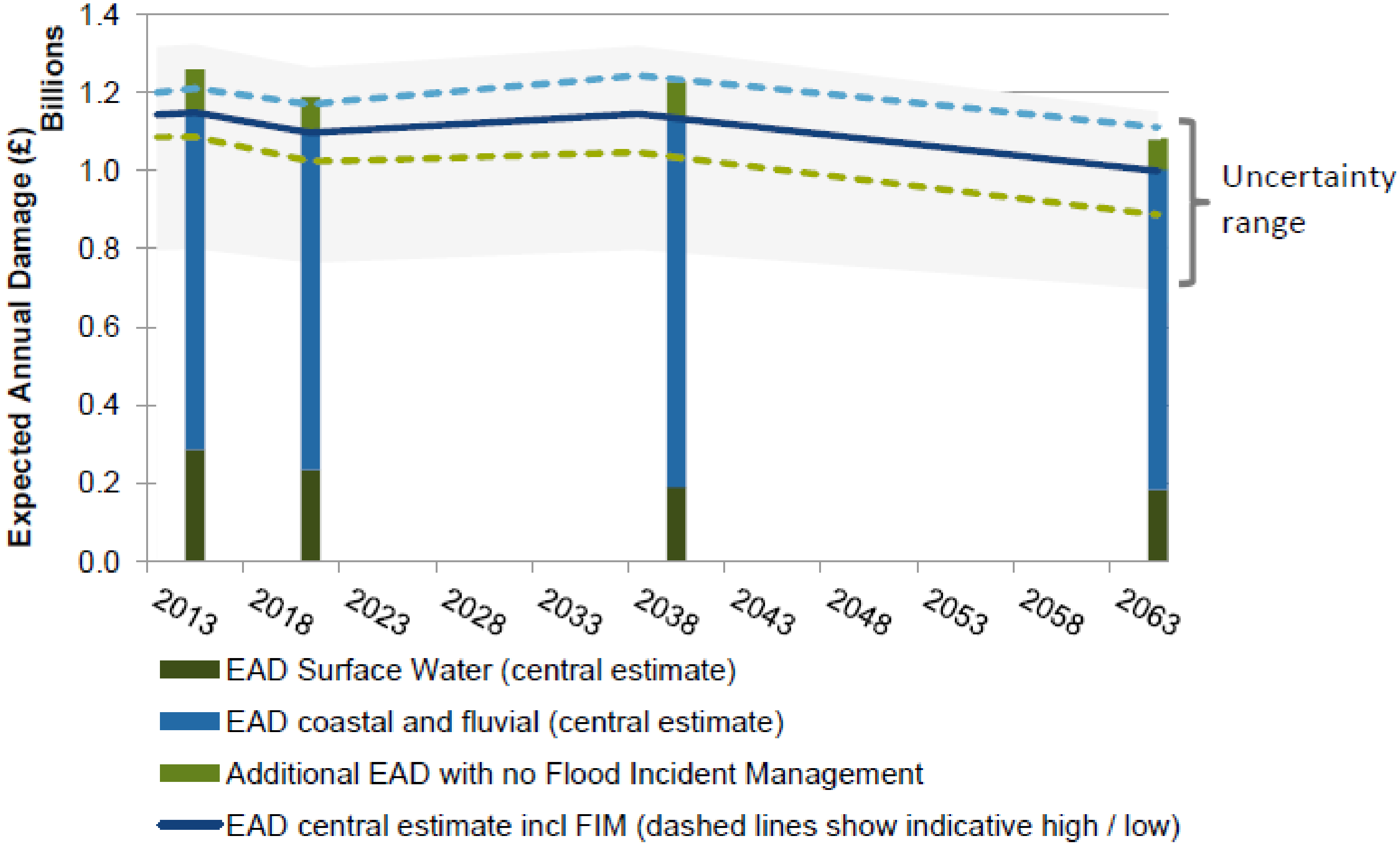
Choosing the future: how much should we invest in flood defence?



Optimal investment level

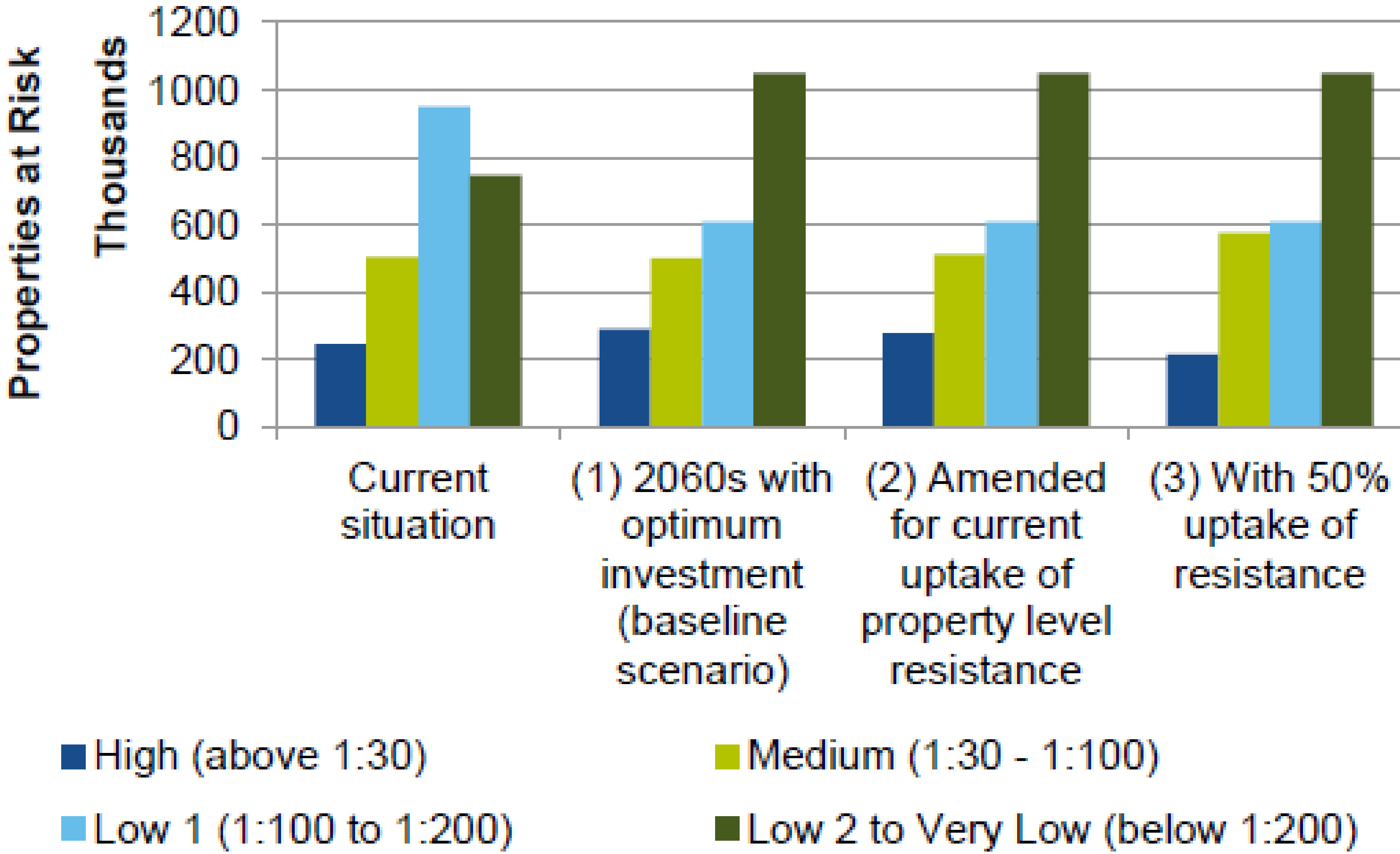
- The optimal 'long-run' investment in FCERM (at around £860 million per year) is 15% more than the current investment level
- This is lower than one might have thought given that schemes funded at the moment typically have a benefit-cost ratio (BCR) of ~8:1
- The objective function near the optimum is quite flat, so not too much should be read into the second significant figure
- Marginal investments near the optimum (i.e. with a BCR just greater than 1.0) are unlikely to compete with other public infrastructure investments
- Given the uncertainties in costs and benefits, in order to avoid the possibility of uneconomic investments it would be wise to focus upon investments with BCR robustly greater than 1.0
- As long as investment is cost-beneficial it does not detract from the optimum

Flood risk need not increase significantly in future, even in a changing climate



The flood defence system can be adapted to changing future conditions

Changing risk profiles



Optimal investment will lead to a profound shift in the risk profile

In future there will be:

- Relatively frequent flood damage to 0.3million high risk properties where community protection is not affordable or justifiable in economic terms.

- Occasional catastrophic flood damage and disruption to urban areas and infrastructure networks when flood defence levels are exceeded.

Property level protection is an important strategic instrument for dealing with residual risk.

Critical assumptions

- Baseline risk estimate
- Timing of investment
- Exclusion of major disruption
- Cost reduction (10% efficiency saving 2015-2021)
- Effect of maintenance on deterioration
- Managed retreat

Recommendations for future development

- Reconfiguring NaFRA so that it can simulate the damage associated with specific (spatial) flood events
  - Validation
  - Construction of the full damage-probability distribution
  - Evaluate costs and benefits of options for insurance/reinsurance.
- Moving towards a global optimisation that incorporates:
  - Optimal timing of replacement
  - The benefits of maintenance
  - Property-level protection for management of residual risk.
- Periodically review the optimum long-term investment analysis to incorporate the effect of investments that are undertaken to reduce flood risk

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Concluding remarks

- LTIS has helped to convince Treasury that the EA is proceeding in a responsible way in allocating public resources
- The results contain very significant assumptions and sensitivities
  - The baseline risk estimate (direct damage)
  - Wider economic impacts
  - The decision rule
- The analysis has provided some important insights:
  - It is feasible to adapt to increasing flood risk
  - It is not feasible to reduce flood risk much
  - Residual risk will continue to need to be managed
  - Cost savings are very important for the business case
- Next steps
  - Addressing assumptions and improving sensitivity analysis
  - Opening up to scrutiny and innovation

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Real options analysis: examples from flood risk management

Jim Hall

Real Options Analysis

- Provides a framework to incorporate uncertainty and the value of flexibility into decision making
- A “Real Option” is an alternative or choice that becomes available through an investment opportunity or action.
- e.g. designing an activity with the flexibility to upgrade in the future provides an option to deal with more (or less) severe climate change.

Options we might wish to consider

- Option to expand
- Option to contract
- Option to switch resources
- Option for phased stage-gate and sequential investments
- Option to delay
- Option to abandon

Real “in” and Real “on”

Wang and De Neufville (2005)

- Real options “on” systems:
  - Focus on the external factors of a system and management of an investment portfolio
- Real options “in” systems incorporate flexibility into the structural design of the system
  - Incorporates flexibility into the structural design of the system

Stochastic versus probabilistic

- Stochastic formulation
  - closed form (e.g. Black-Scholes) or discrete (e.g. binomial lattice) models

- Probabilistic formulation
  - Decision trees, subject to scenarios of exogenous uncertainty
  - Several studies of engineering adaptation decisions:
    - Flood defences (Linquiti and Vonortas, 2012; Woodward et al. 2013, Hino and Hall in prep)
    - Water supply systems (Zhang and Babovic, 2011)
    - Marine protection systems (Babovic, 2009)
  - May also embed stochastic processes in a two-layer (aleatory-epistemic) uncertainty characterisation (e.g. Harvey and Hall, 2011)

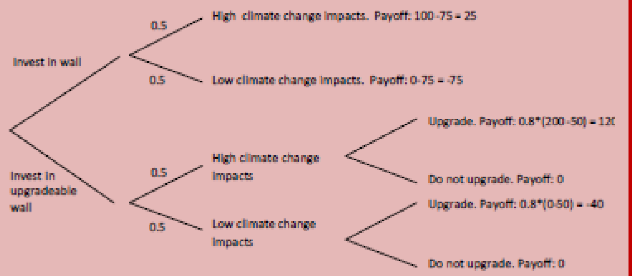
HM Treasury Green Book example: Option to expand

	Probability	Option 1		
		Wall		
		Cost	Benefit	Net benefit
Low climate change	0.5	75	0	-75
High climate change	0.5	75	100	25
Expected benefit				**-25**
		Option 2		
		Upgradeable wall		
		Cost	Benefit	Net benefit
Low climate change	0.5	50	0	-50
High climate change	0.5	90	160	70
Expected benefit				**10**

Box 6: Appraisal using a Real Options approach

Consider a proposal for investing in infrastructure protecting against the impacts of flooding due to climate change. There are two options: invest in a wall, or invest in a wall which has the option to upgrade in the future. There is an equal probability of high or low climate change impacts in the future. The standard wall costs 75, and has benefits of 100 from avoided flooding. The upgradeable wall costs 50, the upgrade costs 50 and would give benefits of 200 from avoided flooding.

The information can be set out in a decision tree:



Simplifying assumptions: residual damages under the "do not invest" strategies have been ignored; the discount factor is 0.8.

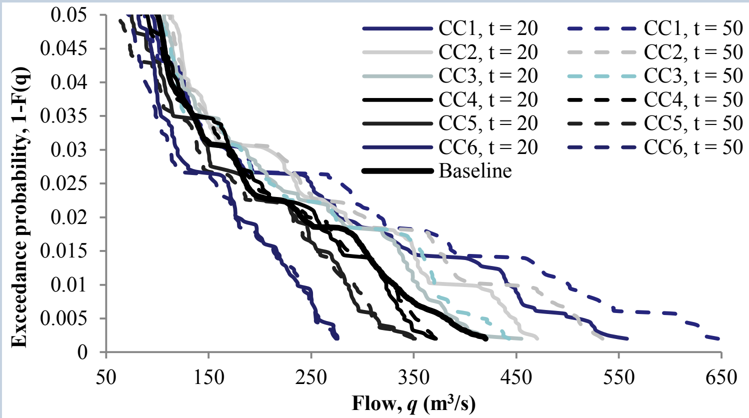
The expected value of investing in the standard wall is a simple NPV calculation, calculating the expected costs and benefits of the investment. The NPV is (0.5*25) + (0.5*-75) = -25. This suggests the investment should not proceed.

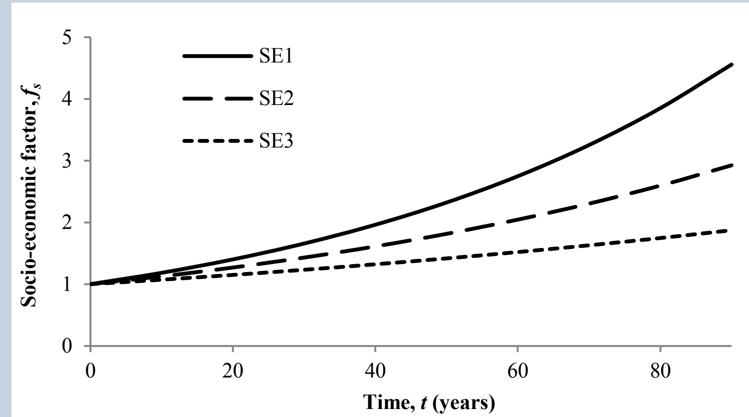
Flexibility over the investment decision allows the possibility to upgrade in the future if the impacts of climate change are high. The expected value of this option can be calculated.

If the impacts of climate change are high enough to warrant upgrading, then the value of the investment is 120. If the impacts are low, then upgrading is not justified since the payoff is negative (-40). Since the investment costs of the upgrade are not realised in practice in the low outcome, they are therefore not incorporated into the NPV. The expected value of investing now with the option to upgrade in the future is (0.5*120) – 50 = +10.

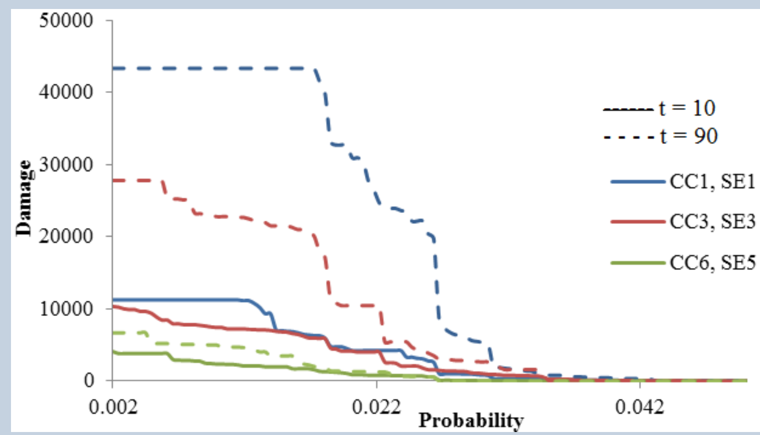
Comparing the two approaches shows an NPV of -25 for the standard approach, and +10 for the Real Options approach. Flexibility to upgrade in the future is reflected in the higher NPV, and switches the investment decision.

Option to expand revisited





- 6 climate change scenarios
- 3 socio-economic scenarios
- Evolving in 20-year time steps



Do-nothing damage-probability function

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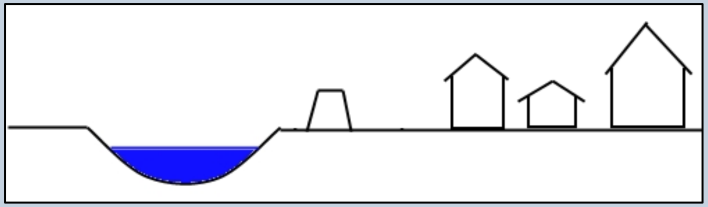
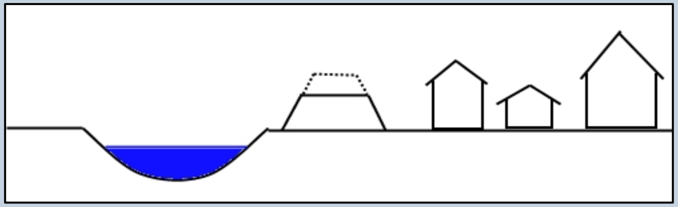
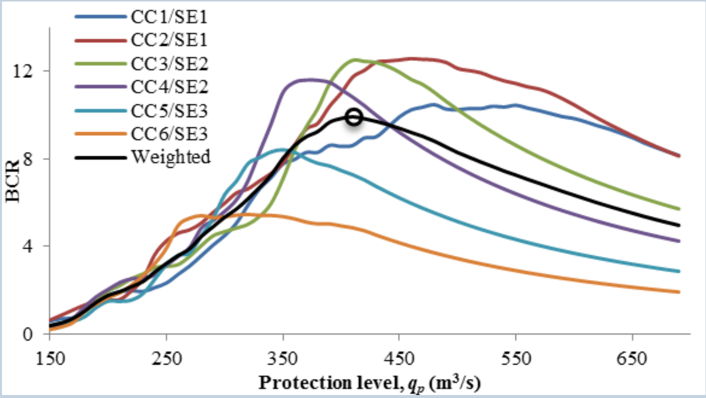
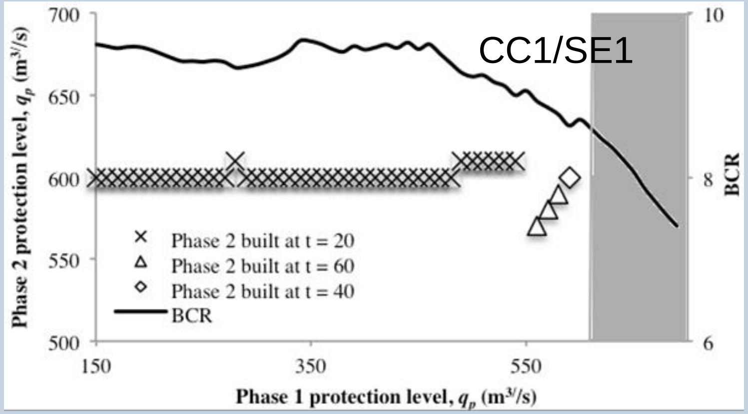
Option to expand revisited

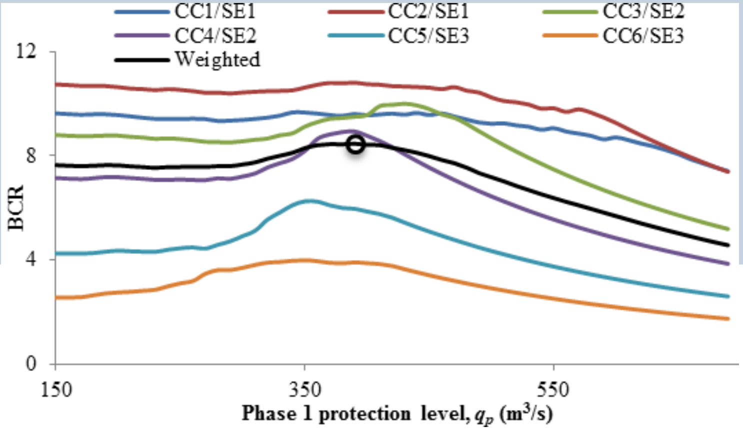




Upgrade triggered at BCR>5







Option to expand revisited

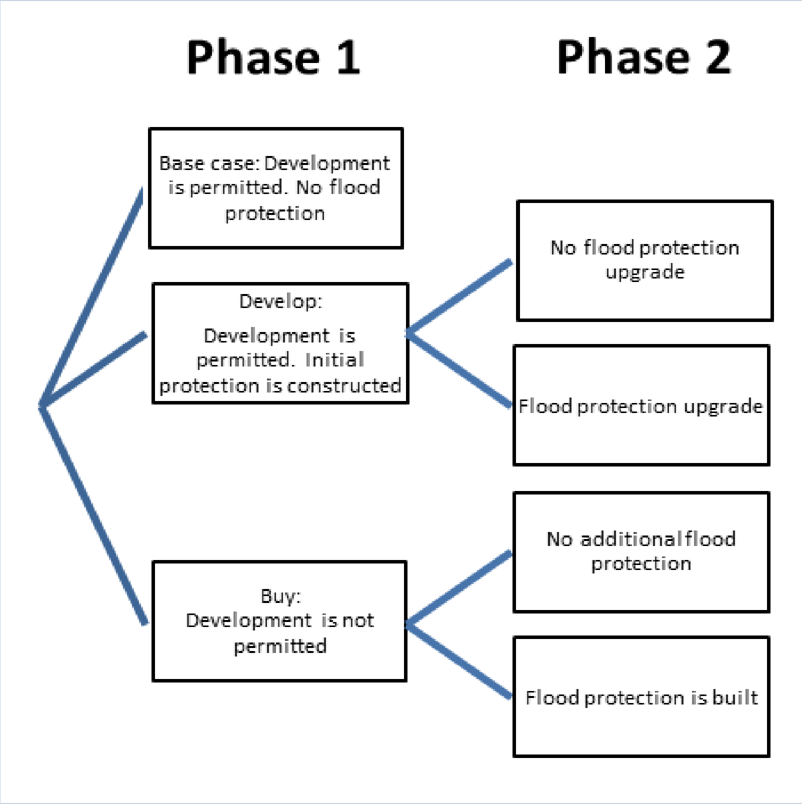
BCR$_A$ - BCR$_F$		Climate change scenario					
		CC1	CC2	CC3	CC4	CC5	CC6
Socio-economic scenario	SE1	1.35	0.54	-0.54	-0.20	-0.16	-0.16
	SE2	0.92	0.29	-0.57	-0.18	-0.16	-0.15
	SE3	0.61	0.11	-0.57	-0.17	-0.16	-0.15

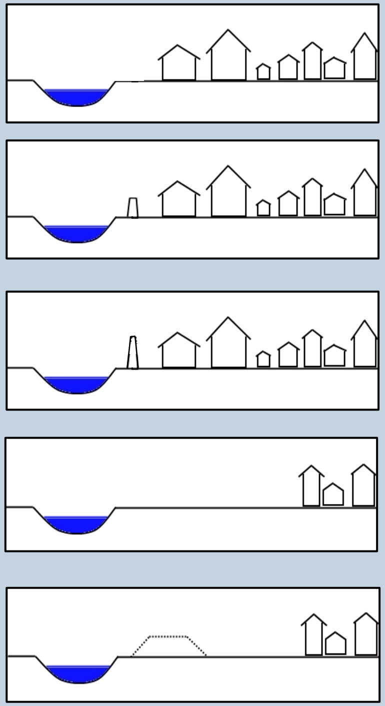
Yellow: Phase 2 is built in the adaptable strategy

Option Value		Climate change scenario					
		CC1	CC2	CC3	CC4	CC5	CC6
Socio-economic scenario	SE1	8462	6469	1369	-395	-321	-321
	SE2	6306	4719	845	-371	-321	-321
	SE3	4903	3636	166	-354	-321	-321

$$Expected\ Option\ Value = \sum_{CC=1}^{6}\sum_{SE=1}^{3} w_{CC,SE}\sum_{t=0}^{T}\frac{1}{(1+s)^t}\left((B_{Adapt}-C_{Adapt})-(B_{Fixed}-C_{Fixed})\right) = £1{,}480k$$

Alternative options to expand: Preventing floodplain development





Lessons learnt

- Real options analysis seems to have become a shorthand for options appraisal under uncertainty with future flexibility
- The instances in which one has to justify expenditure now (i.e. via a positive option value) in order to retain future options are less common
- Calculation of expected option values is “the weakest link”: it often relies on probabilistic information about scenarios which may not be available/justifiable
- Extended sensitivity analysis of decision pathways under a wide range of uncertainties is of value even in the absence of probabilistic information
- Introducing optionality enhances robustness: choices today are less sensitive to future uncertainties