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Llywodraeth Cymru
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Cyfoeth Naturiol Cymru
Natural Resources Wales
Environment Agency

delivering benefits through evidence

Quantifying the benefits of flood risk management actions and advice

Flood incident management and property level responses

Report – SC090039/R Stage 3

Flood and Coastal Erosion Risk Management Research and Development Programme

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- **Delivering information, advice, tools and techniques**, by making appropriate products available.

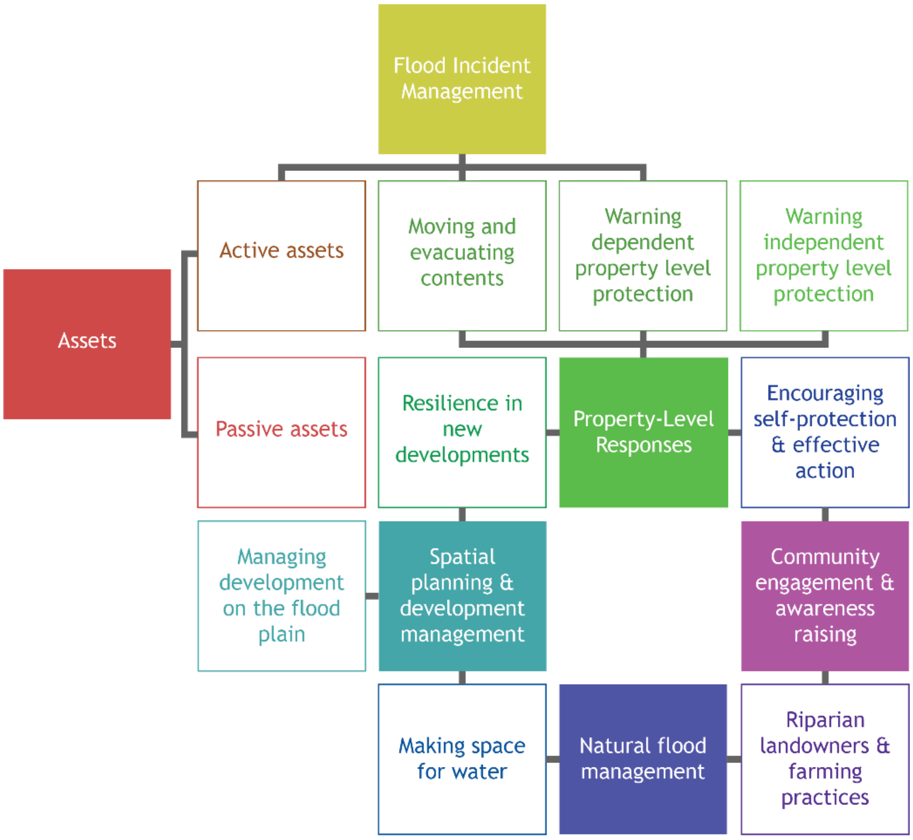
Miranda Kavanagh

Director of Evidence

Executive summary

The Environment Agency aims to deliver Flood and Coastal Risk Management (FCRM) as efficiently as possible. Large capital flood defence schemes are not always financially viable, appropriate or a sustainable solution to manage flood risk in all areas. This project has developed methods to help assess the effectiveness of a wider portfolio of options that can be employed to manage flood risk. It will help achieve risk-based prioritisation of investments across a range of flood risk management options. In particular, the objectives are to enable practitioners to:

- make, justify and communicate flood risk management option selection, supporting investment decisions across a portfolio of flood risk management responses at a range of spatial scales
- identify and strengthen the links and dependencies between the actions and provision of advice by the Environment Agency and the putting in place of responses that reduce flood risk by other authorities, businesses and the public
- ensure that people are protected in the future by considering a broader range of flood risk management options, thus allowing flood risk management practitioners to explore portfolios of responses that are more adaptable to future climate conditions



Key flood risk management actions and their main interactions.

The research has taken a modular approach to develop a toolkit which enables a greater understanding of flood risk management responses and advice, including:

- a **benefits assessment framework** to conceptualise the flood risk management system and the way responses to flood risk are interrelated
- **methods** to quantify the benefits of some of the responses to flood risk
- **case studies** that apply parts of the method at a variety of scales
- **tools** to implement the quantification methods
- **data** and **guidance** to support a range of applications

Benefits assessment framework

The benefits assessment framework is a conceptual model of the flood risk management system. It is designed to help flood risk management practitioners consider a wider range of responses to flood risk and to communicate the interactions and their decisions more effectively. The framework separates responses with a direct benefit (such as operating flood defences, resistance and resilience measures and moving household contents) from those which enable benefits to be achieved through other actions (such as flood forecasting and warning, awareness raising and working with communities). The two types of benefits are linked by sequences (or pathways) of actions.

Quantification methods

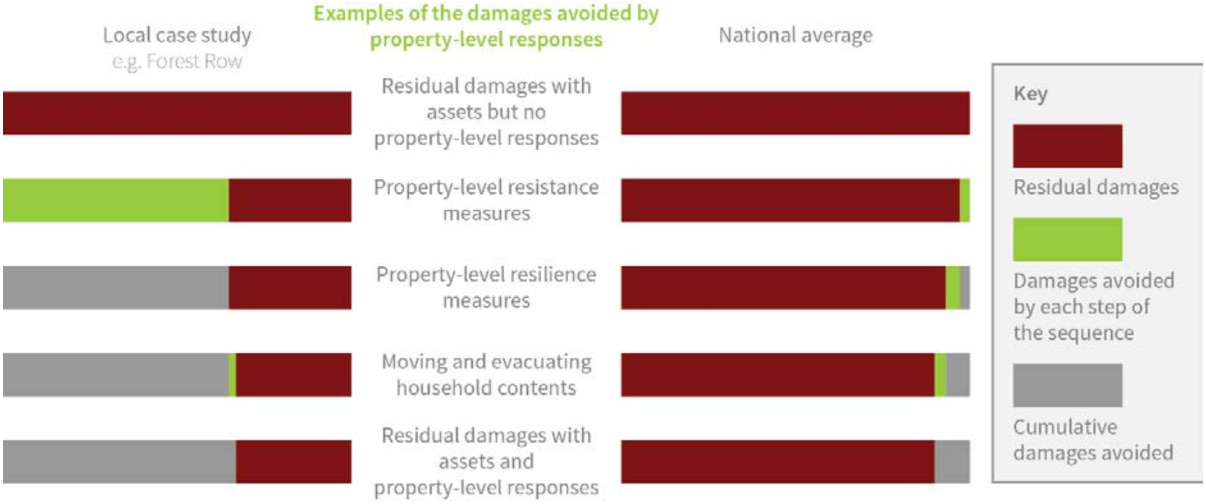
The quantification methods assess the benefits (quantification of the flood risk avoided and the flood risk management actions and advice of the framework) including:

- **Working with assets** such as flood defence operation in response to a forecast flood. The benefits of these responses are quantified by attributing a proportion of the economic damage avoided by the successful operation of defences (that is, the difference between the undefended and residual/defended damage) to each response.
- **Property level responses** consisting of active and passive resistance measures, resilience measures, and moving and evacuating household contents. These benefits are quantified using a series of generic factors multiplied together to obtain a percentage reduction in damage for each response. These percentages are then applied in sequence to the residual damage to quantify the damage avoided.
- **Enabling activities** including investment in flood forecasting and warning, awareness raising and working with communities. These are represented in the values of the factors used in the above calculations. For example, investment in flood forecasting and warning would have an impact on either the percentage of properties receiving a flood warning or (by increasing the lead time of the warning) the action that can be taken in response to that warning.

Case studies

A series of case studies apply the methods developed above. At a national scale, resistance measures (active and passive) are estimated to avoid 3.4% of residual damages. Resilience measures avoid 1.0% of residual damages, and moving and evacuating household contents avoid 4.7% of residual damages. Local applications find that, in specific areas, percentage benefits can be significantly higher (see figure). In Forest Row in East Sussex, active resistance measures could avoid 37% of the residual damage and passive measures could avoid 71% (passive measures quantified in the figure below).

A case study from the Deben Estuary in Suffolk identified how an MDSF2[1] model could be modified to simulate the benefits of property level protection (by altering depth-damage curves to simulate the presence of flood gates or flood-proof doors) and of flood defence operation (by removing flood gates to simulate them not being closed). Two further MDSF2 case studies investigate how benefits can be quantified by post-processing the outputs of existing MDSF2 model runs.



Example of the benefits of property level responses at a national and local scale

Spreadsheet tools

Two spreadsheet analysis tools have been developed to implement the quantification methods. The simple, single-scenario tool ANSR Lite enables users to quantify the benefits of working with assets and property level responses. The tool is divided into three worksheets in an Excel workbook that provide users with different levels of detail, from a high-level appraisal down to a detailed assessment.

ANSR is a more complete tool, allowing users to carry out complex calculations. This includes multi-scenario analysis using ‘investment–benefit’ functions that estimate changes to values in factors based on changes to investment, consideration of wider impacts through ‘benefit uplift factors’ applied as multipliers to the direct property damage, confidence levels, upper and lower bounds, and separation of residential and non-residential property level responses.

Data

By developing the series of case studies, a set of example (national scale) data has been developed. The data are provided in the report, with guidance on how they can vary for different applications (and which data could be applicable for any study) and potential additional data sources.

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[1] The Modelling and Decision Support Framework 2 (MDSF2) is a decision support toolset for quantifying economic and social impacts of flooding and coastal erosion for present day conditions, future scenarios and different flood management options.

Acknowledgements

We thank those who have contributed to the project's three stages through their involvement in the Project Board, attendance at various workshops and one-to-one discussions.

Special thanks go to Roy Cotgrove for his time and effort in arranging a user testing workshop with the Partnership and Strategic Overview (PSO) teams from Wessex, and Devon and Cornwall.

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1 Introduction

The Environment Agency aims to deliver flood and coastal risk management (FCRM) as efficiently as possible. There are many different actions that can be taken to manage flood risk before, during and after flooding. Large capital flood defence schemes are not always a financially viable, appropriate or sustainable solution to manage flood risk in all areas.

In assessing the financial benefits of any proposed flood defence scheme, methods for estimating the cost–benefits of larger structural schemes are well established. The methods for assessing localised protection – such as flood doors, operating flood gates and providing flood warnings to allow the public to move contents or evacuate flood risk areas – is less well defined. This is especially the case when a portfolio of flood risk management (FRM) measures may be required to obtain a certain standard of protection.

This joint Defra and Environment Agency Evidence research and development (R&D) project has developed methods to help assess the effectiveness of a wider portfolio of options that can be employed to manage flood risk. It studies FCRM efficiency based on risk-based prioritisation of investments across a range of flood risk management options. In particular, this project aims to enable practitioners to:

- **Make, justify and communicate flood risk management option selection**, supporting investment decisions across a portfolio of flood risk management responses at a range of spatial scales.
- **Identify and strengthen the links and dependencies between the actions and provision of advice** by the Environment Agency and the delivery of responses that reduce flood risk by other authorities, businesses and the public.
- **Ensure that people are protected in the future.** By considering a broader range of flood risk management options, flood risk management practitioners will be able to explore portfolios of responses which are more adaptable to future climate conditions.

As a result, a need has been identified to develop portfolios of ‘responses’ to flood risk. This report adopts the term ‘responses’ from ‘Foresight: Future Flooding’ (DTI 2004) to refer to all possible actions that can be taken to reduce flood risk in an equitable way, without any bias towards a particular type of structural or non-structural response. It is not to be confused with ‘emergency response’.

Responses could include building, maintaining and operating flood defences, flood incident management, property level responses, and spatial planning and advice. Figure 1.1 summarises a range of responses and how they might interact with each other.

To make informed investment decisions, an understanding of a full portfolio of possible responses and their interconnections is required.

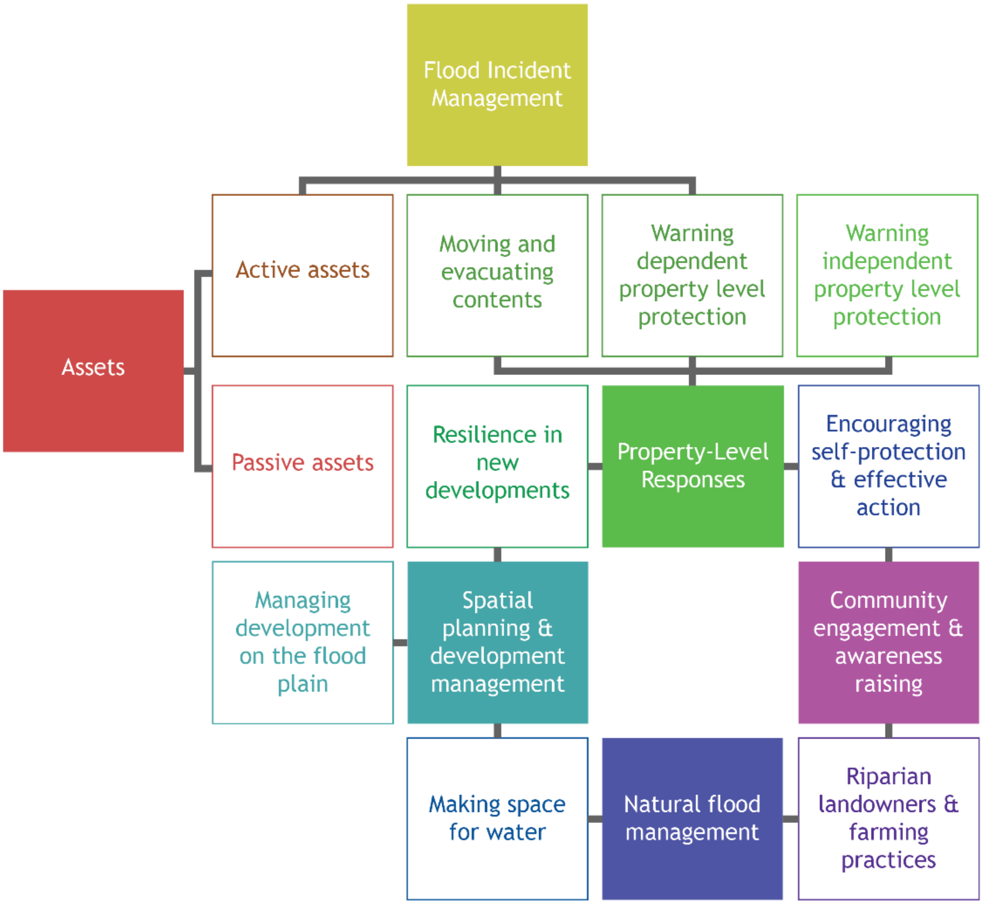

Figure 1.1 **Key flood risk management responses and their main limitations**

While the benefits of flood defences and related responses are well understood and readily quantifiable through established approaches, those of other responses are more difficult to assess and quantify. This could lead to an over-emphasis on expensive structural solutions and underinvestment in other responses that may be more cost-effective.

1.1 Overall approach

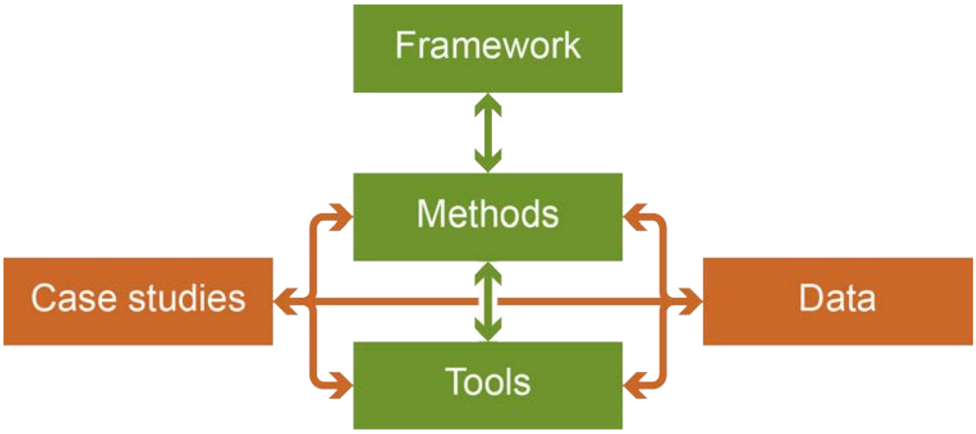

Figure 1.2 **Modular approach to quantifying the benefits of flood risk management actions and advice**

This project has taken a modular approach to quantifying the benefits of flood risk management actions and advice, summarised in Figure 1.2 and mirrored in the structure of this report. Each of the blocks in the figure is represented by a chapter in this report.

The benefits assessment framework introduced in Chapter 2 connects flood risk management actions and advice that achieve a direct benefit to other activities and investments.

Chapter 3 introduces methods to quantify components of the framework, assessing the benefits of responses which do not fit into a typical structural assessment. These methods focus on:

- **Flood incident management** that seeks to reduce the impact of flooding on people and existing property. For example:
    - detection, forecasting and warning
    - working with communities (for example, community groups, flood wardens and flood ambassadors) to improve flood understanding and acceptance of risk, and to encourage effective flood response
    - emergency planning and testing exercising, multi-agency response and recovery
- **Property level responses** that stop water entering properties (resistance) or reduce the damages and speed recovery (resilience and moving contents). For example:
    - resistance responses that reduce the likelihood of water entering a property
    - resilience responses that reduce the damages if flooding occurs and help to speed up recovery
    - moving and evacuating property contents (for example, taking valuables upstairs to protect them)

This research project has also developed and applied a third methodology for quantifying the benefits of the development management advice provided by the Environment Agency. This method has not been published in this report because it is only of relevance to the Environment Agency at a national level. A technical note covering this research is available on request.

Chapter 4 applies the methods developed in Chapter 3 to a number of case studies at a range of scales from national to local. The methods developed in Chapter 3 to quantify the benefits of working with assets and property level responses, are implemented in a pair of spreadsheets tools: ANSR (Appraisal of Non-Structural Responses) and ANSR Lite. These are discussed in Chapter 5.

Chapter 6 brings together the lessons learned in developing and applying the methodologies in the previous chapters to present guidance on data. It covers data requirements, example values at a national scale and potential local variations.

1.2 Target audience

This report is aimed at Environment Agency flood risk management staff, emergency planners, Lead Local Flood Authorities (LLFAs) and planning authorities. It aims to improve understanding of the benefits of flood incident management and property level responses. Table 1.1 identifies the most likely users and uses of the framework and tools.

Table 1.1 Target users and uses of the framework and tools

Primary users	**Potential uses**
Environment Agency – strategic functions	• Supporting evidence presented to government on the benefit of investment in flood risk responses. • Supporting evidence presented to government on the benefit of the advice given by the Environment Agency. • Informing the flood incident management (FIM) and spatial planning policies of risk management authorities (primarily through engagement with LLFAs and planning authorities). • Supporting decisions on balancing investment between different types of response in long-term investment planning. • Communicating the flood risk management system to professional partners and the public.
Environment Agency – delivery functions	• Supporting fluvial and coastal strategies in determining how FIM can improve flood risk management outcomes. • Communicating the flood risk management system to professional partners and the public. • Ensuring revenue-funded flood risk management responses are accounted for in business planning.
Other users	**Potential uses**
LLFAs – policy and strategy functions	• Understanding the flood risk management system and setting boundaries with other partners such as the Environment Agency • Using the benefit framework to help set local flood risk management strategy policy. • Quantifying the benefits of FIM at a LLFA level to help ensure activities are adequately resourced.
LLFAs – delivery functions	• Supporting justification of specific responses (such as property level protection or resilience measures), for example, where a structural solution to local flood risk may not meet funding criteria.
Planning authorities – policy and strategy functions	• Applying the benefit framework to support Local Plan FIM and spatial planning policies and locally derived sustainable drainage system (SuDS) policies.
Planning authorities – development management	• Helping to understand the benefits of mitigation, such as resilience and resistance, where development is considered in flood risk areas.

1.3 Links to the Multi-Coloured Manual

The work presented in this report shares much in common with the Multi-Coloured Manual (MCM) (Penning-Rowsell et al. 2013). Dennis Parker and Sally Priest of the Flood Hazard Research Centre (FHRC) and MCM co-authors, have been involved in this project throughout, from initial development of the method and its application in the case studies to peer review of the stage outputs.

The wider framework is based on the Flood Warning Response and Benefits Pathways model developed by Parker et al. (2008). The concept of multiplying factors together to obtain a percentage damage reduction is an extension of the flood damages avoided (FDA) equation developed by Parker et al. (2007) and published in the MCM (2010 version Table 4.15 and 2013 version Table 4.16). This equation and the values form the basis of the ‘contents moved and/or evacuated’ pathway. The percentage damage reduction calculated by the FDA equation also guides the damage reduction due to flood warnings (MCM 2010 version Table 4.18 and 2013 version Table 4.33) for the weighted annual average damages (WAAD) method. The method in this report could be considered an alternative/extension to that table. Indeed, the WAAD method forms the basis of the method used to quantify the benefits of property level protection in the Emsworth to East Head case study (Section 4.6).

Components of the research presented in this report also form part of MCM 2013. Sections 4.6.2 and 4.6.3 of MCM 2013 detail the method to quantify the benefits of resistance and resilience measures respectively, with pages 4–13 onwards of MCM 2013 providing a step-by-step guide to carrying out this assessment.

1.4 How to use this document

This document is a combination of a research report and a ‘how to’ guide. The intention is for potential users (see Section 1.2) to use this document to help them develop a portfolio of responses and to assess their benefits for a particular flood risk management problem.

The benefits assessment framework (see Chapter 2) can be used to focus workshops, to develop a list of measures and in supporting communications. More detail on its application can be found in Section 2.6.

It is anticipated that users tasked with assessing flood risk management benefits would use either the ANSR Lite spreadsheet (Section 5.3), for a ‘broad brush’ assessment or the ANSR spreadsheet (Section 5.4) for a more detailed analysis.

To assist users, the document contains a user guide (Appendix C), case studies/worked examples (Chapter 4 and Appendix B, respectively) and sample data (Chapter 6).

1.5 Assuring quality throughout the research process

The project has gone through three stages, with steps to ensure its outputs meet the needs of potential users in the Environment Agency and beyond.

In Stage 1, the initial method was developed with Sally Priest of FHRC and outputs were peer reviewed by Dennis Parker of FHRC.

Stage 2 included workshops where the framework, method and ANSR tool were introduced to users at a national strategy level, alongside the Long-Term Investment Strategy. At the end of Stage 2, JBA Consulting conducted an independent review of the complete method and tool.

Stage 3 included wider stakeholder engagement including:

- telephone interviews with potential Environment Agency users
- user workshop attended by Environment Agency staff representing a range of functions

- a second workshop held with members of the Environment Agency’s Partnership and Strategic Overview (PSO) team from the south-west of England

This engagement led to significant improvements in this report’s outputs, including a clarification of terminology and simplification of ANSR to create the ANSR Lite tool.

2 Benefits assessment framework

The benefits assessment framework connects flood risk management actions and advice that achieve a direct benefit to other activities and investments which enable them. This includes the sequence of actions taken following the detection and forecasting of a flood event. For example, a flood warning does not avoid flood impacts unless action is subsequently taken as a result of that warning. Conversely, some actions could not be taken effectively without that warning. For example, a sequence of events could be:

1. Environment Agency invests in awareness raising programmes.
2. Through those programmes, residents become aware that their property is at risk of flooding and of the action they could take.
3. Residents invest in protecting their property with flood guards (supported by self-closing air-bricks and non-return valves).
4. Flooding is forecast, triggering a flood warning.
5. Warning is disseminated.
6. Residents receive the warning in time to take action.
7. Residents put their flood guards in place.
8. Residents' street floods as forecast.
9. Flood guards function as designed, preventing water from entering houses, avoiding damages to the internal building fabric and contents.

The complete framework has been developed from a number of similar sequences of actions that can result in benefits being achieved, and points of investment in the system that affect the extent of those benefits. These sequences of actions are termed 'benefits pathways'. The framework is designed to help understand the flood risk management system and to enable responses to be assessed.

2.1 Previous research and practice

Parker (1991) introduced the flood damages avoided (FDA) equation which sought to quantify the benefits of flood warnings by assessing the damages avoided by residents moving their personal belongings out of the reach of floodwater either within the house or as part of the evacuation process. This was achieved using a single equation made up of a number of factors. These factors were modified and adapted during subsequent iterations of the FDA equation by the Environment Agency (2003) and Parker et al. (2007).

Parker et al. (2008) recognised that 'contents moved and evacuated' is just one of a number of benefits enabled by flood warnings. They introduced the Flood Warning Response and Benefits Pathways (FWRBP) model, which identified the sequences of actions that occur following a flood being forecast. These include:

- the flood warning to the public, leading to residents and other floodplain users taking action

- the internal warning to the Environment Agency and professional partners, leading to the official emergency response

The FWRBP model shows the actions carried out to achieve a benefit by avoiding flood damages or risk to life.

The benefits assessment framework introduced by this project has been developed over the three stages of the SC090039 project and the Flood Incident Management Investment Review. It is an extension of the FWRBP model developed by Parker et al. (2008). This model was selected as the basis for the benefits assessment framework due to:

- its holistic approach – taking into account a broad range of actions that can lead to a reduction in flood damages
- its adaptability, for example, allowing for different quantification approaches and additional responses to be added
- its applicability – Parker et al. (2008) carried out national and local applications of the FWRBP model

While the original FWRBP framework was limited to responses which originate at a flood warning, this extended framework includes a wider range of responses.

2.2 Responses with a direct benefit

Table 2.1 lists the responses included in the benefits assessment framework that are considered to have a direct benefit.

Table 2.1 Responses with a direct benefit in the benefits assessment framework

Type of response	Response
Working with assets	Maintaining watercourse capacity – thereby reducing the likelihood of blockages Operating flood defences Transporting and operating temporary and demountable ‘community level’ flood defences
Emergency responses	Evacuation leading up to and during a flood Search and rescue operations
Property level responses	Resistance measures – both warning-dependent and warning-independent Resilience measures Moving and evacuating contents
Land use planning and development management	Spatial planning and development management to limit future increases in risk Rural land use management, working with natural processes to reduce flood hazard

2.3 Enabling responses

The framework also includes responses that do not in themselves reduce the impacts of flooding, but which enable or enhance the damage-reducing potential of the responses listed in Table 2.1. These enabling responses include:

- flood detection, forecasting and warning
- working with communities (for example, community groups, flood wardens and flood ambassadors) to improve awareness, understanding and acceptance of flood risks and to encourage effective flood response
- emergency planning and exercising, multi-agency response and recovery – to increase the effectiveness of the official emergency response
- direct investment in property level protection – resistance and resilience

There is a further level of enabling activities including technical activities (such as data collection, data management, flood modelling, flood mapping) and policy, process and management activities that underpin many of the other activities. However, these are outside the scope of this report.

Assumption

Responses such as flood detection, forecasting and warning or working with communities have no direct benefit on reducing flood damages. Instead, a benefit is achieved when they enable or enhance the damage-reducing potential of other responses.

2.4 The complete framework

Figure 2.1 presents the complete assessment framework. The type of responses that directly achieve a benefit are listed on the right of the flow chart, together with examples. The rest of the flow chart shows the sequences of actions and investment that enable the responses to achieve benefits in terms of flood damages avoided.

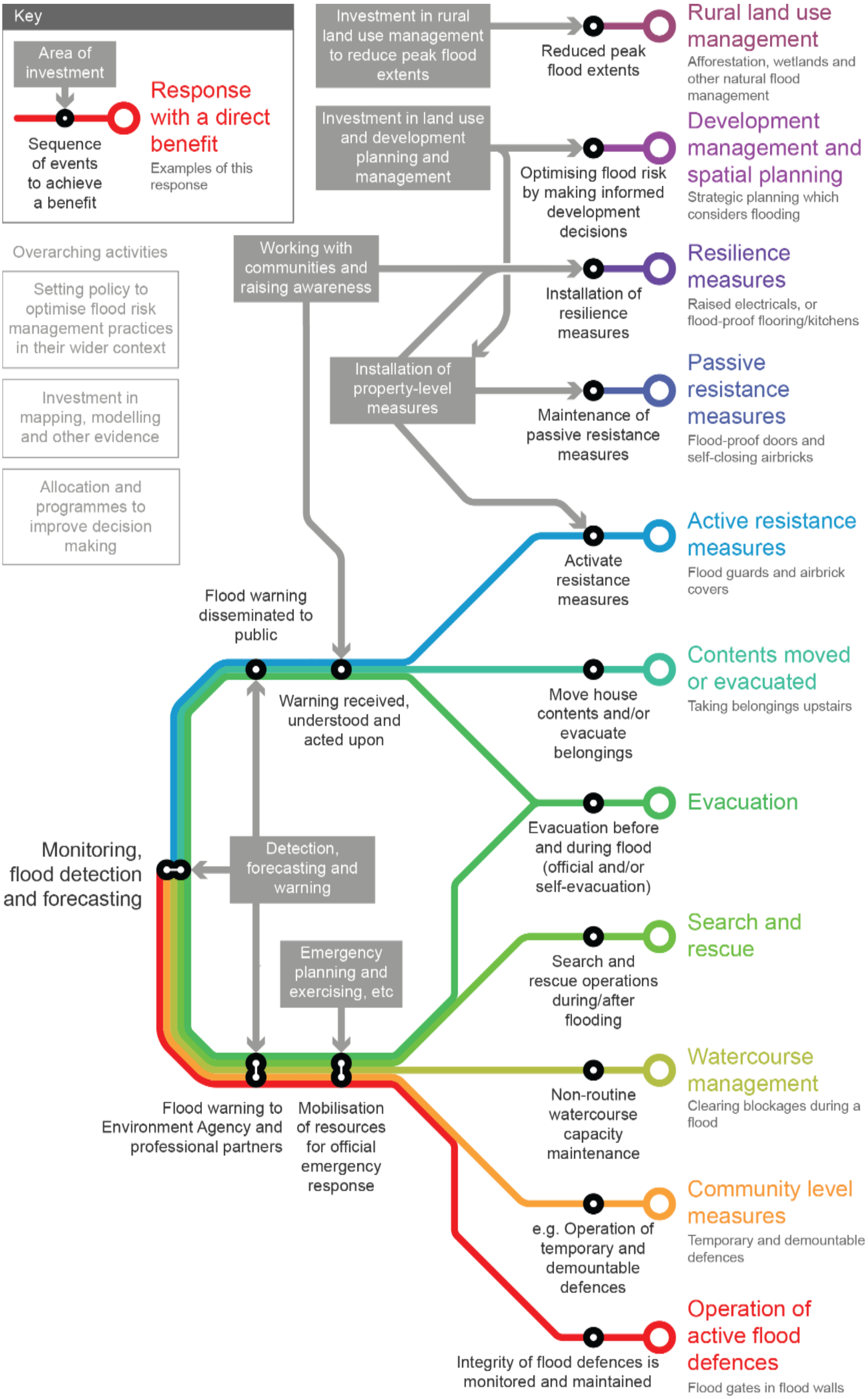

Figure 2.1 **Benefits assessment framework for flood risk management**

2.5 Benefit pathways

The responses with a direct benefit are shown as coloured lines in Figure 2.1, which provides an overview of the interactions that occur between enabling activities and responses. This framework includes evacuation and search and rescue, which directly reduce risk to life. It covers the following responses that directly reduce direct property damages:

- **Operation of active flood defences** – systems where the integrity of flood defences relies on the receipt of a flood warning (for example, due to the need to raise flood barriers or close openings in flood walls)
- **Watercourse management** – to maintain the efficiency of channels to carry river and flood waters
- **Community level measures** – temporary mountable/demountable flood defences that need to be erected or positioned following a flood warning
- **Contents moved or evacuated** – the movement of possessions to higher levels or to locations beyond the floodplain
- **Active resistance measures** – the installation and operation of temporary property level flood-proofing measures contingent on the receipt of a flood warning (renamed from contingent flood-proofing) in the FWRBP calculation
- **Passive resistance measures** – the installation of permanent property level flood-proofing measures that are not contingent on the receipt of a flood warning
- **Resilience measures** – the installation of measures that increase the resilience of a property (reduce the damage sustained) should the property be flooded
- **Development management and spatial planning** – reduction in future increases in flood risks (typically at receptor level) through the planning and management of development
- **Rural land use management** – Natural flood management activities to reduce downstream flood peaks

Table 2.2 provides examples of actions in each pathway and the benefits gained by undertaking each of these actions.

Table 2.2 Examples of benefits for each pathway

Flood warning response	Examples of action	Direct benefits	Indirect benefits	Intangible benefits
Operation of active flood defences	Closure of a flood barrier	Reduced risk of flooding		
	Diversion of flood flows into a flood diversion channel Opening of flood detention of flood storage areas Use of flood storage capacity in flood dam River regulation Emergency repair of failing flood defences Making breaches in secondary flood banks and informal defences to lower flood levels	Reduced direct physical damage to buildings, other property and infrastructure	Reduced loss of industrial production, traffic disruption and emergency costs	Reduced loss of life, adverse health effects, loss of ecological values and cultural values Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors
Watercourse management	Remove blockages from watercourses	Reduced risk of flooding		
	Clear debris screens Weed and tree clearance from channels	Reduced direct physical damage to buildings, other property and infrastructure	Reduced loss of industrial production, traffic disruption and emergency costs	Reduced loss of life, adverse health effects, loss of ecological values and of cultural values Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors
Community level measures	Mountable/demountable flood defences provided for a community, neighbourhood or road	Reduced risk of flooding at community level		
	Community pumping schemes	Reduced direct physical damage to buildings, other property and infrastructure	Reduced loss of industrial production, traffic disruption and emergency costs	Reduced loss of life, adverse health effects, loss of ecological values and loss of cultural values

Flood warning response	Examples of action	Direct benefits	Indirect benefits	Intangible benefits
				Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors
Active resistance measures	Use of property level temporary resistance measures such as manually installed door guards and airbrick covers	Reduced risk of flooding at property level Reduced direct physical damage to buildings, other property and building contents		Reduced adverse health effects such as stress and anxiety Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors
Passive resistance measures	Use of property level permanent resistance measures such as permanent flood-proof external doors, automatic airbricks and external wall render/facing	Reduced risk of flooding at property level Reduced direct physical damage to buildings, other property and building contents		Reduced adverse health effects such as stress and anxiety Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors
Resilience measures	Use of property level resilience measures, such as resilient plaster, resilient kitchens, raised electrics and appliances	Reduced impacts of flooding Reduced direct physical damage to buildings and other property		Reduced adverse health effects such as stress and anxiety Reduced inconvenience of post-flood recovery and reduced

Flood warning response	Examples of action	Direct benefits	Indirect benefits	Intangible benefits
				vulnerability of survivors
Contents moved and evacuated	Moving possessions within properties to a higher level, or moving possessions to another location	Reduced impacts of flooding		
		Reduced direct physical damage to building contents		Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors
Development management and spatial planning	Spatial planning strategies that take account of flood risk	Reduced risk of flooding		
	Development management advice to planning authorities	Fewer or more resilient properties on floodplains, leading to reduced direct physical damage to buildings, other property and infrastructure		Environmental improvements such as provision of green spaces Reduced loss of life, adverse health effects, loss of ecological values and of cultural values Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors Regeneration through enabling development following advice from Environment Agency
Rural land use management	Wetlands and washlands	Reduced risk of flooding		
	Afforestation Working with farmers to reduce run-off through changes to farming practice	Reduced flow downstream, leading to reduced direct physical damage to buildings,	Reduced loss of industrial production, traffic disruption and	Environmental improvements Reduced loss of life,

Flood warning response	Examples of action	Direct benefits	Indirect benefits	Intangible benefits
		other property and infrastructure	emergency costs	adverse health effects, loss of ecological values and cultural values Reduced inconvenience of post-flood recovery and reduced vulnerability of survivors

Notes: Taken from Parker et al. (2008), pp. 51-52, Priest et al. (2008) and Thurston et al. (2008).

2.6 Using the framework

Chapter 3 introduces the methods developed to quantify components of the benefits assessment framework. However, the framework can be useful in its own right by raising awareness of some of the links between different response types and promoting a greater understanding of the complete flood risk management system.

2.6.1 Optioneering

The benefits assessment framework could form the focus of meetings or workshops to develop a list of measures to investigate further to reduce flood risk in an area. An extended version of the framework, including a more complete range of responses, is given in Appendix A. Using an A0/A1 print-out, the framework can inform a range of options which may not have been previously considered. Once measures have been identified, the benefits derived from a range can be calculated using the methods and tools in the following chapters or in the Multi-Coloured Manual.

The following uses of the framework have been identified through workshops with Environment Agency employees.

2.6.2 Communicating with the public

The flood risk management system is complex and difficult to communicate. When communicating with communities, there is often a lack of understanding of the Environment Agency’s responsibilities and capabilities. Similarly, the public does not always understand how investment decisions made in one pathway can impact on other areas or pathways. The framework helps encourage a holistic discussion of the flood risk management system, describing Environment Agency’s responsibilities, and demonstrating how the community and other organisations can contribute to flood risk management.

2.6.3 Communicating with professional partners and colleagues

The framework can be used in discussions with Lead Local Flood Authorities and emergency responders to understand how responses should best be programmed and to understand which organisation has responsibility for each pathway.

In addition, where a capital scheme cannot be justified to reduce flood risk, the framework can be used to help consider partnership revenue-funded activities.

2.6.4 Justifying decisions

There is a clear process for proposing capital schemes and justifying the schemes for inclusion on the Medium Term Plan. The process for consideration and justification of enabling activities (funded through revenue funding) is less clear. The application of the framework, when preparing project business cases, can demonstrate that:

- all options have been considered
- the benefits and costs of all enabling activities have been built into the business case

2.6.5 Area strategic planning

The framework provides a structure for all the FRM activities delivered by the Environment Agency and can be used to justify investment in revenue-funded activities.

If investment in a particular response is planned, the framework may help identify other areas of investment necessary to achieve the planned benefit. For example, in an area with poor response to flood warnings, this could be improved by automatically signing up residents to the flood warning service. However, without raising community awareness to ensure residents understand the warnings and how to respond to them, there is a risk the investment will not lead to the expected benefit. The framework can help identify similar links.

2.7 Limitations

As a conceptual framework, the main limitation of the framework is that it is focused on responses that reduce the impact on properties and, in the case of evacuation, the people in those properties.

The wider benefit of these responses has been considered to a limited degree (see Section 5.6), but other responses that reduce flood risk have been excluded, for example:

- warnings given through cell broadcasting, which could be sent to residents, but could also be sent to any other users of the floodplain such as drivers, people on campsites and leisure users
- road signage to warn drivers of flooded roads

The framework is also focused on property level and flood incident management activities, and so excludes the wider system. The flood risk management framework in Appendix A attempts to provide a more complete view.

3 Methods for quantifying benefits pathways

This chapter discusses how components of the framework introduced in Chapter 2 can be quantified. It covers the following four types of benefits:

- **Benefits of property level responses** – by sequentially applying a series of equations which represent each response
- **Benefits of flood incident management related to enabling the operation of assets** – by attributing a proportion of the damages avoided by assets to those which are dependent on operation following a flood warning
- **Benefits of enabling activities**

The ANSR tools (see Chapter 5) implement the first two types of benefits. They also provide specific approaches to quantifying the benefits of enabling activities under different investment scenarios using investment–benefit functions and quantifying the wider impact of flooding.

The benefits of natural flood management have not been quantified in this project. Recent research for the Scottish Environment Protection Agency (SEPA) and Forestry Commission Scotland (Nutt 2012) attempted to quantify the changes to hydrology that can be brought about by natural flood management, but the research did not quantify the financial benefits.

3.1 Benefits of property level responses

Quantifying the benefits of property level responses is based on a simple generic equation built up from a series of factors modelled on the FDA equation (Parker 1991). Methods have also been developed to represent how changes in investment could lead to changes in the values of the factors of each equation.

3.1.1 Generic equation

Each response that leads to a direct benefit is quantified by a single equation made up of a number of factors. These represent steps in the sequences of actions required to achieve the benefit. These factors are:

- **reliability and availability** of the flood warning process[2] (that is, the percentage of at-risk population that receives a flood warning) taking into account:
  - coverage of the flood warning service (that is, the proportion of properties offered this service)
  - sign up to the flood warning service by those offered it

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[2] Parker et al. (2007) combined previously separate ‘reliability’ and ‘availability’ factors because they align closely with data collection. For example, Environment Agency (2007) asked, ‘During the events of January 2007, did you at any stage receive a warning about the flood, even if that warning was received after the water reached the property?’ A response of ‘no’ could be due to either unreliability in the warning itself, or unavailability of the resident.

  - success rate in forecasting and disseminating a flood warning (service effectiveness)
  - availability of residents to receive the warning, understand its meaning and be in a position to take action
- proportion of the potential damage in the total study area accounted for by properties with this particular measure installed (that is, the level of **uptake** in the response); for example, 50% of properties in an area may have property level protection installed, but those 50% of properties may represent 75% of the damages. In this case the uptake would be 75%
- potential damages avoided by the measure, assuming it is installed and operated successfully on an annual average basis (that is, the **effectiveness** of the response)
- percentage of the potential damages avoided which are actually avoided given the available flood warning lead time (that is, the percentage of responses that are successfully **operated**); for resistance measures, this can be simplified to the percentage of properties that put the measure in place

The **percentage benefit** of any one response is calculated as follows.

Percentage impacts avoided	**=**	**Reliability and availability**	×	**Uptake**	×	**Effectiveness**	×	**Operated**	**=**	**Benefit**
Damage avoided	=	% properties receiving a flood warning	×	% of total damage in study area accounted for by properties with this measure installed	×	% damages potentially avoided by measure	×	% of the potential damage avoided which is actually avoided in the time available	=	Benefit
Example Warning-dependent resistance	=	30%	×	5.0%	×	50%	×	82%	=	0.62%[1]

Notes: [1] $(0.3 \times 0.05 \times 0.5 \times 0.82) \times 100$

To calculate the damages avoided by each response, the percentage impacts avoided are multiplied by the residual annual damages. The use of ‘annual’ rather than ‘event’ damages has implications on the effectiveness factor, as discussed below.

3.1.2 Reliability and availability

The FHRC method, employed by Parker et al. (2007) and by Parker et al. (2008) as part of the FWRBP model, includes a reliability and availability (RAS) factor. This is defined as:

> ‘Proportion or percentage of householders who receive a flood warning message, based upon a) success in disseminating a warning and b) availability of householders to receive it.’

To apply this on a national scale, this factor must additionally take into account the coverage of the flood warning service. The RAS factor can therefore be defined simply as the percentage of at-risk population who receive a flood warning, taking into account:

- coverage – the percentage of the at-risk population that is warned
- subscription rate to the flood warning service – the percentage of the population offered a service who are subscribed to it
- likelihood that a warning is successfully disseminated – the percentage of those subscribed to the flood warning service who are sent a warning
- availability of recipients to receive the warning – the percentage of those who are sent a warning that actually receive it

The RAS factor is not a measure of the proportion of population who respond to the warning. It may be different for residential properties, non-residential properties and the ‘internal’ warning to professional partners (for example, for the emergency response and operating flood defences).

3.1.3 Uptake

Uptake represents the ‘percentage of the total flood damages accounted for by properties which are protected by the measure’, or have the measure installed.

For example, consider a hypothetical study area with 12 properties. Six of the properties have resistance measures installed (50%). In some cases it may be reasonable to use this value of 50% as the uptake. In this case, however, those six properties with resistance measures represent 75% of the damages to the 12 properties. A 50% value would lead to a significant underestimate of the potential benefits of the resistance measures.

In general, it is likely that a simple property count will not lead to a reliable estimate of uptake. However, where no alternative is available (for example, at a national scale) it could be used as an approximation.

Where data are available, uptake can be calculated by quantifying:

1. The annual damage for all properties in the study area, for example, using property points, depth grids for a range of return periods and depth-damage curves, or methods such as weighted annual average damages (WAAD). This is the same as the residual damage described in Section 3.1.6.
2. The unprotected annual damage for properties that have these measures installed – using the same method.

The approach should follow the Flood and Coastal Erosion Risk Management appraisal guidance (FCERM-AG) process (Environment Agency 2010) for calculating annual damage values.

Uptake is item (2) in the list above divided by item (1).

3.1.4 Operated

The operated damages avoided factor represents the ‘percentage of the potential damages avoided which are successfully avoided’, taking into account the expected lead time of the flood warning provided and the resulting effective action that can be taken in the time available.

Some responses, such as flood guards (warning-dependent or active resistance) are ‘binary’ in nature, in that they are either operated or not operated. For these, ‘operated’ can be defined as the ‘percentage of measures successfully operated, given the lead time available’.

For other responses, such as moving and evacuating contents, greater lead times are likely to result in not just a greater percentage of properties taking action, but also a greater percentage of damages being successfully avoided for any given property. For example, Parker et al. (2007) estimated that:

- 55% of the potential damages avoided can be achieved with a lead time <8 hours
- 71% of the potential damages avoided can be achieved with a lead time >8 hours

Priest and Parker (2012) developed a set of updated values (Table 3.1) based on post-flood event surveys. The value for the percentage of active resistance measures put in place is taken from the percentage found to have taken ‘effective action’; the assumption is that, if a property has resistance measures, the first action taken would be to put them in place. These values can be combined with the distribution of properties between each lead time category to estimate the values for any given study area.

Table 3.1 Percentage of potential damages avoided which are actually avoided, for different lead times

Lead time category	0–1 hour	1–8 hours	>8 hours
% of active resistance measures put in place	92%	96%	99%
% of potential damages avoided by moving contents	70%	72%	80%

3.1.5 Effectiveness

The effectiveness factor represents the ‘proportion of the potential damages to protected properties that are avoided if a measure is installed and operated appropriately’.

For example, a value of 100% suggests that, for the properties in the study area which have a measure installed and operate it in a flood event, **all** damages are avoided – even for a very severe flood event. Other factors including operated, reliability and availability then take into account the likelihood that the measure successfully avoids those damages.

To align with the rest of the analysis and the use of annual damages, this effectiveness must be annualised rather than taken from a single event. For example, while a measure might save a large proportion of the potential damages for a high-probability (low return period) event, for others it may save less (or even none). This is especially important if empirical evidence collected after a flood event is being used. In that case, the damage reduction for each measure applies only to that particular event and will not represent the effectiveness over a whole spectrum of possible events.

Effectiveness can be calculated by quantifying the annual damage for properties that have these measures installed:

1. With the protection in place

2. Without the protection in place – equal to item (2) in Section 3.1.3

The approach should follow the FCERM-AG process for calculating annual damage values. Effectiveness can then be estimated as item (1) above divided by item (2).

3.1.6 Benefits of multiple property level responses

The percentage damages avoided by each response are calculated using the equations described above. The benefits of all property level responses can be calculated using the residual annual average damages (AAD) (the AAD estimated to occur when flood defences and other assets are in place) by subtracting a percentage of the residual AAD for each response.

AAD should be taken from a source appropriate to the scale of the study. Possible sources include:

- National Flood Risk Assessment (NaFRA) – for national scale applications
- WAAD
- Modelling and Decision Support Framework 2 (MDSF2)

An alternative is from a damage calculation using the results of to-dimensional modelling (depth grids) combined with property data and depth-damage curves.

The approach should match the approach taken to calculate the uptake and effectiveness values, as discussed in Sections 3.1.3 and 3.1.5 respectively.

Each response is applied sequentially, with the output (residual AAD) of each calculation used as the input AAD for the next, based on a theoretical passage of water through the system (shown in Figure 3.1). It first reaches flood defences and community-level temporary or demountable defences, before reaching properties. At the property, resistance measures are intended to keep water out and resilience measures aim to reduce the impact if water enters the property. Residents can then move their remaining possessions out of reach of the water.

Assumption

The percentage damages avoided by each property level response are applied sequentially, with the inputs to each calculation being taken from the outputs of the previous step.

This sequence attempts to represent the notion that increasing the damages avoided by a response at an earlier stage in the system could potentially decrease the damages avoided by other responses at a later stage in the system. For example, if an area is protected by flood defences, residents are unlikely to avoid damages through moving or evacuating contents – as those damages have already been avoided by the defences.

Figure 3.1 Passage of water through the system

Table 3.2 shows a national example calculation.

Table 3.2 Example calculation of benefits of multiple property level responses

Response			**Percentage damages avoided**	**AAD (£ million)**		
				Input	**Avoided**	**Residual**
Resistance measures	Warning-independent	2.24%	2.85%	1,000	28.6	971
	Warning-dependent	0.615%				
Resilience measures			4.00%	971	38.9	933
Contents moved and evacuated			3.52%	933	32.8	900

Notes: Each response uses the residual AAD from the previous one.
Initial residual AAD is £1 billion.

3.1.7 Using the method

The quantification method and tools are most likely to be useful in the following situations.

- Your economic appraisal has identified that property level protection is the most beneficial solution to a community's flood risk. However, the benefits indicated by the economic appraisal rely on effective action by the community in response to a flood warning. The ANSR tool can help you test the sensitivity of the benefits calculations to the effectiveness of the forecasting and warning system, the flood warning lead time, and how well the community responds to the warnings received.
- There is significant uncertainty about the effectiveness of a forecasting and warning system. You want to test how the effectiveness of the warning system might affect the benefits claimed for both passive and active responses.

- You have a community with different catchments with different catchment response times. You wish to test how effective a property level protection system would be in reducing damages across that community.
- The Environment Agency has a policy that requires defences to be passive wherever possible. However, an economic appraisal rules out passive responses because of their cost. You can use the quantification tools to test how the benefits claimed differ between active and passive systems, and to generate a whole-life cost–benefit assessment to build a business case for passive responses.
- You are working with a non-residential/commercial customer with a high value property and want to quantify the benefits of property level protection for them. You can demonstrate how their effectiveness at responding to a warning can impact on the damages they suffer.

3.1.8 Limitations

The main limitation of this approach to quantifying the benefits of property level protection is that using factors may oversimplify a complex sequence of actions.

The effectiveness and uptake represent the physical ability of a response to avoid damages. They can be a realistic representation of reality as long as the data have been accurately derived.

However, the warning success and operated factors represent the complex behaviour of people in the floodplain. In particular, the single percentage value for warning success may over-simplify the way in which people become aware of a flood. For example, consider these hypothetical cases:

- Resident A receives an official flood warning and has two hours' lead time to take action before floodwater reaches their property. This is nominally the benefit that is being quantified.
- Resident B does not receive an official flood warning, but in a post-flood event survey, responds that they took effective action.

Should the benefit of the action taken by Resident B be subtracted from the benefit of the action taken by Resident A to identify the additional effective action achieved through the flood warning? Did Resident B indirectly become aware of the impending flood risk because they saw a weather forecast? Is that weather forecast a benefit of the overall forecasting and warning system (if not of the warning system)?

The other important limitations of this approach are that it inherently quantifies only a part of the overall framework and presents issues on the availability of data (especially for a high-level assessment).

3.2 Benefits of flood incident management working with assets

While it is reasonable to accept that property level responses further reduce the residual AAD, it is assumed that assets such as flood defences and temporary or demountable defences have already been accounted for in the model used to calculate the AAD (though some calculations do estimate the potential 'undefended' damages). To reduce the AAD further would be double-counting.

Instead, to quantify the contribution that flood incident management makes to the benefit achieved by assets, a proportion of the damages avoided by assets can be attributed to:

- flood defence operation, for example, by closing flood gates or raising flood barriers
- watercourse management to ensure that capacity is maintained, for example, by clearing trash screens, dredging and maintaining the riverbank
- community-based operations such as erecting temporary or demountable defences

This requires an estimate of the undefended AAD so that the damages avoided by assets can be calculated.

Table 3.3 shows an example calculation of the benefits of flood incident management working with assets based on an undefended AAD of £3 billion and a defended (residual) AAD of £1 billion. It demonstrates how the £2 billion avoided can be attributed to different responses. The table also shows how the AAD avoided could be reduced to account for the possibility that responses may not be operated as designed – in this case from £860 million to £729 million. As a result, the total AAD avoided by assets would be reduced to £1.87 billion, resulting in a residual AAD of £1.13 billion, rather than the initial value of £1 billion.

Assumption

AAD estimates used as input values for these calculations assume defences are installed and operated successfully.

Table 3.3 Example calculation of the benefits of flood incident management working with assets

Response	**Percentage AAD avoided attributable to response**	**Likelihood operated as designed**	**AAD (£ million)**		
			Input	**Avoided (if operated as designed)**	**Avoided**
Flood defence operation	28%	98%	2,000	560	549
Watercourse management	10%	50%	2,000	200	100
Community-scale defences	5%	80%	2,000	100	80
Total benefits attributable to FIM	43%	–	–	860	729
Other asset measures (for example, static flood defences)	57%	–	2,000	1,140	1,140
Total	100%	–	–	2,000	1,870

3.2.1 Limitations

This approach to attributing the benefits of assets to those which are active is potentially limited by the co-dependence and lack of exclusivity of some of these responses. For example, flood defence operation may contribute to 28% of the AAD avoided by assets but blockages could well occur in areas of flood defence operation. Actions to avoid blockages are likely to contribute to part of that 28%, as well as part of the percentage of damages avoided by passive defences. One example would be trash screens that form part of sluice structures.

If taken out of context, this approach also has the potential to lead to double-counting. It is important to note that these benefits are counted by attributing some of the benefits provided by assets to those which require operation. They are not additional benefits on top of those provided by assets.

3.3 Benefits of enabling activities

Each response that enables or influences other responses can be represented by its link with a factor in one or more of the equations described above. For example, changing the level of investment in flood warning coverage would affect the value of the reliability and availability factor.

These links are represented on the benefits assessment framework as investment areas connecting to other elements in the framework and can be quantified by making appropriate changes to values of the factors.

These changes could be quantified in a number of ways, including scenario-based modelling or, in the absence of available evidence, expert judgement of the likely changes in factors.

Another approach would be to represent the relationships using a function which links investment to the value of the factor it influences. This so-called ‘investment–benefit’ function would aim to bridge the gap between investments and benefits for responses to flood risk which do not directly achieve a benefit.

3.3.1 Limitations

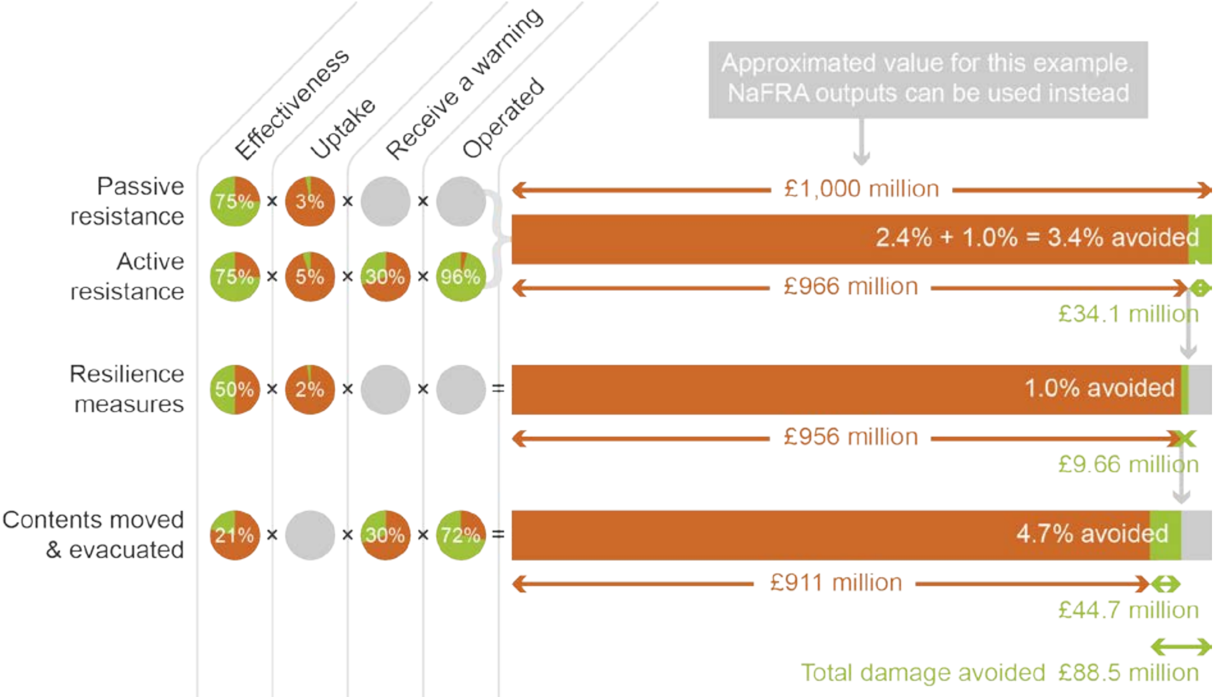
The main limitation to these approaches is that the final factor values do not necessarily show the activities that contribute to them – although the investment–benefit functions in the ANSR tool do list these activities and identify for each which factor they influence.

4 Case studies

This chapter provides summary results and example calculations for a series of case studies to illustrate the application of the various parts of the framework, methods and tools. Full details of the case studies are provided in Appendix B.

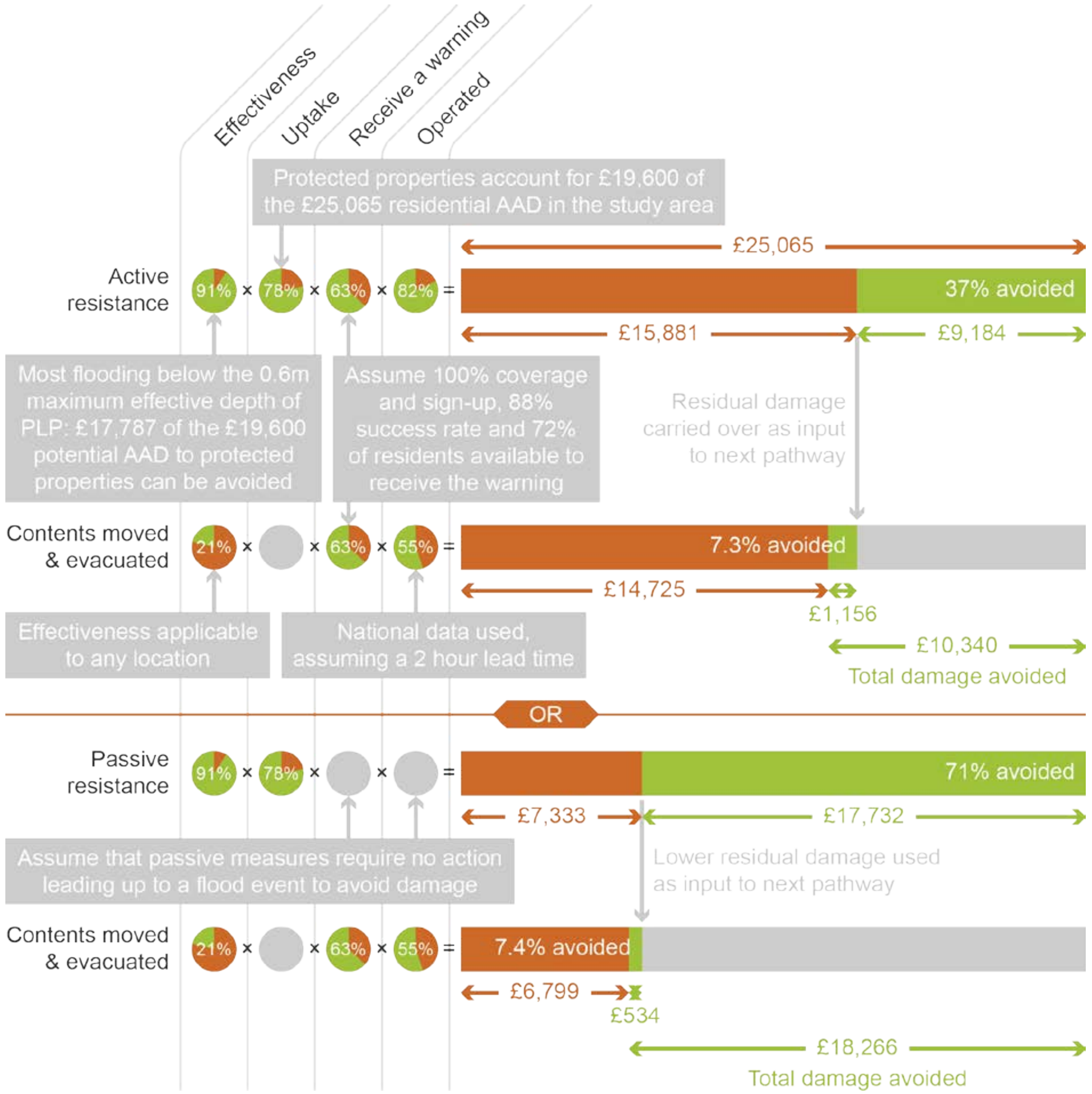
4.1 National scale

This case study builds on analysis for the Environment Agency Long-Term Investment Strategy to assess the benefits of flood risk management actions and advice in England and Wales. This application estimates the benefits of property level responses: resistance and resilience measures; and contents moved and evacuated. The results below use the national average values detailed in Chapter 6.



4.2 Forest Row, East Sussex

Forest Row in East Sussex is subject to fluvial flood risk from the River Medway and its tributary, the Kidbrooke Stream. A Defra-funded property level protection (PLP) scheme completed in 2011 to 2012 protects 47 properties on the Kidbrooke Stream and River Medway. It uses warning-independent resistance (flood-proof doors) and some warning-dependent resistance (flood guards), with self-closing airbricks and non-return valves. This case study estimates the current benefits of property level responses; in this case, resistance measures, and moving and evacuating contents.



4.3 Aylesford, Kent

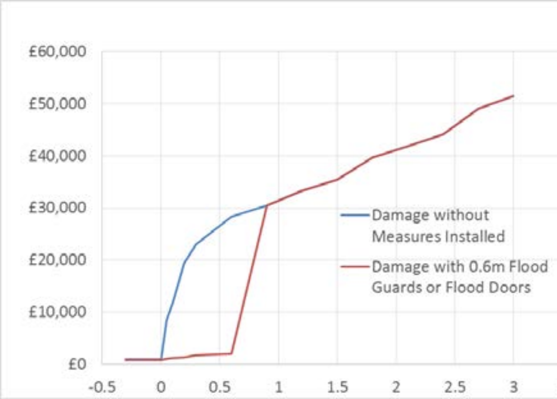
Aylesford in north Kent is at risk of fluvial flooding from the upstream River Medway and a small tributary. It has no Defra-funded PLP scheme but some independently installed resistance measures. This case study estimated the whole-life benefits of property level responses for a hypothetical proposed property level scheme.

Calculations

To carry out the depth-damage calculation, a MCM property classification is required. In this case, an MCM code 1 ‘average’ residential property is assumed. PLP costs are estimated at £4,830 with annual maintenance cost at 5% of capital costs, assuming a 100-year time frame and resistance measures requiring replacement every 20 years.

Depth-damage curves

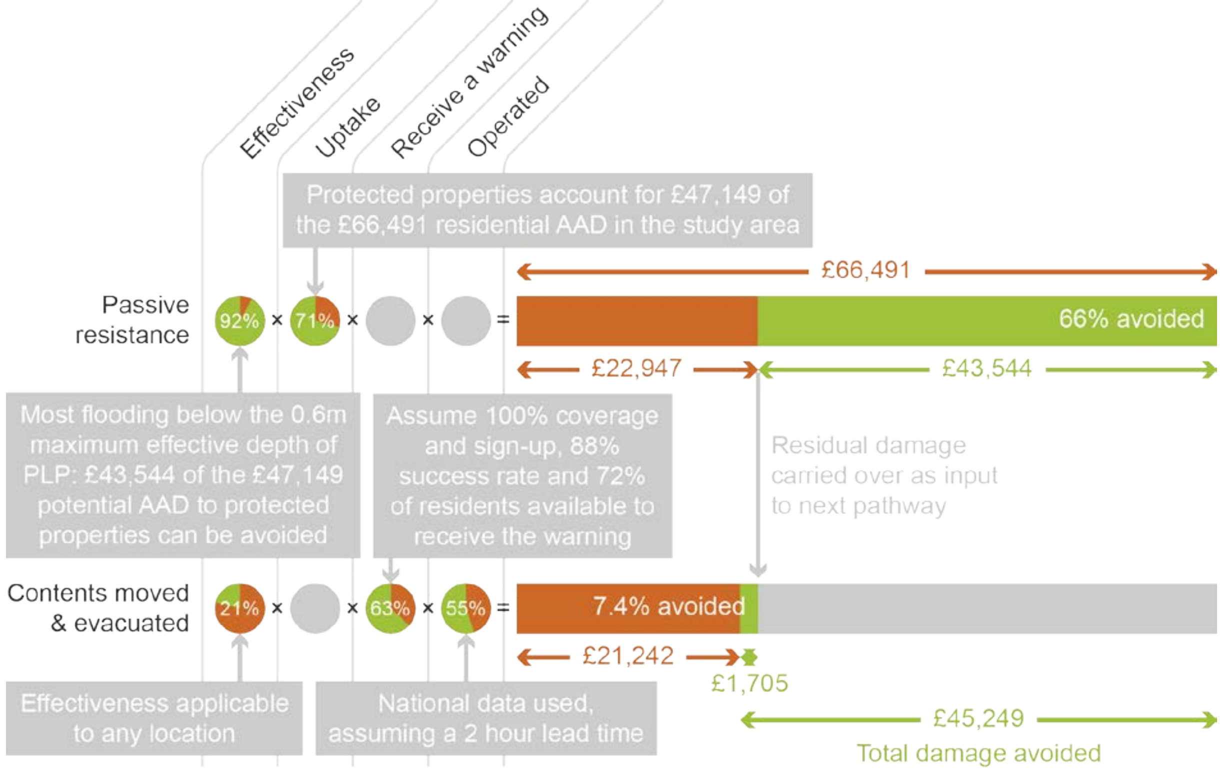
Taken from MCM 2010; PLP assumed damages to reduce for flood depths <0.6 m



Depth-damage calculation: results for an example property in Aylesford

Event probability	Flood depth	Damage without PLP	Damage with PLP
0.5	Null	£0	£0
0.2	Null	£0	£0
0.05	0.35	£43,570	£3,332
0.02	0.43	£45,990	£3,465
0.01	0.45	£46,708	£3,504
0.005	0.47	£47,211	£3,532
AAD		£5,547	£422

Benefit calculations assuming PLP is installed in 20 properties



Protected properties account for £47,149 of the £66,491 residential AAD in the study area

Most flooding below the 0.6m maximum effective depth of PLP: £43,544 of the £47,149 potential AAD to protected properties can be avoided

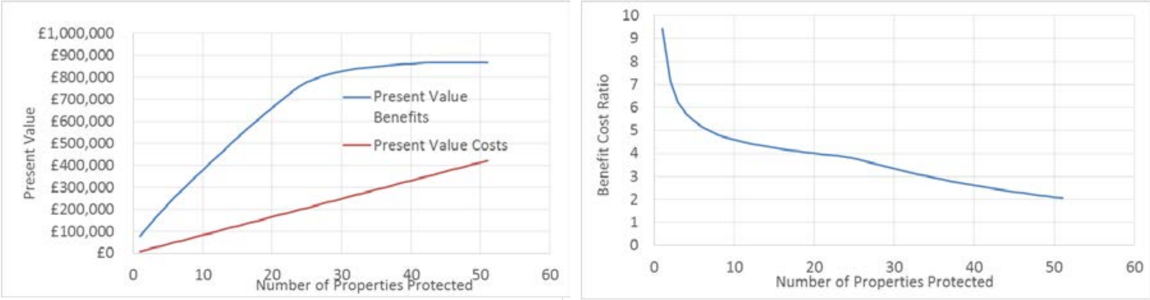
Assume 100% coverage and sign-up, 88% success rate and 72% of residents available to receive the warning

Residual damage carried over as input to next pathway

Effectiveness applicable to any location

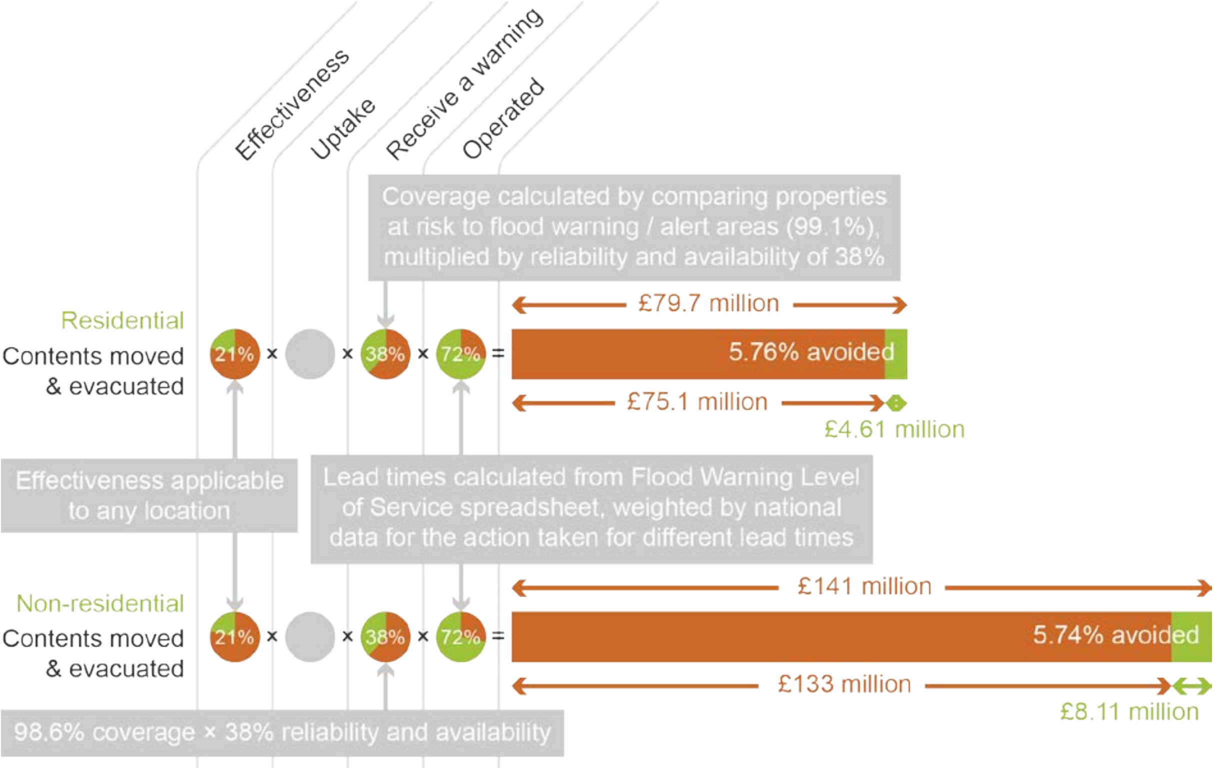
National data used, assuming a 2 hour lead time

Whole-life assessment studying benefits and costs for different levels of investment in PLP



4.4 Lower Aire, Yorkshire

This case study demonstrates how MDSF2 results can be used as inputs to the ANSR tool without the need for additional model runs. This case study assesses the impacts avoided through household contents being moved or evacuated. An MDSF2 model was available for the area and the Lower Aire flood risk management strategy did not consider PLP as an option.

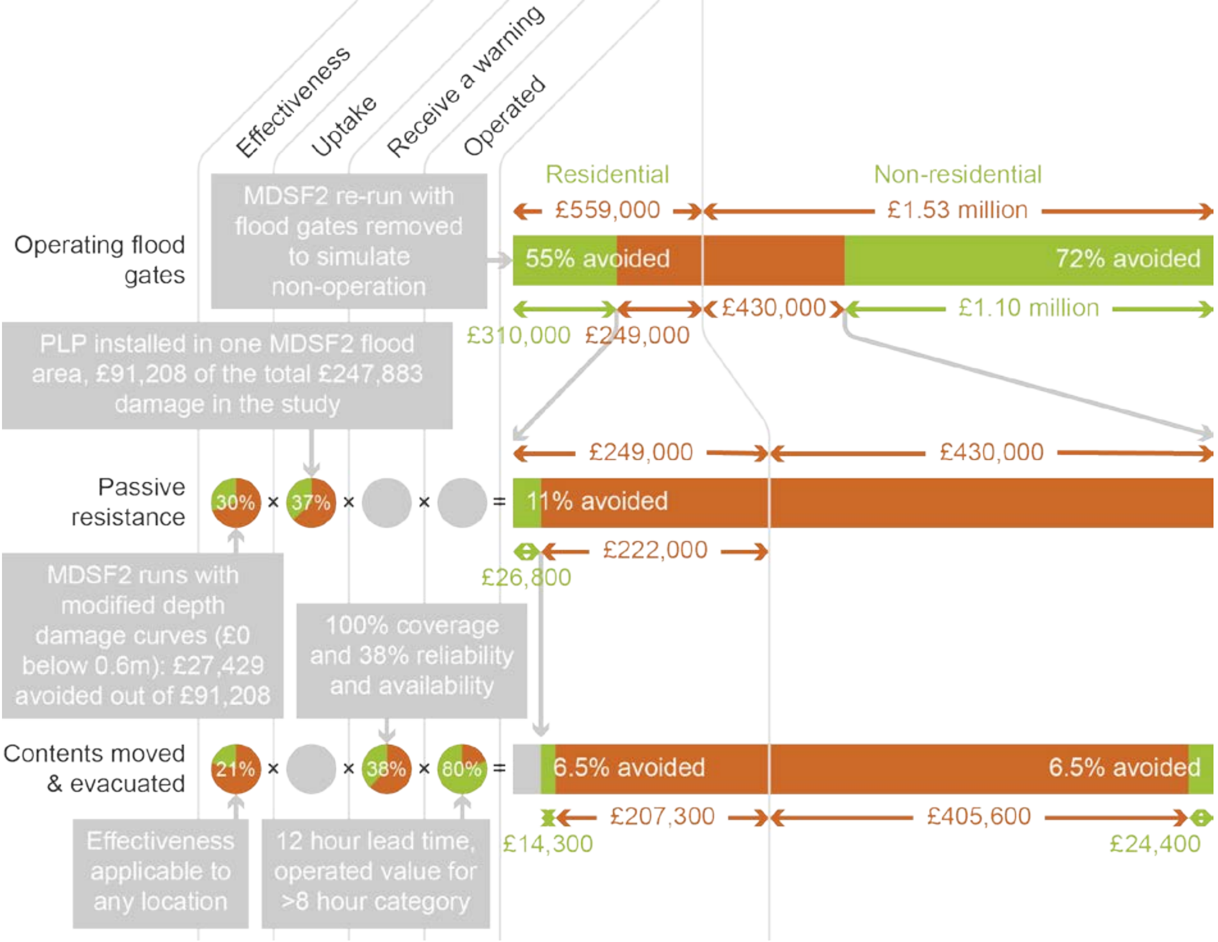


4.5 Deben Estuary, Suffolk

This case study investigates the use of MDSF2 to derive input values for the ANSR tool. By making additional modified scenario runs of an MDSF2 model, it is possible to generate the specific input data required to quantify the benefits of working with assets and property level responses. The MDSF2 model of the Deben Estuary has three scenarios (‘do nothing’ where defences are allowed to deteriorate, ‘do minimum’ where defences are maintained but not improved, and ‘do something’ where new defences are built), each with three snapshots (2015, 2050 and 2114). These were used with two additional runs representing open flood gates and another representing PLP to estimate damages to assess the potential for their implementation.

Deriving input value for the benefits assessment

The MDSF2 PLP run assumed properties are protected up to a level of 0.6 m of flood water. Using the MDSF2 figures, it was possible to identify properties that would gain the most from PLP and, for each sub-area, estimate an update value, which is combined for all sub-areas into one value (see below). In addition, MDSF2 damage figures can be used to estimate effectiveness.



Assessment of future benefits using MDSF2 model runs for 2050 and 2114

Scenario	Year	AAD	AAD avoided by passive resistance	Residual AAD
Present day	2015	£248,000	£26,800	£222,000
2050 (do minimum)	2050	£351,000	£24,900	£326,000
2114 (do minimum)	2114	£1.76 million	£35,100	£1.73 million

This forms the basis of a **whole-life assessment.**

	Warning-independent (passive) resistance	**Warning-dependent (active) resistance**
Whole-life residual impacts with assets only	£16.4 million	£16.4 million
Whole-life impacts avoided by resistance measures	£876,000	£329,000
Whole-life costs	£264,000	£132,000
Benefit–cost ratio	3.31	2.49

4.6 Emsworth to East Head, Hampshire and Sussex

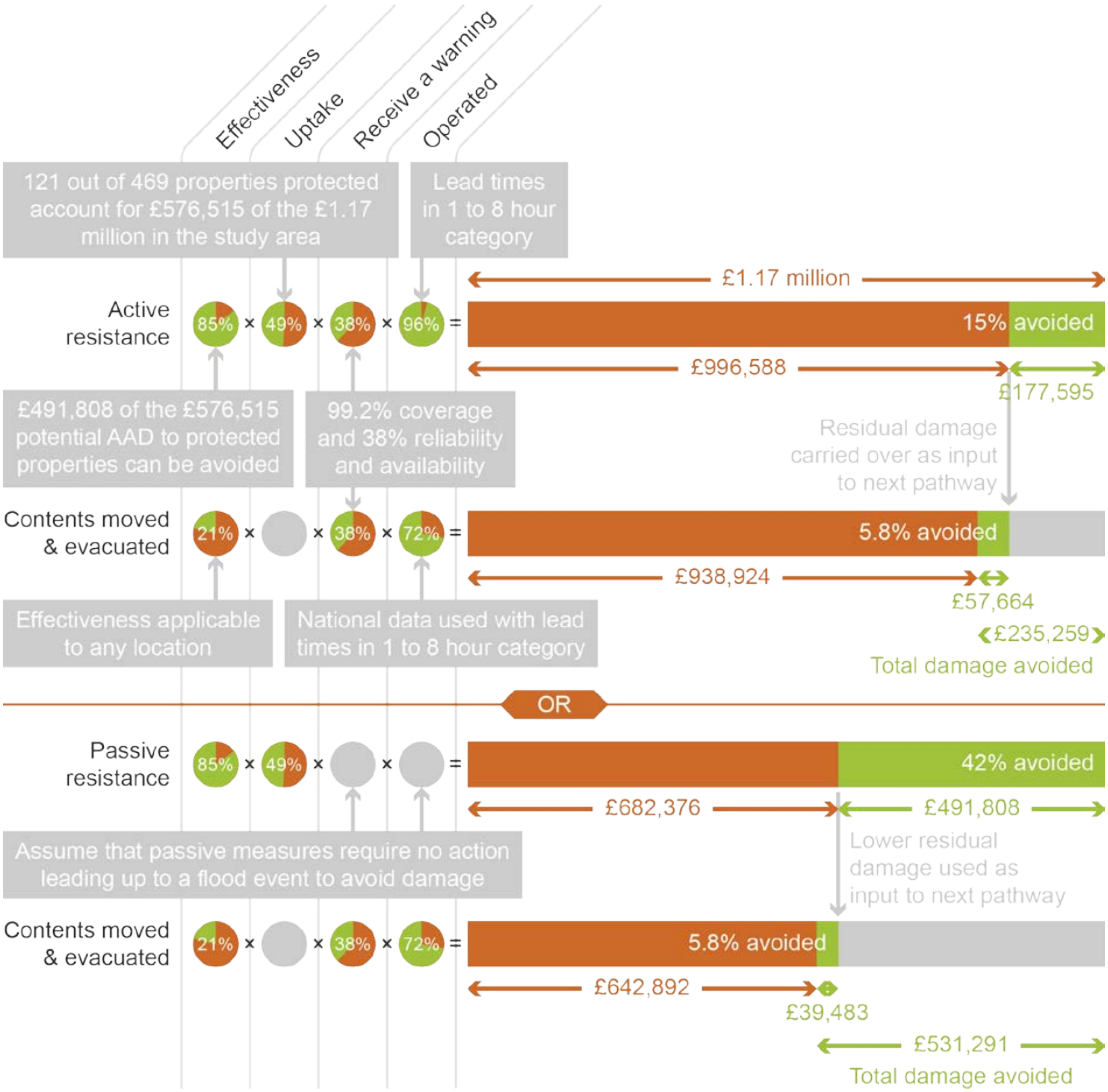
The purpose of this case study is to:

- investigate how MDSF2 results can be used in the ANSR tool without carrying out any further model runs
- quantify the benefits of the responses in ANSR

The aim is to identify a method for estimating the potential benefits of PLP without having to re-run MDSF2. Rather than using the built-in MDSF2 expected annual damages (EAD) calculation, this study followed a WAAD-based method, based on the flood probability of each flood cell. Benefits were calculated for the present day, 2053 ‘do minimum’ and 2112 ‘do minimum’ scenarios. The total direct property damage and residential component were calculated.

Deriving input value for the benefits assessment

The MDSF2 PLP run assumed properties are protected up to a level of 0.6 m of flood water. Using the MDSF2 figures, it was possible to identify properties that would gain the most from PLP and, for each sub-area, estimate an update value which is combined for all sub-areas into one value (see below). In addition, MDSF2 damage figures can be used to estimate effectiveness.



Assessment of future benefits using MDSF2 model runs for 2050 and 2114

Scenario	Year	AAD	AAD avoided by PLP	Residual AAD
Present day	2012	£1,174,183	£937,043	£237,140
2053 (maintain crest levels)	2053	£1,773,856	£1,464,369	£309,488
2112 (maintain crest levels)	2112	£2,264,510	£1,925,120	£339,391

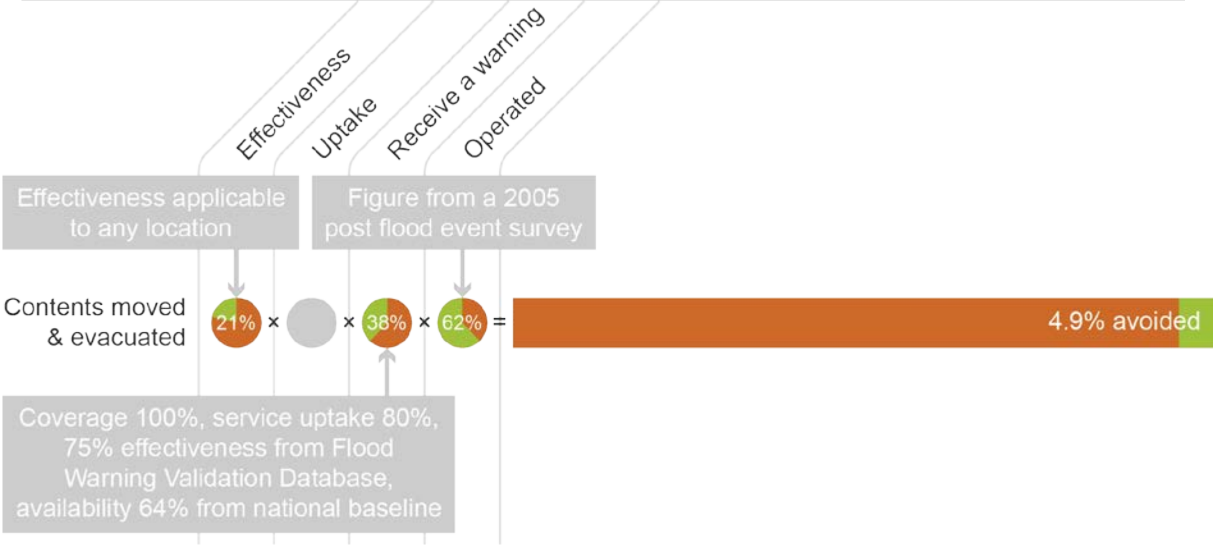
This forms the basis of a **whole-life assessment**.

	Warning-independent (passive) resistance	**Warning-dependent (active) resistance**
Whole-life residual impacts with assets only	£50.9 million	£50.9 million
Whole-life impacts avoided by resistance	£47.5 million	£17.2 million
Whole-life costs	£10.2 million	£5.08 million
Benefit–cost ratio	4.7	3.4

4.7 Appleby-by-Westmorland

Appleby is a small Cumbrian town which suffers primarily from fluvial flooding from the River Eden. Appleby was included in one of the Defra resistance and resilience pilots and, in 2009, 34 properties received funding to install measures. This is discussed in more detail in Appendix B.6. This case study illustrates the benefits of flood warning at a local scale.

The quantified component of this case study is limited to a percentage reduction in damage resulting from contents moved and evacuated. The reasons for this are discussed in detail in Appendix B.6.



5 ANSR spreadsheet tools

Two spreadsheet tools (ANSR and ANSR Lite) implement the quantification method discussed in Chapter 3 to estimate the direct property damages avoided by components of the benefits assessment framework introduced in Chapter 2.

Both tools follow the same basic principle of calculating percentage reductions in damages for each pathway, based on a series of input factors, multiplying them by annualised damages to obtain the damages avoided, and subtracting those damages in sequence.

The spreadsheets aim to enable the quantification of the benefits of:

- working with assets – activating flood defences, erecting temporary or demountable defences and maintaining watercourses
- property level responses – active and passive resilience measures, resistance measures, and moving or evacuating contents

5.1 Working with assets

Required data

- Undefended annual direct property damage
- Residual (defended) annual direct property damage
- Proportion of damage avoided as a result of **active** measures
- Success rate of activating those measures

The tools quantify the benefits of working with assets by allowing the user to associate a percentage of the damage avoided by assets (that is, $Undefended - Residual$ damage) to each warning-dependent (active) asset:

- Flood defence operation – for example, closing flood gates in defence lines, flood barriers
- Community-based operations – for example, erecting temporary and demountable defences
- Non-routine watercourse management – for example, removing blockages

The tool assumes that any percentage not attributed to these actions is assigned to passive flood defences and routine watercourse management.

Users can also attach a ‘success factor’ to each of the warning-dependent actions to account for any probability that they might not be carried out as designed such as flood gates are not closed on time, temporary and demountable defences do not arrive on site on time, or blockages that result in flooding are not entirely prevented.

ANSR splits this success factor into the warning component (reliability and availability) and the percentage operated, while ANSR Lite simplifies this to a single factor. The tools calculate a new damage avoided value for each action (*i*):

$$\begin{aligned}Damage\ avoided_i\\ &= (Undefended - Defended) \times Assigned\ Proportion_i\\ &\times Success\ Factor_i\end{aligned}$$

Thus, a new uplifted residual 'defended' damage value is calculated, where *i* represents each 'working with assets' action:

$$\begin{aligned}&Residual\ damage\\&\quad = Undefended\ damage - \sum_{1}^{i} Damage\ avoided_i\\&\quad - Damage\ avoided_{Passive}\end{aligned}$$

This residual damage value (or the user-inputted residual damage value if the success factor is left at 100%) is used as the input damage value for the benefits of property level responses calculation.

5.2 Property level responses

Required data

- Residual (defended) annual direct property damage
- Values for factors for each pathway included in the application (to a suitable level of detail for the scale and purpose of the application):
    - reliability of the warning process and availability of respondents to receive and act on that warning
    - uptake in the measure – the proportion of the potential damage to protected properties to the total potential damage for the study area
    - percentage of properties in each lead time category – used to calculate the percentage of measures operated in the available time
    - effectiveness of the measure – the proportion of the damage avoided to the potential damage to protected properties

The user can input values for each factor for each pathway, which are then multiplied together to obtain the percentage damages avoided by that pathway.

The percentage operated factor is a special case. Rather than directly inserted values for the factor, values for the percentage operated for different lengths of lead time are given and the user inserts the percentage of properties at risk in each lead time category. The tool then amalgamates this into a percentage operated factor. This approach means that, if the user simulates investment in increasing lead times, they can estimate the benefits by simply changing the percentage distribution and letting the tool calculate the new percentage operated factor.

The tools include the best available data for the percentage operated given a lead time, as collated by Priest and Parker (2012) from post-flood event surveys as part of this project. Users can override this if better data become available.

$$\%Operated = \sum \%Properties\ in\ Category \times \%Operated\ for\ Category$$

The tools calculate the damages avoided by each pathway by applying the percentage damages avoided to the residual damage in sequence, with each calculation using the output damage from the previous calculation as its input. This is intended to avoid double-counting of benefits. For example, an increase in the benefit of resistance measures is likely to decrease the benefit of contents moved and evacuated because, with the resistance measures in place, the interior of the property does not flood.

The percentage damages avoided by active and passive resistance measures are added together before being applied, because they are assumed to be mutually exclusive and to act at the same point in the system. This is because a single entry point to a property which is warning-dependent (active) effectively makes the entire property warning-dependent.

$$\begin{aligned}&\mathit{Damage\ Avoided\ by\ Resistance\ Measures}\\&\qquad= [\%\ \mathit{Active} + \%\ \mathit{Passive}] \times \mathit{Residual\ Damage}\end{aligned}$$

5.3 ANSR Lite

ANSR Lite provides a simple, single scenario implementation of the methods to quantify the benefits of working with assets and property level responses. The tool is divided into three worksheets in a Microsoft® Excel workbook, arranged by the level of depth a user requires:

- **Summary tab** (Figure 5.1). Users insert residual (and, if required, undefended) damage values. For a very high level assessment, ANSR Lite presents results based on the national average values of factors. For more detailed assessments, the summary tab presents the results based on input values inserted on other tabs.
- **Standard inputs tab**. There are sections on the standard inputs tab for attributing damage avoided by assets to each ‘working with assets’ pathway and for inputting the factors for the ‘property level responses’ pathways. Certain values (such as the percentage operated given a particular lead time) are prefilled, based on the assumption that these are: (a) the best available data; and (b) applicable to any location, made locally applicable by the accompanying data. A complete calculation is shown on this tab and is also compiled on the summary tab.
- **Detailed values tab**: The final tab allows users to override the default values if improved evidence becomes available or if higher quality data are available for their particular area of study. These changes feed into the calculations on the standard inputs tab and the summary tab.

Damage inputs

	Residential		Non-residential		Total
Total **undefended** damage	£1,560,000	+	£1,440,000	=	£3,000,000
Total **defended** (residual) damage	£520,000	+	£480,000	=	£1,000,000

i ANSR Lite

ANSR Lite is a cut-down and simplified version of the ANSR spreadsheet, for quantifying the benefits of flood risk management activities such as flood incident management (FIM) and property-level protection, and the benefits of FIM enabling the successful operation of assets.

i Summary (this worksheet)

If you only change the damage inputs on this worksheet, the graphs and values below estimate benefits based on national average figures. For a more detailed assessment, you can edit these figures on subsequent worksheets.

Benefits calculation

Working with (enabling) assets

	Damages avoided
Passive defences	£1,220,000
Active defences	£560,000
Watercourse management	£20,000
Community-scale defences	£200,000

Individual/community response

	Damages avoided
Resistance measures	£33,306
Resilience measures	£9,667
Contents moved and evacuated	£44,775

Figure 5.1 Screenshot of the summary tab of ANSR Lite with sample data

5.4 ANSR

ANSR allows users to carry out more complex calculations than ANSR Lite. Important additional functionality includes:

- ability to provide three values for each factor to present the possible range and uncertainty
- separation of residential and non-residential property level responses
- scenario analysis using ‘investment–benefit’ functions that estimate changes to values in factors, based on changes in investment in particular areas
- consideration of wider impacts through ‘benefit uplift factors’, applied as multipliers to the direct property damage, and giving users the ability to alter the level of effectiveness that each pathway has for each wider impact category
- ability to assign confidence levels to each factor, which are then amalgamated to give users an understanding of the overall level of confidence

ANSR has a number of worksheets and tabs to facilitate this more extensive feature set. The main user workflow is summarised in Figure 5.2 and examined in more detail in the ANSR User Guide (Appendix C).

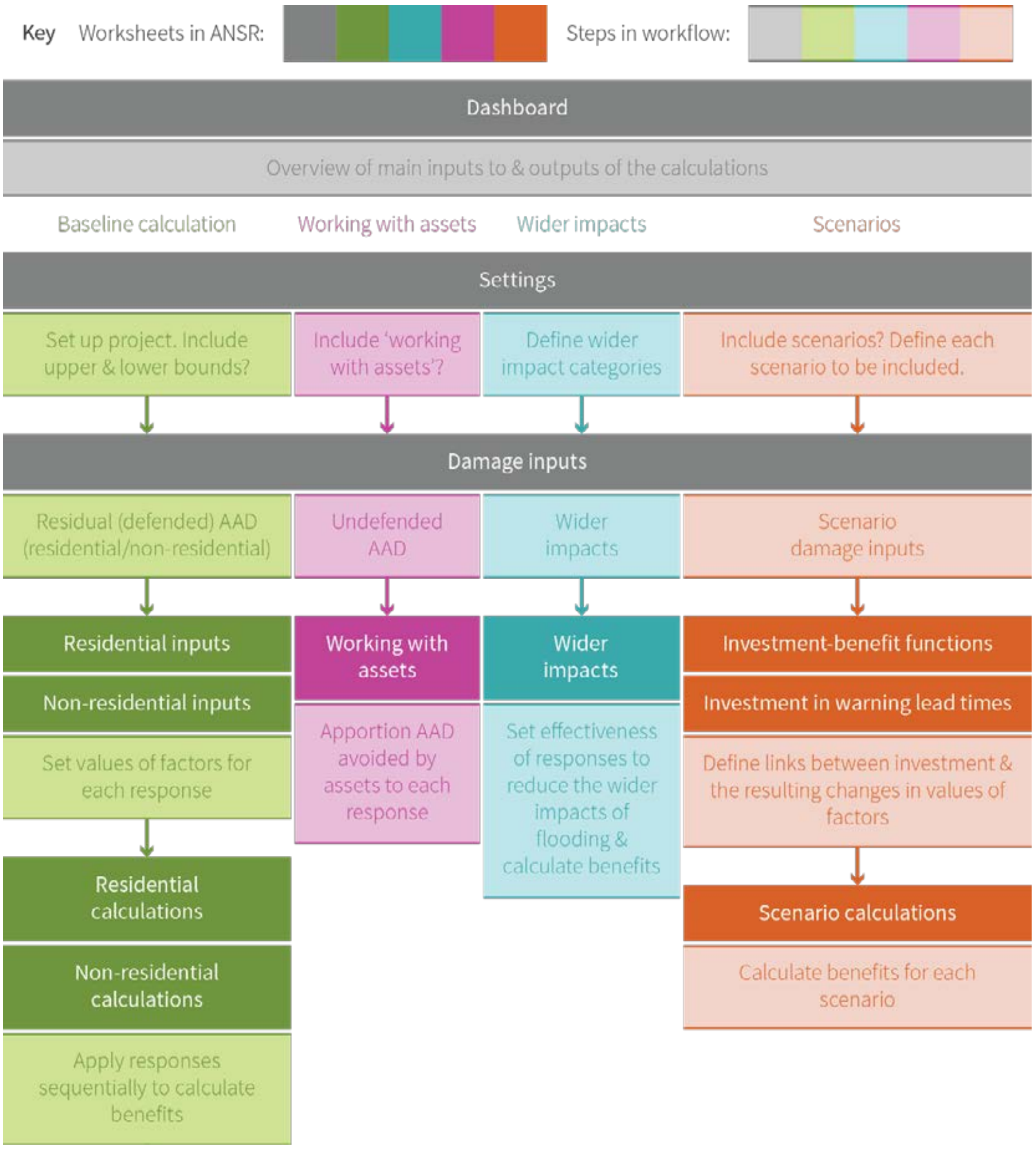


Figure 5.2 Worksheets in ANSR and steps in the workflow

Figure 5.3 shows the ANSR dashboard with an example analysis made up of a baseline and two additional scenarios, quantifying the benefits of working with assets, and residential and non-residential property level responses. Figure 5.3 also shows the corresponding investment and confidence levels.

	Investment Scenarios		
	Baseline	Scenario 1	Scenario 2
Detection, forecasting & warning	£27 Million	£54 Million	£13.5 Million
Emergency planning & exercising	£17.1 Million	£34.2 Million	£8.55 Million
Working with communities	£18.9 Million	£37.8 Million	£9.45 Million
Resistance & resilience	£10 Million	£20 Million	£5 Million
Total Investment:	£73 Million	£146 Million	£36.5 Million

		Direct Property Damages Avoided by NSRs		
		Baseline	Scenario 1	Scenario 2
Toggle	NSRs Working with Assets	£710,856,000	£735,390,099	£359,261,716
FDO	Flood Defence Operation	£548,856,000	£554,400,000	£280,603,146
WCM	Watercourse Management	£90,000,000	£100,990,099	£41,848,503
CBO	Community Based Operations	£72,000,000	£80,000,000	£36,810,068
Toggle	Residential Property-Level NSRs	£46,044,962	£66,342,059	£29,089,490
RST	Resistance Measures	£17,749,441	£20,799,439	£15,030,992
RSL	Resilience Measures	£5,022,506	£9,784,331	£2,550,611
CME	Contents Moved & Evacuated	£23,273,015	£35,758,290	£11,507,887
Toggle	Non-Residential Property-Level NSRs	£42,503,042	£61,238,824	£26,851,837
RST	Resistance Measures	£16,384,100	£19,199,482	£13,874,761
RSL	Resilience Measures	£4,636,159	£9,031,690	£2,354,411
CME	Contents Moved & Evacuated	£21,482,783	£33,007,652	£10,622,665
	Total Damage Avoided:	£799 Million	£863 Million	£415 Million

	Residual Direct Property Damages		
	Baseline	Scenario 1	Scenario 2
Residual Damage with Assets Only:	£1,000,000,000	£1,000,000,000	£1,000,000,000
Residual Damage with Assets & NSRs:	£911,451,996	£872,419,116	£944,058,673

Distribution of Confidence Levels (number of data assigned each level of confidence)

Average Score: 2.91

1	Comprehensive evidence gathered using best practice
2	Reliable analysis and method (but with known deficiencies)
3	Expert judgement, supported by some quantified evidence and/or by consensus at an experts' workshop
4	Expert view based on limited information
5	Unsubstantiated non-expert opinion

Figure 5.3 Screenshot of the ANSR dashboard tab, showing the results of an example analysis

NSR = non-structural response; FDO = flood defence operation; WCM = watercourse capacity maintenance; CBO = community-based operations; RST = resistance measures; RSL = resilience measures; CME = contents moved and evacuated.

5.5 Benefits of enabling activities in a scenario analysis

Required data

- Investment levels under:
  - current conditions, or baseline conditions for the year being studied

  - any investment scenario being studied
- Attribution of investment levels to a range of ‘investment activities’
- For each ‘investment activity’:
  - minimum investment that has to be maintained to continue achieving any benefit, such as the fixed costs, relative to baseline investment
  - maximum possible value of the factor, regardless of how much was invested, relative to its baseline value

ANSR quantifies the benefits of ‘enabling’ activities (see Section 3.2.1) by estimating their effect on the value of factors in the equations under different investment scenarios.

The tool has a function to represent the relationship between the level of investment in a given activity and the value of the factor it influences. The function is based on the general equation, $y = ba^{-x} + c$. This was chosen as it tends towards an asymptotic maximum value, which is assumed to be a reasonable representation of the reality of diminishing returns (that is, the higher the value of a factor, the more difficult or expensive it becomes to increase the value further).

ANSR uses the minimum investment level required to achieve any benefit (for example, the fixed costs, the point where the curve crosses the x-axis) and the maximum value that could be achieved no matter how much was invested (the asymptotic maximum) to generate this ‘investment–benefit’ function. A third point on the curve is derived from the assumption that, if investment continued at its current level, the values of the factors (the percentage damages avoided) would also remain fixed (1× investment = 1× relative value of the factor it influences).

Figure 5.4 shows an example function, with a maximum value of 2.4× the baseline value and a minimum investment of 0.1x the baseline investment.

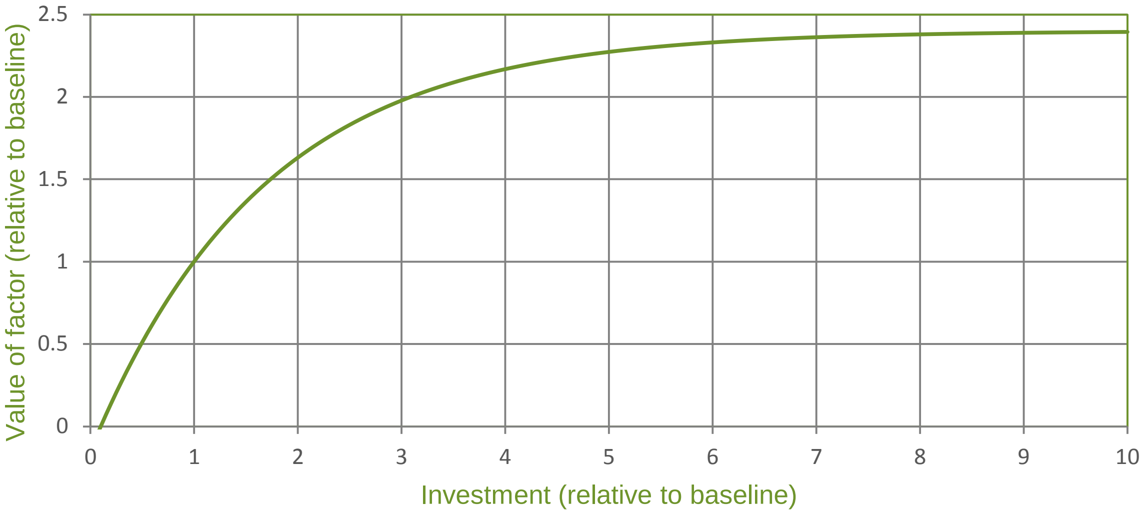


Figure 5.4 Example ‘investment–benefit’ function.

5.6 Wider impacts

Parker and Priest (2012) developed the concept of ‘benefit uplift factors’ as part of this project and the Flood Incident Management Investment Review (Halcrow Group 2013).

The concept addresses the need to quantify not just the direct property damages but also a broader array of flood impacts – within the constraints of limited data available to quantify those impacts accurately.

In the ANSR tool, direct property damages can be uplifted to account for the wider impacts of flooding using a series of uplift factors – in the form of ratios to the direct property damage. These could be categorised in any way that is relevant to the particular application, but ANSR includes the following categories:

- other economic impacts (in addition to direct property damages)
- infrastructure impacts
- health and social impacts
- risk to life
- institutional impacts (for example, trust in the Environment Agency)
- other impacts

The categories were developed as part of the Flood Incident Management Investment Review (Halcrow Group 2013) and used in this project.

The flood/catchment type and socioeconomic characteristics of the affected population are important factors in determining the magnitude of the uplift. Ratios have been estimated for each permutation of these important factors. The results suggest the unquantified benefits may be as or more important than the quantified ones.

Responses to flood risk may be more or less effective at reducing these wider impacts than they are at reducing direct property damages. ANSR allows users to adjust the 'effectiveness' factor for each pathway and for each wider impact category to allow for this variation.

A limitation of this approach is that the estimation of wider impacts is directly linked to (dependent on) direct property damages. For regional and national applications, where the uplift factors are derived from similar large-scale datasets, the approach may be sufficiently accurate for many decision-making tasks. However, for smaller spatial scales, where local factors are important, the approach is less likely to be able to represent the wider impacts. For example, a community may experience no property damages but still suffer wider impacts such as infrastructure and other economic impacts. The benefit uplift approach would erroneously estimate zero wider impacts in this case.

6 Data

The case studies present in Chapter 4 provide an understanding of the data requirements of applying the methods described in this report and how to satisfy those requirements. In particular, the national scale case study (Section 4.1) provides estimates of input values for high-level applications and potential data sources and the local case studies (Sections 4.2 to 4.7) give an idea of the potential of variability that may be possible, given specific conditions, and highlighting the need for locally specific data for applications.

6.1 Data requirements

The data requirements for a national and local scale application are quite similar, but the means to obtain those data vary significantly. A local application requires data at a more detailed level with information specific to the area.

Table 6.1 summarises the data requirements of different types of analysis and provides national example values. Appendix D presents a more complete set of information including:

- data sources for the national values shown below
- a discussion of potential local variations to those values
- possible sources of data or methods for calculating values

Table 6.1 Summary table of data requirements with national example values

Factor	Example value	Required for
Undefended damage	£3 billion	Working with assets
Residual (defended) direct property damage	£1 billion	Any application
Residential component of damage	52%	Property level responses (if considering residential and non-residential properties separately)
Proportion of damage avoided by active flood defences	28%	Working with assets (if applicable in the study area)
Proportion of damage avoided by community-based operations	1%	Working with assets (if applicable in the study area)
Proportion of damage avoided by watercourse management	10%	Working with assets (if applicable in the study area)
Percentage of properties which receive a warning (reliability and availability)	30%	Property level responses (active resistance and contents moved and evacuated)
Distribution of properties in lead time categories	0–1 hour lead time: 13%	Property level responses (active resistance and contents moved and evacuated)

Factor	Example value	Required for
	1–8 hours: 70% >8 hours: 17%	
Uptake in resistance measures	8%	Property level responses (active and passive resistance)
Uptake in passive (warning-independent) resistance measures	3%	Property level responses (passive resistance)
Uptake in active (warning-dependent) resistance measures	5%	Property level responses (active resistance)
Effectiveness of resistance measures (average damages avoided if they are installed)	75%	Property level responses (active and passive resistance)
Percentage of active resistance measures successfully operated (given that a property receives a warning and has the measure installed)	0 to 1 hour lead time: 92% 1 to 8 hours: 96% >8 hours: 99%	Property level responses (active resistance)
Uptake in resilience measures	2%	Property level responses (resilience measures)
Effectiveness of resilience measures	50%	Property level responses (resilience measures)
Effectiveness (maximum potential damages avoided) of moving and evacuating contents	21%	Property level responses
Percentage of the potential damage avoided by moving and evacuating contents which is avoided in the time available	0 to 1 hour lead time: 70% 1 to 8 hours: 72% >8 hours: 80%	Property level responses

In addition to the above data, an ANSR analysis investigating the changes in benefits for different scenarios requires investment levels in the relevant activities for a baseline scenario (for example, present day or baseline for year x) and for any investment scenarios being studied. Each investment activity (linked to a factor in the equations) needs data on the minimum investment required to achieve any benefit (‘fixed costs’) relative to the baseline level of investment, and the maximum possible value of the linked factor (regardless of how much was to be invested).

6.2 Data issues

Finding data, in particular for a national scale application where detailed modelling is not available, has proved to be challenging. Crucial areas where further research is needed to improve the quality of data include:

- **Percentage of people who actually receive a flood warning.** The current data are based on a combination of Environment Agency key performance indicators (KPIs) and research carried out by Parker et al. (2007) that predates automatic sign-up to the flood warning service.
- **Action that people take as a result of a flood warning of various lead time lengths (and compared with the action they take with no warning at all) to obtain more accurate 'operated' values.** The current values are high, even for very short lead times, suggesting that people may take a significant level of action regardless of whether they consider themselves to have received a warning. This also raises the question of what exactly should be counted as a benefit to the Environment Agency. The work by Priest and Parker (2012) as part of this project has progressed this but more is needed to obtain a better idea of the impact of different lead times.
- **Associating potential changes in investment to changes in the values of factors to enable scenario analysis**. The Flood Incident Management Investment Review project (Halcrow Group 2013) identified potential changes to factors under different investment scenarios through a process of expert judgment. This is an important area where evidence-based data are unavailable.

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List of abbreviations

AAD	annual average damage
ANSR	appraisal of non-structural responses
BCP	business continuity planning
CBO	community-based operations
CFMP	Catchment-scale Management Plan
CME	contents moved and evacuated
DCLG	Department for Communities and Local Government
D&FR	Development and Flood Risk
Defra	Department for Environment, Food and Rural Affairs
EAD	Expected Annual flood Damages
EF	effectiveness
FCRM	flood and coastal risk management
FDA	flood damages avoided
FDO	flood defence operation
FHRC	Flood Hazard Research Centre
FIM	flood incident management
FRA	Flood Risk Assessment
FRM	flood risk management
FWLoS	Flood Warning Level of Service
FWRBP	Flood Warning Response and Benefit Pathways [model]
KPI	key performance indicator
LLFA	Lead Local Flood Authority
LPA	Local Planning Authority
MCM	Multi-coloured Manual
MDSF	Modelling and Decision Support Framework
NaFRA	National Flood Risk Assessment
NPPF	National Planning Policy Framework
NRD	National Receptor Dataset
NSR	non-structural response
OM	Outcome Measure
OP	operated
PLP	property level protection

PPS	Planning Policy Statement
PR	ability to respond
PVd	Present Value of damages avoided
RA	reliability and availability
RAS	reliability and availability
RSL	resilience measures
RST	resistance measures
SAMP	Strategic Asset Management Plan
SAR	search and rescue
SEPA	Scottish Environment Protection Agency
SFRA	Strategic Flood Risk Assessment
SoP	standard of protection
SuDS	sustainable drainage system
UP	uptake
WAAD	weighted annual average damages
WCM	watercourse capacity maintenance
WIR	warning-independent resistance
WDR	warning-dependent resistance

Appendices

Appendix A Benefits assessment framework

Appendix B Case studies

B.1 Forest Row

Forest Row in East Sussex is subject to fluvial flood risk from the River Medway and its tributary, the Kidbrooke Stream. A 2011 to 2012 Defra-funded PLP scheme protects 47 properties on the Kidbrooke Stream and Medway with mainly warning-independent resistance (flood-proof doors) and some warning-dependent resistance (flood guards), with self-closing airbricks and non-return valves.

This case study estimates the current benefits of property level responses (in this case resistance measures and moving or evacuating contents) in reducing the risk of flooding from the Kidbrooke Stream.

B.1.1 Deriving input values for the benefits assessment

As with the national-scale application, the benefits of a given response to flood risk are calculated using a standard set of equations (Table B.1). Compared with the national-scale application, however, the local application requires a much more detailed approach to derive appropriate input values.

Table B.1 Example generic equation to calculate the percentage damages avoided by a response to flood risk

Percentage damages avoided	**=**	**RA**	×	**UP**	×	**OP**	×	**EF**
		Reliability and availability		Uptake		Operated		Effectiveness

B.1.1.1 Resistance measures

Uptake

The total residential AAD from the Kidbrooke Stream is estimated at £25,065. Thirty-five properties in the PLP scheme are at risk of flooding from the Kidbrooke Stream. These 35 properties contribute to £19,600 of the AAD. Therefore:

$$Uptake = \frac{19600}{25065} = 78.2\%$$

Effectiveness

Thurston et al. (2008) and Stevens and Chatterton (2012) developed a method for calculating the benefits of property level protection at the national scale. A crucial component is that internal inventory damage and internal building fabric damage are reduced to zero when the flood depth is below the 0.5 m maximum effective depth of the resistance measures, while other elements of the property damages remain unaffected by the presence of resistance.

Applying this logic to each individual property results in £17,787 of the £19,600 potential AAD being avoided if resistance measures are put in place successfully. Therefore:

$$Effectiveness = \frac{17787}{19600} = 90.7\%$$

Reliability and availability

It is assumed that coverage and service uptake is 100%, as sign-up to the flood warning service is a requirement of participation in the PLP scheme. The probability that a warning will be successfully disseminated is estimated at 88%, based on Environment Agency KPIs. The probability that residents will be available to receive the warning is estimated at 72%. Therefore:

$$Reliability\ and\ availability = 100\% \times 88\% \times 72\% = 63\%$$

Operated

The value for the percentage of properties with resistance measures in place is assumed to be equivalent to the percentage of residents who take effective action. This assumption is made because, if a resident takes any action, putting their flood guards in place will be their first action. This has been estimated at 82%, based on the mean value from a series of post-flood event surveys nationally in 2006 and 2007.

$$Operated = 82\%$$

Warning-independent or warning-dependent?

Although it is known that the scheme includes a combination of warning-independent (flood-proof doors) and warning-dependent (flood guards) resistance measures, the exact breakdown of that combination is not known. Pre-scheme documentation describes the planned split as being heavily biased towards warning-dependent, but from discussions with local staff, it appears there was a shift towards using flood-proof doors part way through the project.

If all properties had warning-independent resistance:

$$\begin{aligned}\boldsymbol{Damages\ avoided} &= \boldsymbol{Uptake} \\ &\quad \times \boldsymbol{Effectiveness} \\ &= 78.2\% \times 90.7\% \\ &= 70.9\%\end{aligned}$$

If, however, all the properties had warning-dependent resistance:

$$\begin{aligned}\boldsymbol{Damages\ avoided} &= \boldsymbol{Reliability}\ \textbf{and}\ \boldsymbol{Availability} \times \boldsymbol{Uptake} \times \boldsymbol{Operated} \\ &\qquad \times \boldsymbol{Effectiveness} \\ &= 63\% \times 78.2\% \times 82\% \times 90.7\% \\ &= 36.6\%\end{aligned}$$

B.1.1.2 Resilience measures

There is no record of resilience measures being installed in Forest Row, so uptake is set at zero.

B.1.1.3 Contents moved and evacuated

Data from the England and Wales application were used to estimate the additional AAD avoided by moving and evacuating contents:

$$\begin{aligned} \boldsymbol{Damages\ avoided} &= \boldsymbol{Reliability}\ \textbf{and}\ \boldsymbol{Availability} \times \boldsymbol{Operated}\\ &\qquad\qquad \times \boldsymbol{Effectiveness}\\ &= 63\% \times 55\% \times 21\%\\ &= 7.28\% \end{aligned}$$

B.1.2 Results

Table B.2 summarises the results of the benefits calculation for both warning-independent and warning-dependent resistance measures.

Table B.2 Summary of results for the benefits of PLP at Forest Row

		Annual damages and damages avoided	
Type of resistance measure installed in properties in scheme		Warning-independent resistance	Warning-dependent resistance
Annual average damage without property level responses		£27,434	£27,434
Residential property level responses			
RST	Resistance measures	£17,787	£9,252
RSL	Resilience measures	£0	£0
CME	Contents moved and evacuated	£541	£1,176
Total damages avoided by residential property level responses		£18,328	£10,428
Non-residential property level responses			
RST	Resistance measures	£0	£0
RSL	Resilience measures	£0	£0
CME	Contents moved and evacuated	£100	£100
Total damages avoided by non-residential property level NSRs		£100	£100
Total damages avoided by property level responses		£18,428	£10,528
Residual damages with property level responses		£9,005	£16,905

B.1.3 Discussion

This study identifies significant data issues. For a detailed local assessment, the important data are depth grids that a two-dimensional hydraulic model would output, not available for the River Medway. Data from the National Receptor Dataset (NRD) are also limited, as there is no detailed breakdown of types of residential property such as types, ages or social classification of property.

The comparison of warning-dependent and warning-independent resistance measures highlights the importance of accurate estimation of the values for the warning components of the calculation. As it stands, this calculation estimates that warning-independent resistance measures could avoid 71% of the AAD, significantly more than the 37% for warning-dependent resistance measures. This does not take into account the potential increase in awareness that property level protection may offer and subsequent increases in the effectiveness of the residents' actions.

However, the study suggests there is potential for significant reductions in damages through the careful use of resistance measures. The Kidbrooke Stream is a strong location for warning-independent resistance, as there is a high probability of flooding but depths rarely (if ever) exceed the maximum effective depth of resistance measures.

B.2 Aylesford

This local fluvial worked example explains the process for calculating the whole-life benefits of property level responses, with calculations for a worked example: a hypothetical proposed PLP scheme in Aylesford, Kent.

The general approach and guidance are written in plain text.

The Aylesford-specific approach and results are in green boxes.

B.2.1 Background

Aylesford in north Kent is at risk of fluvial flooding from the upstream River Medway and a small tributary. It has no Defra-funded PLP scheme but may have some independently installed resistance measures. This example calculates the potential benefits of PLP in reducing the risk of flooding from the tributary.

B.2.2 Data requirements

- Ordnance Survey background maps (for information)
- National Receptor Dataset for the study area
- Flood depth grids for a range of return periods (or terrain data and water level grids)
- Multi-Coloured Manual depth-damage data
- Local flood warning information, if available:
  - likely lead times for the area
  - likely effectiveness of residents' responses, based on their level of engagement with flood risk and other community factors

B.2.3 Calculations

B.2.3.1 Receptor data

To carry out the depth-damage calculation, an MCM property classification is needed. MCM depth-damage data are provided for a variety of residential property types, but the NRD only provides a basic classification (MCM code 1 for the 'average' residential property). However, it does also provide floor areas, which could be used to more accurately calculate the damages using the MCM code 1.

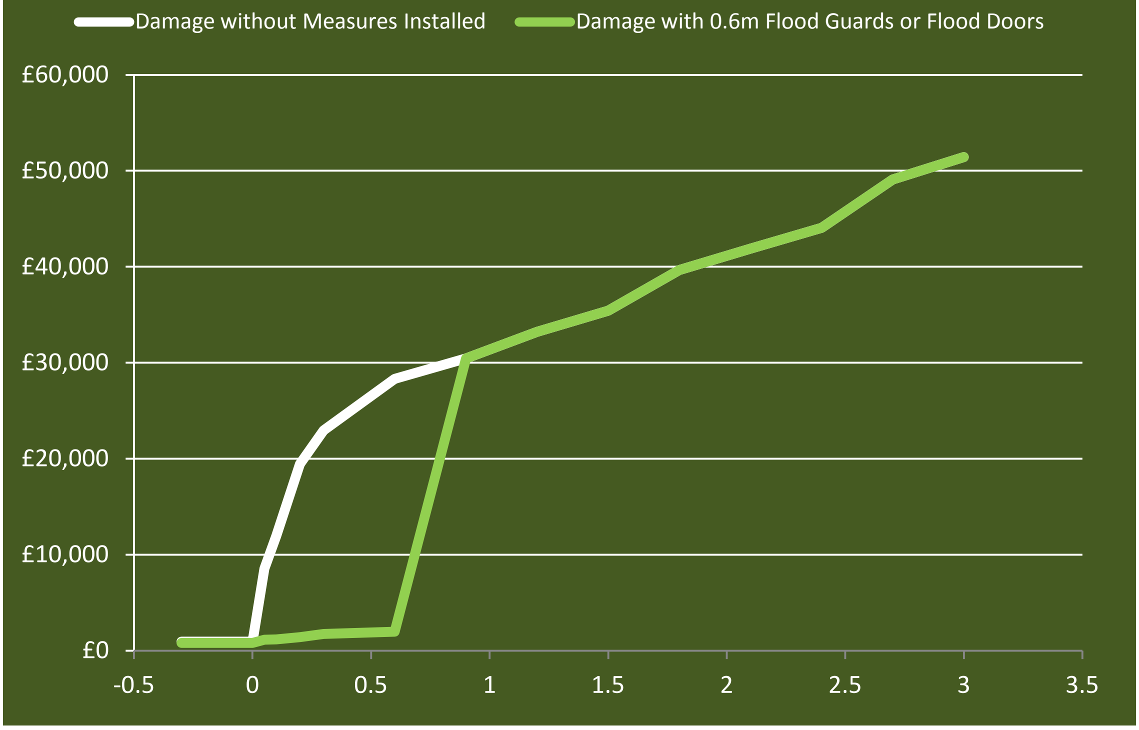
For a comprehensive study, the more detailed classifications (for property type, age and social classification) may be needed. Google Street View or a site visit could be used to observe the property type and judge the property age from the architectural style of the property. Historical maps may also be of use in determining the property age.

For this example, MCM code 1 was used for all residential properties, with damages based on the floor area given in the NRD.

B.2.3.2 Depth-damage curves

Standard depth-damage curves need to be supplemented with adjusted curves for protected properties. In this example, properties are assumed to be protected by resistance measures (flood-proof doors or flood guards) up to a depth of 0.6 m, combined with complementary measures required to ensure protection up to that depth (such as non-return valves, self-closing air bricks and, if necessary, window guards). With these measures in place, it is assumed that the internal inventory damage and internal building fabric damage would be reduced to 0 for flood depths less than 0.6 m, but that external inventory and external building fabric damage would be unaffected.

The depth-damage curves (taken from MCM 2010) shown below were used for the Aylesford case study. The graph shows per-property damages, which were divided by the average property floor area given in MCM and then multiplied by the floor area for each property.



B.2.3.3 Depth-damage calculation

A depth-damage calculation is required for each property with and without PLP installed. This could be carried out using a spreadsheet (by calculating damages with and without PLP using flood depths and damages given above) or using a damage calculation tool (such as ISIS Damage Calculator) with standard and modified depth-damage databases. The results are then combined to calculate the AAD with and without PLP installed per property (Table B.1).

If estimated future depth grids are also available, these can be used to create multiple epochs. However, the limited lifespan of PLP may mean that multiple epochs are not necessary. At this stage, these will be separate instances of the calculation.

Results for an example property in Aylesford.

Event probability	**Depth**	**Damage without PLP**	**Damage with PLP**
0.5	Null	£0	£0
0.2	Null	£0	£0
0.05	0.35	£43,570	£3,332
0.02	0.43	£45,990	£3,465
0.01	0.45	£46,708	£3,504
0.005	0.47	£47,211	£3,532
AAD		**£5,547**	**£422**

B.2.3.4 Costs

The installation costs need to be calculated. These could be based on the protection requirements of an ‘average property’ (for example, with one front and one rear door requiring protection) or a more specific assessment of each individual property’s needs.

If the installation is a one-off investment with responsibility passed to the resident, then annual maintenance costs may not need to be considered. However, the following questions need to be considered.

- If the community has high rates of residency changes (people moving in and out of the community), is an ongoing education programme required to ensure all residents remain aware of the flood risk and necessary actions to maintain and install the measures?
- Are residents likely to invest their own money in maintaining measures? If not, should maintenance costs be included in the assessment to ensure they perform as designed for their lifespan? Or should future benefits be reduced to account for a lack of maintenance?
- What will happen at the end-of-life of the measures? If it is deemed to be the responsibility of the resident, then the lifespan of the protection is limited to (say) 20 years. If the measures will be replaced at their end-of-life, the lifespan of the scheme is extended, but a cost will be incurred each time they are replaced. Will flood hazard change in the future to the point where these measures are no longer suitable?

For this example, the average cost per property of £4,830 was taken from the review by JBA Consulting of the Environment Agency/Defra-funded schemes, with annual maintenance costs set at 5% of the capital cost (taken from Stevens and Chatterton 2012).

B.2.3.5 Which properties are protected?

The outputs of the depth-damage calculation can be used to identify the properties that would benefit most from PLP. This is likely to be properties with a high probability of low depth flooding. Other factors may influence which properties should be protected. These include such as protecting a whole terrace to ensure all the properties are protected or, for socio-political reasons, protecting properties that do not achieve a significant benefit. For example, it may not be acceptable to a community for one property in a row of properties to remain unprotected even though there is no economic argument for investing in it.

For this example, properties are ranked by the AAD avoided as a means of prioritising investment. Based on this, a full range of possible investment levels and the resulting benefits could be considered from one property to all properties protected. This does not take into account other factors that may lead to different properties needing protection**.**

B.2.3.6 Flood warning inputs

If warning-dependent resistance measures (flood guards) are being considered, the following flood warning inputs are also required:

$$\begin{aligned}&\%\,Reliability \text{ and } Availability\\ &= \%\,of\ residents\ who\ receive\ a\ flood\ warning\ and\ are\ available\ to\ act\ on\ it\end{aligned}$$

$$\begin{aligned}&\%\,Operated\\ &= \%\,of\ residents\ with\ flood\ guards\ who\ install\ them\ before\ the\ onset\ of\ flooding\end{aligned}$$

Reliability and availability can be estimated from post-flood event survey questions, asking if residents receive a flood warning. If not available, national data (from Environment Agency KPIs) could be used, with the proviso that local factors may mean these data are not representative.

For this example, reliability and availability is estimated as 63% using national values of the flood warning service effectiveness (88%) and the availability of residents to receive a warning (72%). Coverage and uptake in the flood warning service are assumed to be 100% for this area, as this would be a funding requirement for the property level protection.

Also from post-flood event surveys, the percentage of residents taking ‘effective’ or ‘appropriate’ action can be used as a proxy for the operated factor, assuming that if residents with flood guards take any effective action, it will be to install flood guards.

This example assumes that flood-proof doors would be installed, so the flood warning inputs are not considered as part of the PLP calculation.

B.2.3.7 Inputs for contents moved and evacuated

To calculate the benefits of moving and evacuating belongings, the reliability and availability factor can be used, although the operated factor must also take into account **time**. Unlike putting a flood guard in place, the damages avoided by moving belongings are not ‘binary’. More time could allow more belongings to be moved and therefore a higher proportion of damages avoided. For example, according to data from Table 4.16 of the 2013 version of the Multi-Coloured Manual, 56% of the moveable inventory damages can be avoided with lead times up to eight hours compared with 71% with lead times greater than eight hours.

The MCM also assesses the effectiveness of moving and evacuating belongings, estimating that 52% of total potential damages are inventory damages (rather than building damages) and 41% of those are moveable.

This example assumes that lead times will be less than eight hours, so uses an operated value of 56% for contents moved and evacuated. The effectiveness is calculated as 52% × 41% = 21%.

B.2.3.8 Present day ANSR calculation

From the above calculations, the key inputs to the ANSR calculation are the flood warning inputs, plus:

$$Input\ AAD = Unprotected\ AAD\ of\ all\ properties$$

$$\%\ Uptake = \frac{Unprotected\ AAD\ of\ protected\ properties}{Unprotected\ AAD\ of\ all\ properties}$$

$$\%\ Effectiveness = \frac{Protected\ AAD\ of\ protected\ properties}{Unprotected\ AAD\ of\ protected\ properties}$$

The percentage damages avoided by the PLP are calculated as:

$$\%\ Damages\ Avoided = Reliability \text{ and } Availability \times Uptake \times Operated \times Effectiveness$$

For flood guards or flood doors (assuming residents always remember to shut the door correctly):

$$\%\ Damages\ Avoided = Uptake \times Effectiveness$$

This calculation can be combined in ANSR with the additional damages avoided by residents moving their belongings (contents moved and evacuated) using the inputs discussed above:

$$\%\ Damages\ Avoided = Reliability\ \&\ Availability \times\ Operated \times Effectiveness$$

For this example, if 20 properties are protected:

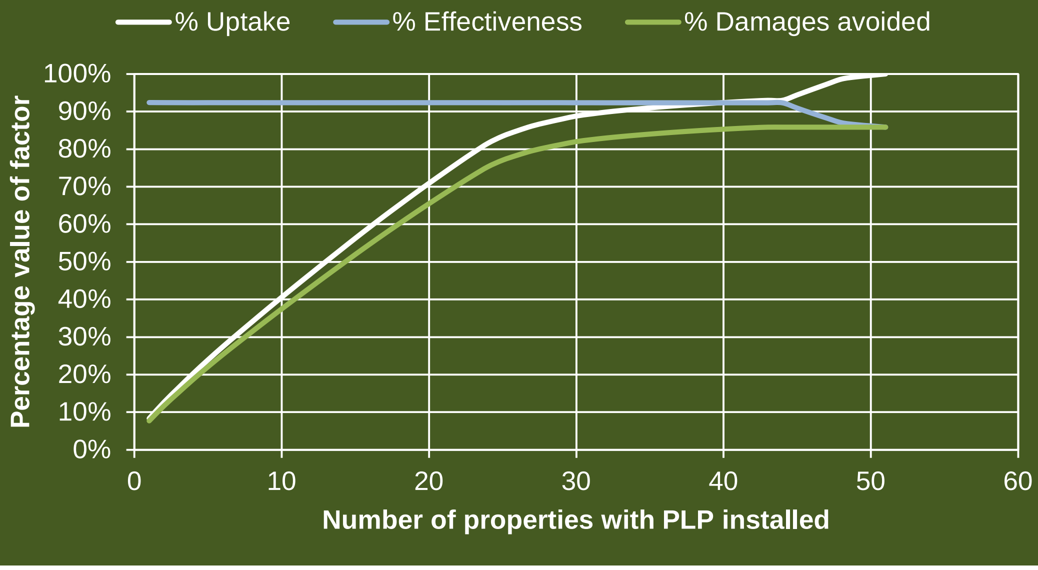
$$\boldsymbol{Input\ AAD = Unprotected\ AAD\ of\ all\ properties = £66,491}$$

$$\%\ \boldsymbol{Uptake} = \frac{\boldsymbol{Unprotected\ AAD\ of\ protected\ properties}}{\boldsymbol{Unprotected\ AAD\ of\ all\ properties}} = \frac{\boldsymbol{£47,149}}{\boldsymbol{£66,491}} = \boldsymbol{71\%}$$

$$\%\ \boldsymbol{Effectiveness} = \frac{\boldsymbol{AAD\ avoided\ at\ protected\ properties}}{\boldsymbol{Unprotected\ AAD\ of\ protected\ properties}} = \frac{\boldsymbol{£43,544}}{\boldsymbol{£47,149}} = \boldsymbol{92.4\%}$$

$$\%\ \boldsymbol{Damages\ Avoided = Uptake \times Effectiveness = 71\% \times 92.4\% = 65.5\%}$$

Or for all possible levels of investment:



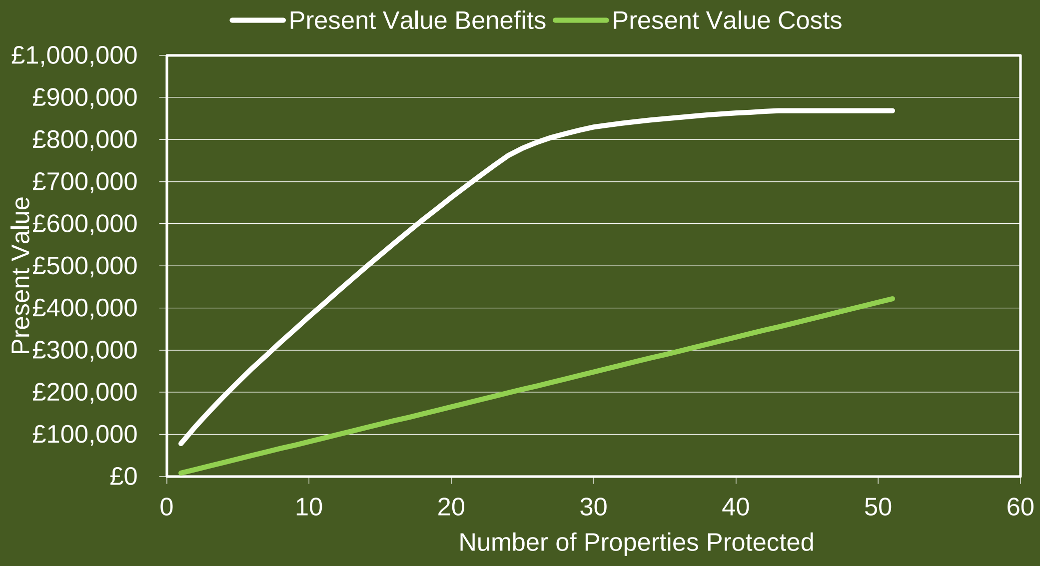
B.2.3.9 Whole-life assessment

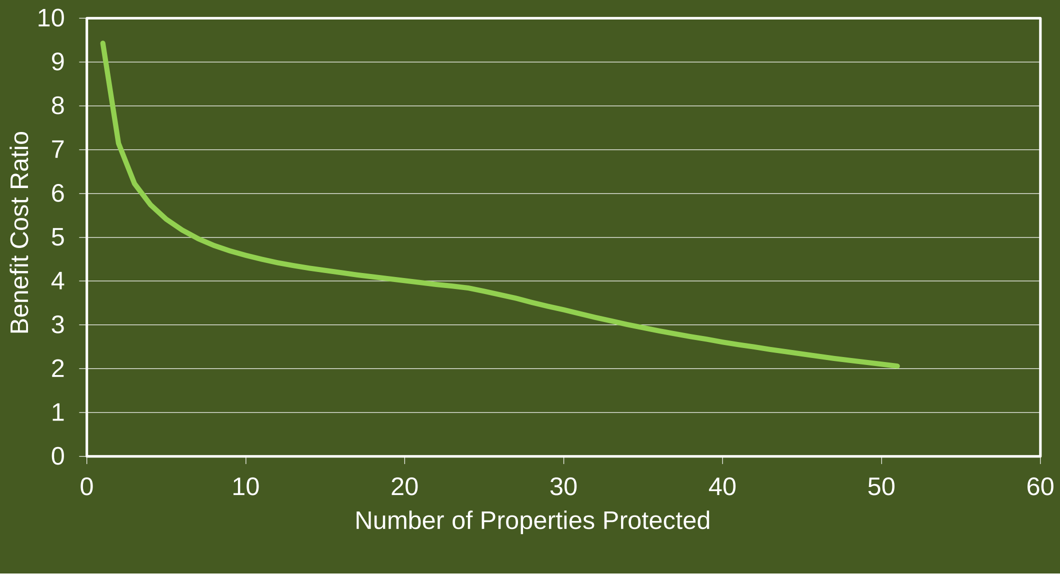
In addition to the ‘snapshot’ view provided by ANSR, with annualised damages (possibly for multiple epochs) and costs estimated, a whole-life assessment can be carried out as follows.

- Select the period of time covered by the assessment based on either the estimated lifespan of the measures (~20 years) or a complete 100-year assessment if they will be replaced at their end-of-life.
- Calculate the annualised benefits of the measures. For flood doors, this is assumed to be $Unprotected\ AAD - Protected\ AAD$, but for flood guards the benefit needs to be reduced as discussed above (taking into account the need for residents to take effective action).
- If data for multiple epochs are available, the benefits at each epoch can be calculated, interpolating benefits for intermediate years.
- Add annual installation and maintenance costs.
- Calculate and sum the Net Present Value (NPV) for each year in the whole-life assessment (discounting the costs/benefits in each year):
  - $Discount\ Rate_{Year\ n} = \begin{cases} n < 30, 0.035 \\ 30 \le n \le 75, 0.03 \\ n > 75,\ 0.025 \end{cases}$

- $Discount\ Factor_{Year\ n+1} = \frac{Discount\ Factor_{Year\ n}}{1+Discount\ Rate}$
- $Net\ Present\ Value_{Year\ n} = Value_{Year\ n} \times Discount\ Factor_{Year\ n}$

The graphs below show the results of the whole-life assessment of costs and benefits in Aylesford. The x-axis of both graphs shows the change in costs and benefits achieved with different levels of investment (different numbers of properties protected).





B.3 Lower Aire

The purpose of this case study is to investigate how MDSF2 results can be used in the ANSR tool without carrying out any further model runs and to quantify the benefits of the responses in ANSR. Parameters for the local area have been estimated based on the limited available data (which includes the EAD and other values generated by MDSF2 and the appropriate Flood Warning Level of Service spreadsheet) and adjusted national data.

To provide a useful worked example, information specific to this case study is written on the left and general guidance applicable to other applications is written on the right in the green boxes.

This case study

General guidance

B.3.1 Derivation of input data

For this case study, the key available data were:

- An MDSF2 model (in the form of a complete Microsoft® Access database) with results for present day and 100-year model runs for the following scenarios:
  - Do nothing
  - Maintain standard of protection
  - Maintain crest levels
- Flood warning level of service spreadsheet for Yorkshire and north-east England.
- Flood warning area and flood alert area ESRI shapefiles.

The main data requirements of ANSR are:

- Input damage values (optionally additional damage values to allow the benefits of working with assets to be calculated)
- Flood warning success:
  - coverage
  - service uptake
  - service effectiveness
  - availability of residents to receive and act on the warning
- % operated for different lead time categories:
  - contents moved and evacuated
  - warning-dependent resistance (if relevant)
- Percentage of properties in each lead time category
- % uptake of:
  - warning-dependent and warning-independent resistance measures
  - resilience measures
- Uplift factors for the wider impacts of flooding

B.3.1.1 Damages

The MDSF2 modelling derives EAD values for residential properties, non-residential properties and agricultural damage for each impact cell (tblCell_Task08Step01). These data were extracted to a spreadsheet, which summed the total direct property damage (excluding agricultural damage) and calculated the residential component of that damage.

Extract the EAD values for each impact cell from the MDSF2 table (tblCell_Task08Step01) to a spreadsheet.

Sum the total direct property damage (excluding agricultural damage) and the residential component of that damage (residential property damage divided by total property damage).

B.3.1.2 Working with assets

MDSF2 does not make ‘undefended’ damage values available unless explicitly calculated, for example, the Strategic Asset Management Plans (SAMPs) approach. These values are required to accurately calculate the benefits of FIM working with assets. The MDFS2 database shows only one point asset, so it was assumed that the

To quantify the benefits of FIM working with assets, specific model runs would be needed from MDSF2 to generate the following outputs:

- damage values with no defences
- damage values with flood defences not operated (flood gates left open)
- damage values with temporary or demountable defences not installed

benefits of operating flood defences and temporary or demountable defences were minimal in this area.

- damage values with no watercourse capacity maintenance (increased risk of blockages)

The benefits of working with assets are considered in the Deben Estuary case study (Section B.4).

B.3.1.3 Flood warning success

Coverage

At a broad scale, coverage is defined as the proportion of properties at risk offered a flood warning service.

The impact cells with an EAD greater than zero, both inside and outside flood warning and/or flood alert area, were identified. Data from MDSF2 Table tblCell_Task08Step01 (EADs per impact cell and property counts per impact cell) were used to calculate the coverage by a number of different metrics.

For each metric, the value of the metric for impact cells inside the flood warning and alert areas, and the value for impact cells outside were calculated.

The property count is the metric that most closely represents the national-scale definition of coverage, but at a more detailed level (and to fit more precisely with the other factors in the ANSR calculations), the coverage should be represented by the percentage of potential damage covered by a flood warning service, for which the percentage of damage which is inside flood warning/alert areas would be an estimate. This is likely to be higher than the raw property count as the at-risk properties not protected by a flood warning service are likely to have a lower probability of flooding or lower impacts if it does flood. Hence investment in providing them with a flood warning service may not have been prioritised.

Table B.3 highlights the large amount of variation in the coverage depending on the way it is calculated.

Identify the impact cells with an EAD greater than zero. Then divide them into two sets: cells inside flood warning or flood alert areas, and cells outside.

Use the EAD per impact cell from MDSF2 table tblCell_Task08Step01 to derive the EAD for properties covered by flood warnings $EAD_{FWA/FAA}$ and for properties not covered by flood warnings $EAD_{Not:FWA/FAA}$. The coverage can be calculated by:

$$\%Coverage = \frac{EAD_{FWA/FAA}}{EAD_{FWA/FAA} + EAD_{Not:FWA/FAA}}$$

ANSR separates the residential and non-residential benefit calculations. , so do this calculation separately for residential property damage and non-residential property damage.

ANSR separates residential and non-residential calculations. The separate coverage values based on the percentage of residential damage and the percentage of non-residential damage covered by a flood warning and/or flood alert area were therefore used, that is, 99.1% and 98.6% respectively.

Table B.3 Calculating flood warning coverage.

Metric	Coverage of flood warning areas	Coverage of flood warning and/or flood alert areas
Impact cell count	38.9%	92.1%
Residential property count	30.9%	95.1%
Non-residential property count	43.4%	89.8%
Total property count	34.2%	93.7%
Residential damage	15.3%	**99.1%**
Non-residential damage	15.9%	**98.6%**
Total damage	15.7%	98.8%

This case study	General guidance

Service uptake, service effectiveness and availability of residents

For this case study, national data were used, as discussed to the right.

In the absence of local data, the value of 38% from the ’reliability and availability‘ factor in Parker et al. (2007) serves as a proxy for the combined service uptake, service effectiveness and the availability of residents to receive a warning.

B.3.1.4 ‘% operated’ for different lead times

Contents moved and evacuated

For this case study, national data were used, as discussed to the right.

Priest and Parker (2012) offer useful values for the percentage success in avoiding damages (% operated) by ‘contents moved or evacuated’ for different lead times, derived from post-flood event survey data. Although these values (Table B.4) exclude the impact that community awareness has on flood warning response, they offer the best available figures. As these values are lead time-agnostic, if combined with appropriate lead time data, they should be generally applicable unless geographic discrepancies in community awareness are considered to have a significant impact.

Table B.4 Percentage ‘operated’ for ‘contents moved or evacuated’ for each lead time category

Lead time	% operated for ‘contents moved or evacuated’
0–1 hour	70%
1–8 hours	72%
More than 8 hours	80%

This case study

B.3.1.5 Lead times

The flood warning areas in the study area were identified by intersecting the MDSF2 flood areas shape with the flood warning area shapes in ArcGIS. These areas were then identified in the flood warning level of service (FWLoS) spreadsheet for Yorkshire and the north-east.

Flood warning areas were grouped using the lead time categories discussed above (Table B.5) and, using the property count provided by FWLoS for each area, the percentage of total properties was estimated. As many areas stated only that they met or exceeded the two-hour target lead time for fluvial areas, most fit into ‘1–8 hour’ lead time category (Table B.6).

General guidance

Determine lead times using the FWLoS spreadsheet, if available. If the area has experienced flooding since the spreadsheet became active, recorded lead times should be available. If not, then target lead times could be used (for example, two hours for fluvial).

Group flood warning areas using the lead time categories above and employ the FWLoS property count for each area to sum the number of properties in each lead time category and hence the percentage.

This approach is limited by areas with no data available and the potential for values (based on a small number of flood events) to be unrepresentative of an ‘average’ flood event.

Table B.5 Flood warning area property number and lead time data

Flood warning area	Number of properties	Recorded lead time	Lead time category
River Aire at Airmyn	312	~2	1–8
River Aire at Allerton Bywater	260	2	1–8
River Aire at Allerton Ings, Barnsdale Road and properties	4	>2	1–8
River Aire at Beal	106	~2	1–8
River Aire at Birkin	38	>8	> 8
River Aire at Brotherton	47	2.8	1–8
River Aire at Burn Lane	8	~2	1–8
River Aire at Carlton	329	0–1	0–1
River Aire at Castleford Lock Lane	314	2	1–8
River Aire at Central Castleford	215	2	1–8
River Aire at Drax	174	~2	1–8
River Aire at Ferrybridge	77	0–7	1–8
River Aire at Ferrybridge – The	99	0–7	1–8

Flood warning area	Number of properties	Recorded lead time	Lead time category
Square and High Street			
River Aire at Gowdall	120	1.5–9.75	1–8
River Aire at Hensall	81	~2	1–8
River Aire at Hirst Marsh and West Marsh	9	~2	1–8
River Aire at Kelllington	240	~2	1–8
River Aire at Knottingley	509	~2	1–8
River Aire at Methley Junction	152	2	1–8
River Aire at Mickletown	669	2	1–8
River Aire at Mickletown – Mill Lane, Nelson Court and Lower Mickletown	75	2	1–8
River Aire at Newland	65	~2	1–8
River Aire at Snaith and Lidgate	464	~2	1–8
River Aire at Snaith Ings	15	4.75	1–8
River Aire at Temple Hirst and Hirst Courtney	51	>8	> 8
River Aire at West Haddlesey and Chapel Haddlesey	171	~2	1–8
Total	**4604**		

Table B.6 Percentage of properties in each lead time category

Lead time category (hours)	Number of properties in this category	Percentage of total properties in this category
0–1	329	7.1%
1–8	4186	87.2%
>8	89	1.9%

This case study

B.3.1.6 Property level protection

None of the PLP schemes reviewed by JBA Consulting (2012) are within the study area. There is no mention of PLP in the Lower Aire flood risk management strategy, MDSF2 database and MDSF2 pilot study report (Palmer 2013), so it was assumed that no government funded schemes were planned. We therefore set the uptake to zero, based on the assumption that we have recorded the benefit of government-funded activities, even though privately-funded protection may exist.

Based on the way MDSF2 presents

General guidance

The benefits of PLP are considered in the Deben Estuary case study.

results (internally calculating EAD but not outputting usable depth information), without re-running the MDSF2 model, it was not feasible to calculate the effectiveness of any hypothetical resistance and resilience measures, other than using national averages.

B.3.1.7 Wider impacts

The pilot study report identified that fluvial flooding impacts the ‘majority’ of the 21 flood areas but tidal flooding impacts only two areas. It was therefore assumed that fluvial flooding impacts the other 19 areas.

None of the flood warning areas are rapid response catchments (according to FWLoS), but over a quarter of the flood warning lead times are less than an hour, so a ‘short’ catchment response time/lead time was assumed.

Without specific data, a medium Social Flood Vulnerability Index was assumed.

This suggested average uplift factors of 2.00 for fluvial flooding and 3.50 for tidal flooding. From this and the stated 19:2 division of flood areas, the overall uplift factor was estimated as follows.

$$Uplift = \frac{19 \times 2.00 + 2 \times 3.50}{21} = 2.14$$

Parker and Priest (2012) quantified the wider flood impacts that result in addition to direct property damages, categorised by:

- the source of flooding
- the catchment response/lead time
- the Social Flood Vulnerability Index of the study area

These values provide a combined ‘wider impacts’ factor. If there are multiple sources of flooding, and if the relative influence of each source of flooding is known, estimate a combined uplift factor.

This uplift factor can also be broken down to specific wider impacts in the ANSR tool.

The Flood Incident Management Investment Review (Halcrow 2013) set uplift factors to:

- 0.5× the direct property damages for other economic impacts
- 0.5× for infrastructure
- 0.7× (fluvial) or 1.7× (coastal) for health and social impacts

Risk to life, institutional (the reputation of the Environment Agency) and ‘other’ impacts were set to zero to show they had been considered but not quantified.

Following the Flood Incident Management Investment Review approach, the health and social factor was set to 0.84 to obtain the overall uplift factor of 2.14. This is similar to the value of 0.8 obtained from a weighted average (using the 19:2 split) of the 0.7 uplift factor for fluvial and the 1.7 uplift factor for coastal.

ANSR allows users to set the effectiveness of each pathway at reducing each wider impact.

It was estimated that property level responses (contents moved or evacuated and PLP) would be effective at avoiding other economic impacts (for example, avoiding business disruption) and health and social impacts, but that they would not reduce infrastructure damages. Infrastructure protection that follows the same principles as property level responses may exist.

B.3.2 Results

‘Contents moved and evacuated’ is the only pathway active in the Lower Aire case study. Additional data would be required to quantify the benefits of working with assets or resistance and resilience measures. Some of this information could be calculated by re-running the MDSF2 models with some alterations, as explored in other case studies.

Table B.7 and Table B.8 show the direct property damages avoided by contents moved and evacuated for residential and non-residential properties respectively.

Table B.7 ANSR calculation for residential contents moved and evacuated

CME_{Res}	=	Residual damages	×	Reliability and availability	×	Operated	×	Effectiveness
	=	£79.7 million	×	37.7%	×	71.8%	×	21.3%
	=	£79.7 million	×	5.76%				
	=	£4.61 million						

Table B.8 ANSR calculation for non-residential contents moved and evacuated

$\text{CME}_{\text{Non-res}}$	=	Residual damages	×	Reliability and availability	×	Operated	×	Effectiveness
	=	£141 million	×	37.5%	×	71.8%	×	21.3%
	=	£141 million	×	5.74%				
	=	£8.11 million						

Table B.9 and Table B.10 show the overall results for ANSR for direct property damages and all impact categories respectively.

Table B.9 ANSR calculation results for direct property damages

	Direct property damage		
	Residential	**Non-residential**	**Total**
Residual impacts with assets only	£79.7 million	£141 million	£221 million
Impacts avoided by flood warnings	£4.61 million	£8,11 million	£12.7 million
Residual impacts with assets and flood warnings	£75.1 million	£133 million	£208 million

Table B.10 ANSR calculation results for all impact categories.

	Direct property damage	Wider impacts			Total impacts
		Other economic	Infrastructure	Health and social	
Residual impacts with assets only	£221 million	£111 million	£177 million	£186 million	£695 million
Impacts avoided by flood warnings	£12.7 million	£6.39 million	–	£10.8 million	£29.9 million
Residual impacts with assets flood warnings	£208 million	£104 million	£177 million	£186 million	£665 million

B.3.3 Discussion and conclusions

In this study, the results of the Lower Aire MDSF2 model were used to assess:

- the benefits of flood risk responses in ANSR
- the applicability of ANSR as a post-processing tool to MDSF2 without re-running any models

The results of this study suggest that moving and evacuating household contents avoids 5.7% of the direct property damage and 4.3% of total impacts.

The 2013 version of the Multi-Coloured Manual gives a WAAD value for unprotected properties of £4,728, or £4,559 with a flood warning. Using this 3.6% reduction in damage suggests that flood warnings should avoid £7.9 million of direct property damage in the Lower Aire.

Thus, the ANSR approach has, in this case, produced more favourable results (£12.7 million). This could be because the coverage in this study area is higher than the national average or the percentage operated is more favourable (MCM uses a percentage operated value of 56%).

The main learning point of this case study is that it shows the limitations in using the outputs of MDSF2 models in ANSR without explicitly re-running models to generate the required input values.

This study could have extended its reach to include a wider range of pathways, but that would have meant resorting to national average values that may not be directly applicable to the study area.

B.4 Deben Estuary

This case study investigates the use of MDSF2 to derive input values for the ANSR tool. By undertaking additional modified scenario runs of an MDSF2 model, it is possible to generate the specific input data required to quantify the benefits of working with assets and property level responses in the ANSR tool.

In this worked example, information specific to this case study is written on the left and general guidance applicable to other applications is written on the right in the green boxes.

This case study

General guidance

B.4.1 Input data derivation

Parameters for the local area were estimated using two additional MDSF2 runs – one representing open flood gates and another representing PLP, as well as a baseline model run. This was accompanied by the appropriate FWLoS spreadsheet and adjusted national data.

The main data requirements of ANSR are:

- Input damage values – optionally additional damage values to allow the benefits of working with assets to be calculated
- Flood warning success:
  - coverage
  - service uptake
  - service effectiveness
  - availability of residents to receive and act on the warning
- % operated for different lead time categories:
  - contents moved and evacuated
  - warning-dependent resistance (if relevant)
- Percentage of properties in each lead time category
- % uptake of:
  - warning-dependent and warning-independent resistance measures
  - resilience measures
- Uplift factors for the wider impacts of flooding

B.4.1.1 MDSF2 model

Choosing a model

The MDSF2 model for the Deben Estuary has three scenarios (‘do nothing’, ‘do minimum’ and ‘do something’), each with three snapshots: 2015, 2050 and 2114.

All three snapshots of the ‘do minimum’

To calculate the benefits of FIM enabling the operation of flood defences and the benefits of simple PLP (resistance measures effective up to 0.6 m), use three sets of MDSF2 runs:

1. Modified depth-damage curves for

scenario were used as the basis of the study. In this case, defences are assumed to be repaired after breaching and maintained to extend their life, but not replaced at their end-of-life and gradually degrading.

It may have been more suitable to use a ‘maintain crest levels’ scenario, as this would have allowed the case study to investigate how property level responses could mitigate the increased future risks due to climate change. However, this scenario was not available.

The original intention had been to use the ‘do something’ scenario as it already included PLP, but errors were found in the way they were included. As this scenario also included considerable investment in defences, this did not present itself as a useful baseline case.

From the ‘do minimum’ scenario, three variants of the original model (run for each of the three snapshots) were produced, as discussed in the numbered points on the right. In the first run of each set, no changes were made to the damage values, so the results of this should have been the same as those in the original study.

all impact cells with the addition of 0.6 m and 0.601 m depths, with damages linearly interpolated between available data

2. PLP is included by taking the above model and setting the damage values for all depths up to and including 0.6 m to zero, and making no changes to damage values for depths from 0.601 m and up
3. Open flood gates, represented by forcing flood gates by lowering their height to ground level so they overtop[3]

Additional sets of runs could also be used to represent resilience measures (altering depth-damage curves appropriately) and temporary and demountable defences (lowering their height to ground level so they overtop, if the baseline model includes them). Planning and development management could be represented by creating a ‘without planning and development management’ scenario with additional properties in the MDSF2 database. Finally, an undefended scenario could be developed for completeness.

B.4.1.2 Damages

The EAD was extracted from the MDSF2 results for the nine model runs, broken down by flood area. The ‘do minimum’ run provides the residual damage with assets for ANSR.

Strictly speaking, ANSR requires a damage value with no assets and a percentage of the damages avoided by assets that can be attributed to operating flood defences. For the ‘open flood gates’ scenario, 100% of the increase in EAD from the baseline (‘do minimum’) scenario can be attributed to flood gates. As such, there was no true undefended

Extract EAD values from MDSF2 by impact cell or by flood area, using the MDSF2 post-processing tools, where appropriate.

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[3] MDSF2 has two inflow modes: overtopping (non-failure) and breaching (failure). To represent flood gates being open, the flood gates were forced to ‘fail’ by overtopping only. The fragility curves of all flood gates were adjusted so that no breaching would occur (setting the failure probability to zero for all loads). The spill/crest level of each gate was then set to ground level, so that overtopping occurs for any positive water level. Finally, the standard of protection (SoP) was set to the appropriate value (derived from the water level information in the database). SoP forms a part of the overtopping calculations in MDSF2.

scenario, but the benefit assigned to flood defence operation is still valid.

The EAD values from the set of runs with PLP installed allowed the benefits of installing PLP in each flood area to be estimated, as discussed below.

B.4.1.3 Working with assets

As discussed above, the benefits of FIM enabling the operation of assets by quantifying the EAD with flood gates opened were estimated. It was assumed that the difference between this EAD and the EAD with normal operation (flood gates closed) can be wholly attributed to closing flood gates and hence flood forecasting triggering action to close those gates.

ANSR also includes the ability to uplift damages based on the probability that flood gates are not closed successfully. No information was available to substantiate estimates of this probability, so it was assumed that this value could be approximated to 100%.

An examination of the area using Google StreetView (for example, Figure B.1) suggested that the flood gates require manual closure.

ANSR can be used to quantify the benefits of enabling flood defence operation (for example, shutting flood gates), enabling community-level defence operation (such as temporary or demountable defences) and maintaining watercourse capacity.

If there are no MDSF2 flood areas with both flood gates and temporary or demountable defences, they can be considered independent and a scenario with them removed can be run to obtain the necessary EAD values for ANSR. This will quantify the percentage of damages avoided by both types of defence through FIM activities.

If, however, they are not independent, the simple percentage attribution used by ANSR is not sufficient and it may be more appropriate to group them together as a single ANSR pathway.

Figure B.1 Example flood gates at Woodbridge in the Deben Estuary

B.4.1.4 Flood warning success

Coverage

Four flood warning areas cover the whole study area, so coverage was assumed to be 100%.

As introduced in the Lower Aire Case Study, the coverage can be calculated by:

$$\% \, Coverage = \frac{EAD_{FWA/FAA}}{EAD_{FWA/FAA} + EAD_{Not:FWA/FAA}} \qquad 8$$

Service uptake, service effectiveness and availability of residents

For this case study, national data were used, as discussed to the right.

In the absence of local data, the value of 38% from the ‘reliability and availability’ factor in Parker et al. (2007) serves as a proxy for the combined service uptake, service effectiveness and the availability of residents to receive a warning.

B.4.1.5 ‘% operated’ *for different lead times*

Contents moved and evacuated

For this case study, national data were used, as discussed in more detail in the Lower Aire case study (Section B.3).

% operated for contents moved and evacuated can be taken from Priest and Parker (2012):

- 0–1 hour lead time: 70%
- 1–8 hours: 72%
- >8 hours: 80%

Warning-dependent resistance

For this case study, we used national data, as discussed in more detail in the Lower Aire case study (Section B.3).

% respondents who took some action, assumed to be a proxy for the % operated for warning-dependent resistance can be taken from Priest and Parker (2012):

- 0–1 hour lead time: 92%
- 1–8 hours: 95.8%
- >8 hours: 98.9%

B.4.1.6 Lead times

The FWLoS spreadsheet assumed that lead times for all four flood warning areas are 12 hours, so 100% of properties fit

Determine lead times using the FWLoS spreadsheet, if available, as explained in the Lower Aire case study (Section B.3).

into the '>8 hours' lead time category.

B.4.1.7 Property level protection

Benefits

The flood areas were ranked to identify where PLP would be most beneficial, as shown in Table B.11. From that, the ANSR input values were calculated (Table B.12).

One flood area (number eight) represents 37% of the total EAD in the study and offers the greatest potential for benefits to avoid damage through PLP. An appropriate % uptake value to represent protecting all 13 properties in this area (36.8%) was chosen, giving a % effectiveness value of 30.1%.

Linearly interpolating between the values in Table B.12 enabled the changes in benefit that occur for different levels of investment across the wider study area to be calculated. A table with the percentage of properties protected, percentage uptake and percentage effectiveness was created before VLOOKUP functions in Excel were used to find the ANSR inputs for each snapshot year for any given percentage of properties protected.

Calculate the benefits of PLP using the additional set of MDSF2 runs introduced above. Using the EAD per flood area from the baseline scenario (with no PLP), and the reduction in EAD per flood area that the PLP scenario offers, calculate the EAD avoided per property to identify where PLP would be most beneficial. Use this and/or other factors to rank flood areas by their priority for investment.

From this, calculate the cumulative EAD and EAD avoided for each level of investment (for each additional flood area protected), in order to calculate the ANSR input values:

$$Uptake = \frac{Cumulative\ EAD}{EAD\ for\ all\ flood\ areas}$$

$$Effectiveness = \frac{Cumulative\ EAD\ avoided}{Cumulative\ EAD}$$

Note that uptake is a percentage of damages, not simply of the number of properties.[4]

Table B.11 Flood areas in the Deben Estuary study ranked by EAD avoided by PLP per property

Flood area	EAD per property	EAD avoided per property	Number of

---

[4] The high percentage of total damages (37%) represented by just 3% of the total number of properties highlights a potential for confusion when deriving ANSR input values:

- When considering PLP, it is useful to think of uptake terms of the percentage of the total *properties* protected, which provides a direct link to calculating the cost of protection.
- In ANSR, for uptake and effectiveness to together represent the damages avoided, uptake should be the percentage of the total *damages* that the protected properties represent.

To circumvent this issue, one of the following approaches is needed:

1. Use an uptake value that represents the percentage of total damages protected, and calculate the corresponding percentage of properties protected that equates to that for each snapshot year.

2. Use an uptake value that represents the percentage of properties protected, and uplift the effectiveness by an appropriate amount.

We tried approach two but, for this case study, it resulted in effectiveness percentages above 100%, which is likely to lead to confusion. We therefore adopted approach one, although this did mean that for any given number of protected properties, the actual uptake varies between the snapshot years.

			properties
8	£7,016	£2,110	13
13	£813	£332	23
1	£920	£251	12
7	£658	£140	7
15	£357	£126	329
10	£114	£81.4	1
2	£116	£5.81	42
5	£0.108	£0.108	3

Table B.12 Calculating ANSR input values for the Deben Estuary

Flood area	Cumulative EAD	Cumulative properties protected	Uptake	Cumulative EAD avoided	Effectiveness
8	£91,208	3.02%	36.8%	£27,429	30.1%
13	£109,907	8.37%	44.3%	£35,076	31.9%
1	£120,944	11.2%	48.8%	£38,084	31.5%
7	£125,551	12.8%	50.6%	£39,067	31.1%
15	£242,896	89.3%	98.0%	£80,596	33.2%
10	£243,010	89.5%	98.0%	£80,678	33.2%
2	£247,882	99.3%	100%	£80,922	32.6%
5	£247,883	100%	100%	£80,922	32.6%

This case study

General guidance

Costs

There are 13 properties in flood area eight. Costs were assumed as:

- £5,000 per property for warning-dependent resistance
- £10,000 per property for warning-independent resistance

These costs were based on estimates from the Forest Row PLP scheme. Both warning-dependent and warning-independent resistance were considered.

Estimate the average per-property cost of a portfolio of PLP measures (or, if more specific property types are available, estimate different costs for each property type) that provide protection up to 0.6 m, using flood guards for warning-dependent resistance or flood-proof doors for warning-independent resistance, combined with self-closing airbricks or airbrick covers and non-return valves.

Whole-life analysis

A 21-year life was assumed, as estimated by Stevens and Chatterton (2012). Zero maintenance costs during the life of the measure were also assumed.

A 100-year whole-life analysis was carried out, linearly interpolating between the

Estimate the lifespan and maintenance costs of a typical PLP scheme.

Calculate the installation costs for the properties chosen to be protected.

Carry out a whole-life assessment for:

three available snapshot years.

The levels of uptake in PLP were varied from 0% to 100% of properties protected to calculate the changes in benefit–cost ratio. An Excel VBA macro was used to perform the calculation for every percentage of properties protected and write the results to a table. This was also linked to the VLOOKUP functions discussed above to obtain the correct uptake and effectiveness values for every number of properties protected and for each snapshot year.

The benefits of warning-dependent resistance were calculated using the ANSR calculation (multiplying by 'reliability and availability' and 'operated') to reduce the benefits.

- the lifespan of the measures
- a 100-year period where the measures are replaced at their end-of-life and benefits continue
- a 100-year period where the measures are not replaced at their end-of-life and benefits cease

Use the standard 'Green Book' (HM Treasury 2003) method for calculating the Present Value damages, benefits and costs using discount rates and factors.

B.4.1.8 Wider impacts

Wider impacts were considered as part of the Lower Aire case study (Section B.3). This case study focused on direct property damages.

See the Lower Aire case study.

B.4.2 Results

B.4.2.1 Present day and 'snapshot' calculations

The active pathways in the Deben Estuary case study are 'flood defence operation', 'warning-independent resistance' (WIR) and/or 'warning-dependent resistance' (WDR) and 'contents moved or evacuated' (CME).

Figure B.2 shows how the present day damages avoided by resistance measures increase as more properties are protected. Figure B.3 and Figure B.4 show how uptake and effectiveness vary throughout the three snapshot years with different percentages of properties being protected. Figure B.3 also includes a line showing uptake equal to the percentage of properties protected (as assumed by large-scale ANSR applications) to highlight the importance of calculating uptake, based on the percentage of damages protected.

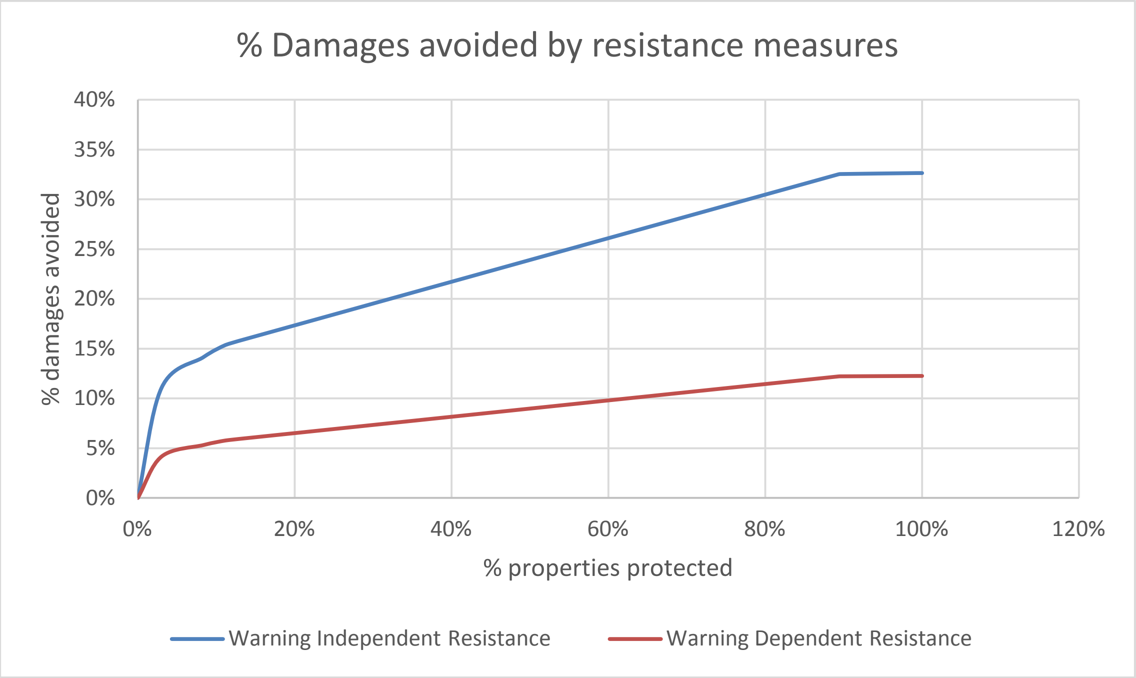


Figure B.2 Percentage damages avoided by resistance measures for 0–100% uptake

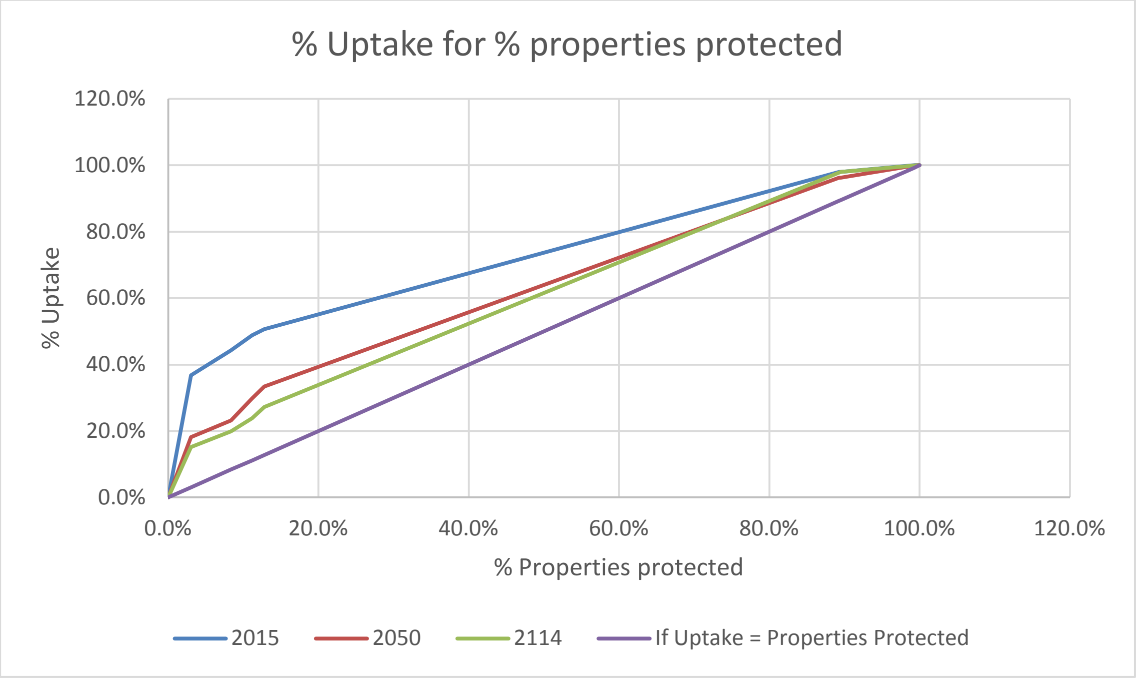


Figure B.3 Percentage uptake for 0–100% of properties protected by resistance measures

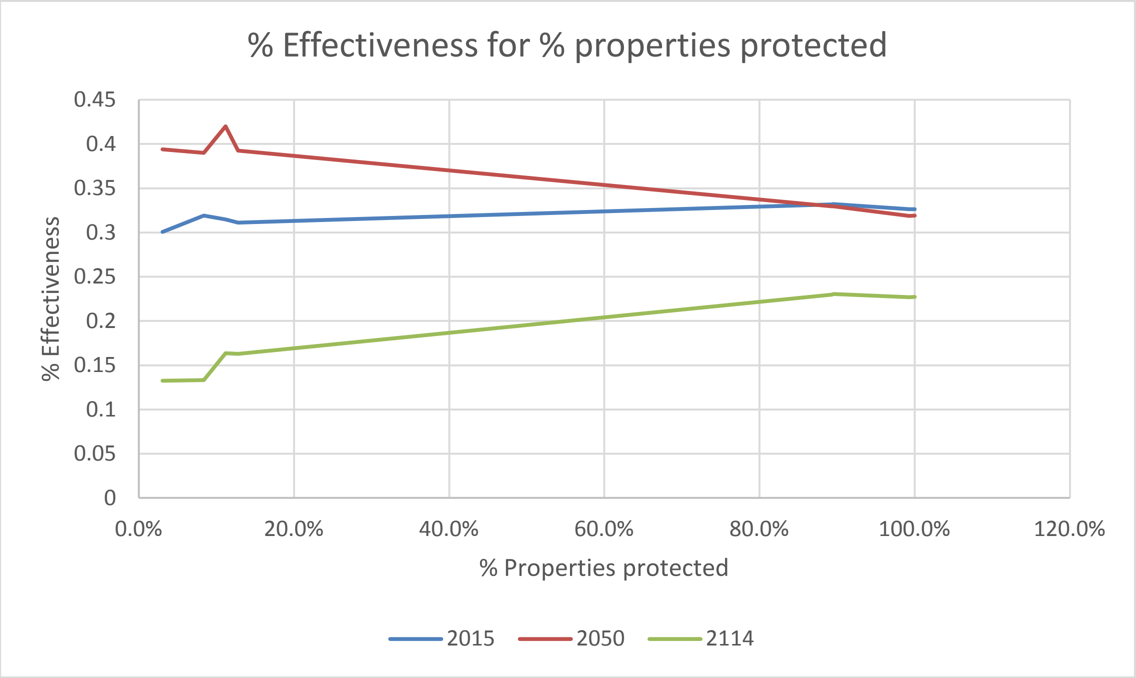


Figure B.4 Percentage effectiveness for 0–100% of properties protected by resistance measures

For illustrative purposes, it is assumed that the 13 properties (3%) in flood area eight are protected, resulting in an uptake value of 36.8% and an effectiveness value of 30.1%.

Table B.13 and Table B.14 compare the damages avoided by warning-independent resistance if these 13 properties are protected, and Table B.15 shows the damages avoided by contents moved and evacuated.

Table B.13 Annual damage avoided by warning-dependent resistance if 13 properties are protected

WDR_{Res}	=	Residual damages	×	Reliability and availability	×	Operated	×	Uptake	×	Effectiveness
	=	£248,000	×	37.7%	×	98.9%	×	36.8%	×	30.1%
	=	£248,000	×	4.16%						
	=	£10,300								

Table B.14 Annual damage avoided by warning-independent resistance if 13 properties are protected

WIR_{Res}	=	Residual damages	×	Uptake	×	Effectiveness
	=	£248,000	×	36.8%	×	30.1%
	=	£248,000	×	11.1%		
	=	£27,400				

Table B.15 Annual damage avoided by contents being moved or evacuated, assuming the 13 properties are protected by warning-independent resistance

CME_{Res}	**=**	**Residual damages**	×	**Reliability and availability**	×	**Operated**	×	**Effectiveness**
	=	£220,000	×	37.7%	×	80.0%	×	21.3%
	=	£220,000	×	6.48%				
	=	£14,300						

Table B.16 and Figure B.5 show the complete results of the ANSR calculation for the Deben Estuary (present day) calculation.

Table B.16 Table of ANSR calculation results for direct property damages

		Direct property damage		
Impacts	**Impacts avoided**	Residential	Non-residential	Total
Total impacts with flood gates open		£559,000	£1.53 million	£2.09 million
	Impacts avoided by flood gates being closed	£310,000	£1.10 million	£1.41 million
Residual impacts with assets only		£249,000	£430,000	£680,000
	Impacts avoided by warning-independent resistance	£27,400	£0	£27,400
	Impacts avoided by moving or evacuating contents	£14,300	£24,400	£38,800
Residual impacts with assets and flood warnings		£207,300	£405,600	£613,800

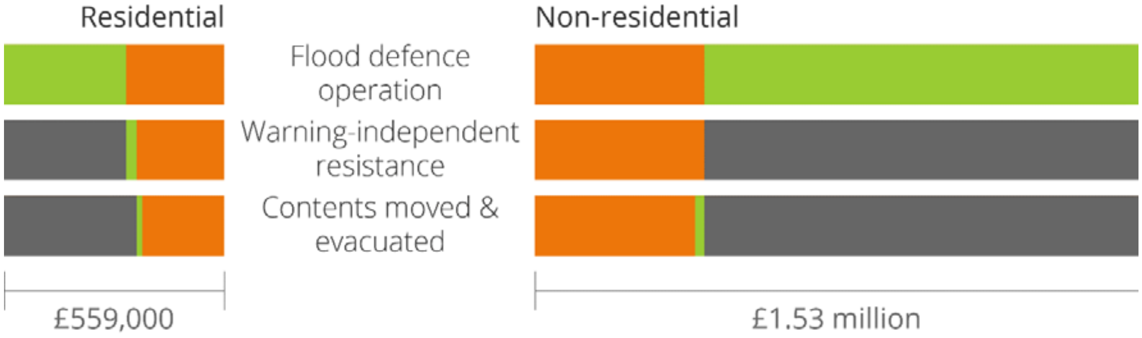


Figure B.5 Diagram of ANSR calculation results for direct property damages

B.4.2.2 Whole-life calculations

Using the method described above, the potential benefits of PLP were estimated in the Deben Estuary study area. Figure B.6 shows how the benefit–cost ratio varies for different percentages of properties protected, installing all warning-independent resistance (all WIR), all warning-dependent resistance (all WDR) or half warning-independent and half warning-dependent (50% WIR, 50% WDR).

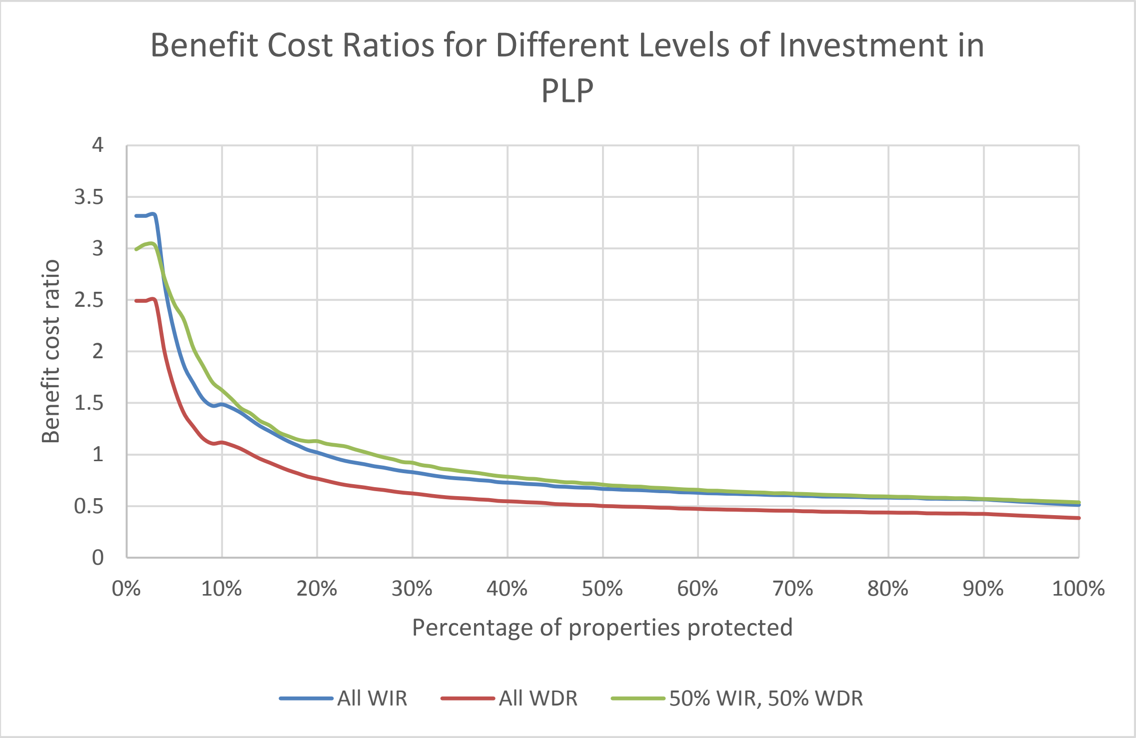


Figure B.6 Benefit–cost ratios for PLP with increasing percentages of properties protected

Extending the present day calculation, it was assumed that the same 13 properties would be protected for the complete duration of the whole-life assessment.

Table B.17 shows the results for each snapshot year, assuming that warning-independent resistance were installed in the 13 properties. Table B.18 shows the different costs of benefits of warning-independent and warning-dependent resistance over a 100-year whole-life assessment, showing that warning-independent resistance achieves a benefit–cost ratio of 3.3.

Table B.17 Annual residential damages and residential damages avoided by PLP for the three snapshot years, assuming 13 properties are protected by PLP

Scenario	Year	AAD	AAD avoided by PLP	Residual AAD
Present day	2015	£248,000	£26,800	£221,000
2050 (do minimum)	2050	£351,000	£24,900	£326,000
2114 (do minimum)	2114	£1.76 million	£35,100	£1.73 million

Table B.18 Whole-life costs and potential benefits of PLP in the Deben Estuary study area

	Warning-independent resistance	Warning-dependent resistance
Whole-life residual impacts with assets only	£16.4 million	£16.4 million
Whole-life impacts avoided by resistance measures	£876,000	£329,000
Whole-life costs	£264,000	£132,000
Benefit-cost ratio	3.31	2.49

B.4.3 Discussion and conclusions

In this study, the Deben Estuary MDSF2 model was re-run to assess:

- the benefits of property level responses to flood risk
- the benefits of FIM enabling assets
- the compatibility of ANSR with the MDSF2 approach

The results of this study suggest that the closure of flood gates contributes significantly to the damages avoided by assets. In this case, flood gates remaining unclosed more than doubles the annual damage. If this can be entirely attributable to FIM activities, this represents a significant benefit for FIM.

The important learning point of this case study is that it shows that the ANSR approach is broadly compatible with MDSF2 with the following caveats and notes:

- To be most useful, additional MDSF2 runs are needed to represent different scenarios.
- Results need to be processed to be useful in ANSR. For some values, like EAD, this is simple addition and subtraction. For others, like uptake and effectiveness, the calculations are less simple.
- At this level, there is a direct link between the uptake and effectiveness values, so the consequences of any change in uptake on the effectiveness need to be considered.

Directly working with the MDSF2 model allows the extraction of more useful information to quantify accurately the benefits of a greater number of pathways than when simply using damage value outputs.

The laborious (but relatively easily definable and programmatic) nature of the processing required to obtain meaningful results suggests that some form of helper tool would be useful to set up automatically and run the necessary MDSF2 re-runs and process results into a useable form. This could also provide a decision support tool to help users identify areas for improvement or investment, or where FIM and property level responses could be used in conjunction with assets.

The link between uptake and effectiveness may raise a question of the usefulness of separate factors that have to be split from damages avoided, only to be recombined in each pathway's calculation. There is, however, value in conceptually splitting them, and being able to see how the effectiveness changes as more properties are protected and may be helpful to decision makers.

B.5 Emsworth to East Head

The purpose of this case study is, like the Lower Aire case study (Section B.3), to investigate how MDSF2 results can be used in the ANSR tool without carrying out any further model runs and to quantify the benefits of the responses in ANSR. The specific goal of this study is to identify a method for estimating the potential benefits of PLP without having to re-run MDSF2.

To provide a useful worked example, information specific to this case study is written on the left and general guidance applicable to other applications is written on the right in the green boxes.

This case study

General guidance

B.5.1 Input data derivation

Parameters for the local area were estimated based on the EAD and probability of flooding from MDSF and the appropriate FWLoS spreadsheet and adjusted national data. There was no access to any other available data.

The main data requirements of ANSR are:

- Input damage values – optionally additional damage values to allow the benefits of working with assets to be calculated
- Flood warning success:
    - coverage
    - service uptake
    - service effectiveness
    - availability of residents to receive and act on the warning
- % operated for different lead time categories:
    - contents moved or evacuated
    - warning-dependent resistance (if relevant)
- Percentage of properties in each lead time category
- % uptake of:
    - warning-dependent and warning-independent resistance measures
    - resilience measures
- Uplift factors for the wider impacts of flooding

B.5.1.1 Damages

As with Lower Aire case study (Section B.3), EAD data were extracted from the MDSF2 results, in this case for the present day, 2053 ‘do minimum’ and 2112 ‘do minimum’ scenarios, and used to calculate the total direct property damage and residential component.

Only 563 out of 101,544 impact cells registered as having an EAD greater

A method was developed (based on previous work by Halcrow for NaFRA) that uses the Multi-Coloured Manual WAAD method to estimate damage values and the benefits of PLP. This is required because, at this more local scale, water levels should be used to estimate the benefits of PLP and MDSF2 does not output water levels (only EAD than £0 in the present day (630 in 2112).

As explained to the right, the internally generated EAD does not allow the benefits of PLP to be calculated. So for this case study the properties with an EAD greater than £0 were taken and the WAAD-based calculation explained on the right was made.

values).

A method developed by Halcrow to calculate the WAAD from NaFRA MDSF2 outputs (as an alternative to the built-in EAD calculation) takes the probability of flooding for each impact cell from MDSF2 and converts it to a standard of protection). Table 4.33 of the 2013 version of MCM (Table 4.18 in MCM 2010) reduces WAAD values based on the SoP. The Halcrow method estimates the damage per property by linearly interpolating between values in Table 4.33 using the SoP taken from the NaFRA outputs.

Table 4.33 in MCM 2013 is calculated using the more in-depth Table 4.32. Table 4.32 is based on a distribution of flood depths for each return period of flood event. Table 4.33 is therefore generated by setting damages for flood events with a lower return period than the required SoP to zero. For example, for a five-year SoP, damage for a five-year flood event is set to zero.

MCM 2013 Table 4.32 was duplicated in a spreadsheet. The method above was then used to calculate WAAD values to verify that the same values as in Table 4.33 were achieved.

The new method builds on these ideas. To estimate damages for each impact cell:

- Convert the probability of flooding for each impact cell to a standard of protection.
- Using a spreadsheet version of MCM 2013 Table 4.32 (Table 4.17 in MCM 2010), for each impact cell, set the damages for flood events with a lower return period than the SoP to zero. If the SoP is between two SoPs from the WAAD table, repeat for the SoP above and below the value and linearly interpolate between the two WAAD values.
- Multiply the WAAD value for each impact cell by the number of residential properties in that cell.

B.5.1.2 Working with assets

The benefits of FIM working with assets were not quantified in this case study.

See the Deben Estuary case study for the benefits of FIM working with assets.

B.5.1.3 Flood warning success

Coverage

The method was followed to calculate the EAD of properties inside and outside flood warning and/or flood alert areas, and hence the coverage.

$$\%\,Coverage = \frac{£1.63\,million}{£1.64\,million} = 99.2\%$$

As introduced in the Lower Aire Case Study (Section B.3), the coverage can be calculated by:

$$\%\,Coverage = \frac{EAD_{FWA/FAA}}{EAD_{FWA/FAA} + EAD_{Not:FWA/FAA}}$$

Service uptake, service effectiveness and availability of residents

For this case study, we used national data, as discussed to the right.

In the absence of local data, the value of 38% from the ‘reliability and availability’ factor in Parker et al. (2007) serves as a proxy for the combined service uptake, service effectiveness and the availability of residents to receive a warning.

B.5.1.4 ‘% operated’ *for different lead times*

Contents moved and evacuated

For this case study, national data were used, as discussed in more detail in the Lower Aire case study (Section B.3).

% operated for contents moved and evacuated can be taken from Priest and Parker (2012):

- 0–1 hour lead time: 70%
- 1–8 hours: 72%
- >8 hours: 80%

Warning-dependent resistance

For this case study, national data were used, as discussed to the right.

The post-flood event survey data presented by Priest and Parker (2012) also provides a percentage of respondents who put flood boards in place. This incorporates the percentage of respondents who have flood boards (and relies on a shared understanding of what flood boards are), which is specific to the areas studied. It cannot be generalised and is therefore not applicable to one case study area.

The data does, however, provide a percentage of respondents who 'took some action'. Assuming (as in the national application) that residents with flood guards will (if they take any action at all) put their guards in place, this percentage is a proxy for the % operated for warning-dependent resistance (Table B.19). As above, this does not take community awareness into account but can be generalised otherwise.

Table B.19 Percentage 'operated' for warning-dependent resistance for each lead time category

Lead time	% operated for warning-dependent resistance
0–1 hour	92.0%
1–8 hours	95.8%
>8 hours	98.9%

This case study

General guidance

B.5.1.5 Lead times

Limited lead time information was available. The FWLoS spreadsheet assumed that flood warning areas all meet the target lead times of two hours for fluvial areas and six hours for tidal areas. This could be because there had been insufficient (or no) flood events from which to measure lead times. Based on this information, all areas (and hence 100% of properties) fit into the '1–8 hours' lead time category.

Determine lead times using the FWLoS spreadsheet, if available, as explained in the Lower Aire case study (Section B.3).

B.5.1.6 Property level protection

Benefits

For this case study, the approach described on the right was carried out to estimate the potential benefits of installing PLP in this area, assuming that there are currently no measures installed. It was therefore possible to consider the benefits that could be

As explained above, a local-scale application of the ANSR methodology requires a greater level of detail than a large-scale application, so water levels should be used to identify more precisely the benefits of PLP.

achieved for different levels of investment (uptake).

The calculation was repeated for each of the three snapshots to assess the change in the benefits of PLP over time. This also allowed a whole-life assessment of the costs and benefits of PLP to be carried out.

Uptake in PLP for non-residential properties was assumed to be 0.

To quantify the benefits of PLP, continuing the damage calculation above:

- Assuming a 100% uptake in PLP, set the damages for flood depths below or equal to 0.6 m to zero.
- Calculate a second WAAD value for each impact cell.
- Identify the number of properties in impact cells for which PLP is estimated to reduce damages.

Impact cells can be sorted by the amount of benefit that can be achieved (AAD avoided per property). If the aim is assess the benefits of various levels of investment, build up a correlation between uptake (% of properties with PLP installed) and effectiveness (% of the AAD of the protected properties that is avoided). ANSR can be linked to this table by using a VLOOKUP function in Excel to search for the uptake and return the corresponding effectiveness value.

Costs

The number of properties in impact cells for which PLP was estimated to reduce damages was identified.

Based on an estimated cost of installing PLP for both warning-dependent and warning-independent, the cost of installing PLP was calculated.

Based on estimates from the Forest Row PLP scheme, costs were assumed to be:

- £5,000 per property for warning-dependent resistance
- £10,000 per property for warning-independent resistance

Estimate the average cost of a portfolio of PLP measures that provide protection up to 0.6 m using flood guards for warning-dependent resistance or flood-proof doors for warning-independent resistance.

Whole-life analysis

A 20-year life, as estimated by Stevens and Chatterton (2012), was assumed. Zero maintenance costs during the life of the measure were also assumed.

A 100-year whole-life analysis was carried out, assuming that 100% of properties are protected where a benefit could be achieved by PLP. It was also assumed that the scheme would be

Estimate the lifespan and maintenance costs of a typical PLP scheme.

Calculate the installation costs for the properties chosen to be protected. Carry out a whole-life assessment for:

- the lifespan of the measures
- a 100-year period where the measures are replaced at their end-of-life and benefits continue

replaced like-for-like at its end-of-life.

The three available snapshot years were used with linear interpolation between them to build a 100-year picture.

The benefits of warning-dependent resistance were calculated using the ANSR calculation (multiplying by 'reliability and availability' and 'operated') to reduce the benefits.

- a 100-year period where the measures are not replaced at their end-of-life and benefits cease

Use the standard 'Green Book' method (HM Treasury 2003) to calculate the present value damages, benefits and costs using discount rates and factors.

B.5.1.7 Wider impacts

Wider impacts were considered as part of the Lower Aire case study (Section B.3). This case study focused on direct property damages.

See the Lower Aire case study.

B.5.2 Results

B.5.2.1 Present day calculations

The active pathways in the Emsworth to East Head case study are 'warning-independent resistance' and/or 'warning-dependent resistance' and 'contents moved and evacuated'.

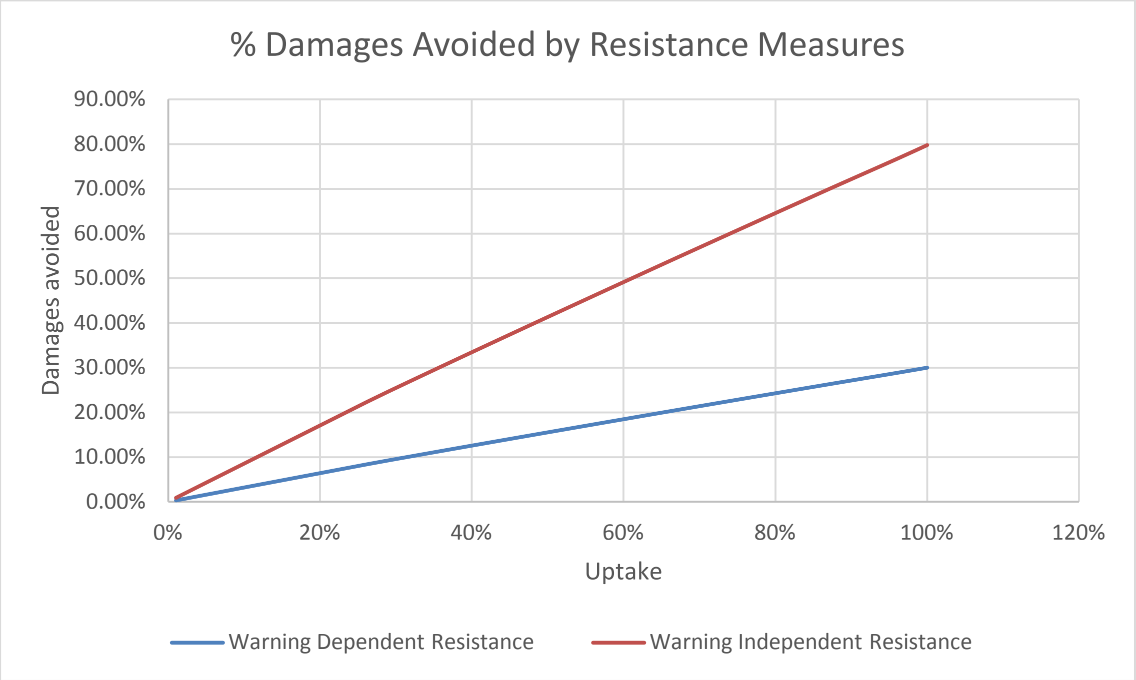


Figure B.7 Percentage damages avoided by resistance measures for 0–100% uptake

Figure B.7 shows the damages avoided by resistance measures taking into account uptake, effectiveness and (for warning-dependent resistance) reliability and availability, and operated. Figure B.8 shows how the effectiveness decreases with increased uptake, albeit not by a significant amount.

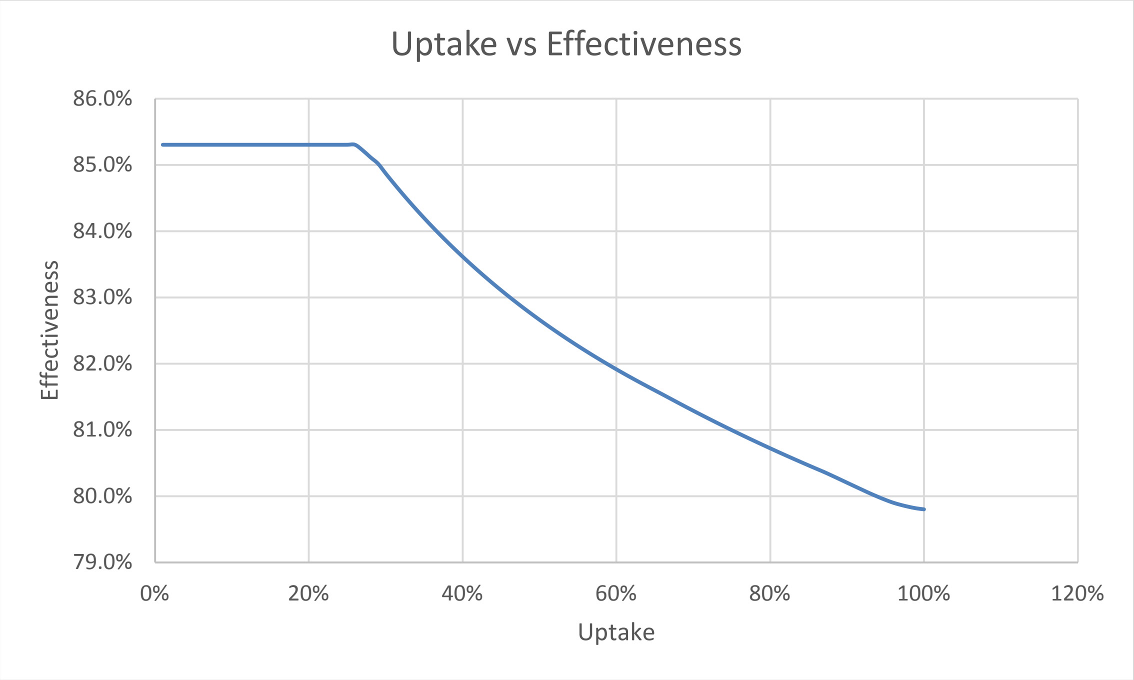


Figure B.8 Percentage effectiveness for 0–100% uptake in resistance measures

For illustrative purposes, an uptake of 49% (protecting 121 properties out of the 469 at risk for the present day) was used. This is the highest uptake that achieves the maximum effectiveness value of 85.3%. Table B.20 and Table B.21 compare the damages avoided by warning-independent resistance if these 121 properties are protected, and Table B.22 shows the damages avoided by contents moved and evacuated.

Table B.20 Damages avoided by warning-dependent resistance if 121 properties are protected

WDR_{Res}	=	Residual damages	×	Reliability and availability	×	Operated	×	Uptake	×	Effectiveness
	=	£1.17 million	×	37.7%	×	95.8%	×	49.1%	×	85.3%
	=	£1.17 million	×	15.12%						
	=	£178,000								

Table B.21 Damages avoided by warning-independent resistance if 121 properties are protected

WIR_{Res}	=	Residual damages	×	Uptake	×	Effectiveness
	=	£1.17 million	×	49.1%	×	85.3%
	=	£1.17 million	×	41.9%		
	=	£492,000				

Table B.22 Damages avoided by contents being moved or evacuated, assuming that the 121 properties are protected by warning-independent resistance

CME_{Res}	=	Residual damages	×	Reliability and availability	×	Operated	×	Effectiveness
	=	£1.17 million	×	37.7%	×	72.0%	×	21.3%
	=	£1.17 million	×	5.79%				
	=	£57,700						

Table B.23 ANSR calculation results for direct property damages

	Direct property damage		
	Residential	**Non-residential**	**Total**
Residual impacts with assets only	£1.17 million	£317,000	£1.49 million
Impacts avoided by warning-independent resistance	£492,000	£0	£492,000
Impacts avoided by moving and evacuating contents	£39,500	£18,200	£57,600
Residual impacts with assets and flood warnings	£643,000	£298,000	£941,000

B.5.2.2 Whole-life calculations

The method described above was used to estimate the potential benefits of PLP in the Emsworth to East Head study area.

Table B.24 shows the results for each snapshot year, assuming that warning-independent resistance were installed in all 496 properties for which PLP would have a benefit (in any of the three snapshots). Table B.25 shows the different costs and benefits of warning-independent and warning-dependent resistance.

Table B.24 Annual damages and damages avoided by PLP for the three snapshot years, if all properties are protected by PLP

Scenario	Year	AAD	AAD avoided by PLP	Residual AAD
Present day	2012	£1,174,183	£937,043	£237,140
2053 (maintain crest levels)	2053	£1,773,856	£1,464,368	£309,488
2112 (maintain crest levels)	2112	£2,264,510	£1,925,120	£339,391

Table B.25 Whole-life costs and potential benefits of property level protection in the Emsworth to East Head study area

	Warning-independent resistance	Warning-dependent resistance
Whole-life residual impacts with assets only	£50.9 million	£50.9 million
Whole-life impacts avoided by warning-independent resistance	£47.5 million	£17.2 million
Whole-life costs	£10.2 million	£5.08 million
Benefit-cost ratio	4.7	3.4

This case study

General guidance

B.5.3 Discussion and conclusions

In this study, the results of the Emsworth to East Head MDSF2 model were used to assess:

- the ability of PLP to mitigate the potential increases in risk that are likely to result from climate change
- the ease with which MDSF2 results could be manipulated to estimate the benefits of PLP

The main learning point of this case study is that, although there are significant limitations in using the outputs of MDSF2 models in ANSR without re-running models, there are potentially methods available to circumvent these limitations to calculate the benefits of property level responses. For other responses, however, it may be more difficult.

While feasible with the available data, the method remains relatively untested and may not be applicable at such a local scale. However, the method may well be useful at a national scale, for which the WAAD data used in the calculation is derived. It may also be a useful tool to determine areas where more detailed studies would be valuable. This would be limited by the fact that the WAAD depth-probability distributions do not take into account local variations that may make a particular area more or less suited to PLP.

B.6 Appleby-by-Westmorland

A local fluvial application is required to draw out the most important issues and changes in the FIM benefit assessment framework when it is applied at a local scale. This case study was developed to:

- test the robustness of the complete ANSR approach at a local level
- examine the majority of the pathways
- investigate the quality and application of available Environment Agency datasets at a local level within the ANSR approach

The focus was on providing a deeper narrative of some of the issues encountered when developing a case study.

B.6.1 History and flood risk

Appleby is a small Cumbrian town with a population which suffers primarily from fluvial flooding from the River Eden. The town has a long history of flooding with notable events in 1928, the late 1960s and 1995. Between 70 and 80 properties were affected by flooding in 1995, and 53 commercial and residential properties flooded in 2005. Most recently, the town experienced flooding in 2009, albeit at a lower severity than the 2005 flood event.

B.6.2 Managing risk

The area has a well-established flood warning service with four different flood warning areas (the most recent flood warning area has been established to deal with surface water flood warning) with high rates of uptake of the service by the community.

The area to the south of the river is protected by a flood defence completed in 1995, owned and operated by the Environment Agency. This has a standard of protection of 1% and consists partly of a fixed asset but with a significant gap which is closed at times of flooding by closing 23 flood gates.

Appleby was included within one of the Defra resistance and resilience pilots and, in 2009, 34 properties received funding for the installation of measures.

B.6.3 Applying the extended FWRBP model

The extended FWRBP model was applied to each of the activated pathways which, in this case study, was all pathways except community level measures. Each of the results of the pathways is discussed below.

B.6.3.1 Estimating average annual damages

Estimating average annual damages at the local level for Appleby proved to be difficult. This is of great importance to the application of the extended FWRBP model because it provides the basis for the rest of the calculations, as demonstrated by the sensitivity analysis of the method within the inception report.

Two main sources of information were identified to provide this estimation. The first is the Eden Catchment Flood Management Plan (CFMP) which provides an overall figure for EAD of **£1.6 million,** divided between non-residential, residential and agricultural losses. However, only limited details are provided about how this figure was obtained (for example, using MDSF and the National Property Dataset) with little information about the process or scale at which the figures have been generated.

The CFMP provided estimates for three different annual probabilities (10, 1 and 0.1%). Although these do not provide very detailed information, utilising the FCERM PAG spreadsheet has permitted a redrawn damage probability curve (which is used for other pathways) and recalculation of the EAD. This process generated a very different value for EAD of **£2.8 million**, with a very different result for non-residential properties but residential properties in line with the original CFMP estimate.

The second source of an estimate was from the System Assessment Management Plans which utilise the NaFRA methodology to estimate expected weighted annual average damages, and therefore benefits, under different scenarios. This uses a coarse approach to estimation and, due to changes to the NaFRA modelling and the input data between the 2009 to 2010 and the 2010 to 2011 datasets, two significantly different values are provided using the ‘no defence’ scenario. The older dataset suggests that EAD has a value of **£716,645** with the newer data reducing this value to **£198,118**.

B.6.3.2 Defence assets and watercourse capacity maintenance

The SAMPs data can be used to assess the benefits of defence assets and watercourse capacity maintenance. However, like the EAD estimate, two very different estimates are provided due to the different NaFRA datasets.

For Appleby defences, the 2009 to 2010 figures suggest that the benefits are £445,214 (or 62% of estimated EAD) which reduces to only £9,183 (5% of estimated EAD). The defences in Appleby rely on the timely closure of the 23 main flood gates near the swimming pool, as well a number of other gates. It has been assumed here that, if the main gates are not closed, then damage saving from these defences will be minimal as an approximately 30 m gap in the defence would remain. The impact of the failure to shut some of the more isolated or smaller gates is more difficult to assess. It might be possible to use the RAFT tool, developed by HR Wallingford, and treat these gaps as minor breaches to assess the impact of the non-closure of gates.

Either of the figures for defence assets (for example, £445,000 or £9,000) may be deducted from the overall EAD value to provide an estimate of the residual risk. However, for all the benefits to be accrued and the total figure to be used, it must be assumed that these defences are operated in a timely manner if flooding is likely. All indications from the Environment Agency FIM team suggest that this is the case.

Channel conveyance benefits reduce from £15,442 in 2009 to 2010 to (2% of AAD) to £0 benefits in the 2011 to 2012 calculation. Thus, overall in Appleby the benefit of channel conveyance is low. This was confirmed in general by the local FIM team, but they pointed out that the clearance of certain trash screens during flood had a direct impact on the likelihood of flooding in a couple of properties.

In general, the SAMPs approach is likely to be useful for the estimation of these types of benefits and they clearly provide a starting point for estimation. However, the change in outputs would need to be verified using local knowledge and, at this local scale, the outputs might prove to be too coarse if comparing them with data that have been derived more locally.

B.6.3.3 Detection, forecasting and warning

This element of the ANSR tool incorporates a number of different components including coverage of the service, service uptake, effectiveness of the service and the availability of residents and business owners to respond to warnings.

To estimate these values for Appleby it has been necessary to use a mix of local, regional and national figures about flood warning performance. For Appleby, the best available figures are provided in Table B.26.

Table B.26 Calculation of reliability and availability for Appleby

RA	=	Service coverage[1]	×	Service uptake[2]	×	Service effectiveness[3]	×	Availability[4]
	=	100%		80%		75%		64%
	=	38.4%						

Notes:

[1] Coverage was estimated by the local Environment Agency FIM team based on the fact that all properties at risk are offered a flood warning scheme.

[2] Service uptake was estimated from averaging the numbers of properties signed up to the service in each of the flood warning areas as a proportion of the total numbers at risk.

[3] Service effectiveness was estimated from regional values for the flood warning performance measures from the Flood Warning Validation Database in May 2011.

[4] The local survey evidence was considered to be quite dated and to potentially underestimate the figure for availability. The highest estimated figure was adopted from the national baseline.

B.6.3.4 Property level protection

Although 34 properties were involved in the pilot study, there is little information about the types of measures implemented or their costs and benefits. Therefore, it was assumed that all damage savings require a flood warning as images from the 2009 event illustrate.

Two methods were trialled to estimate the benefits of these measures to resistance and resilience at a local scale. Each method was applied separately to residential and non-residential properties. Each has its own particular methodological advantages and disadvantages, but also has further issues and assumptions related to its application within Appleby.

The first method is to use a damage-probability curve and estimate the damages that would be avoided by employing these measures as a proportion of the total damages. There are a number of assumptions related to this, including whether those properties which have installed PLP measures are typical of the overall population of properties. In the case of the Appleby situation, the problems with the method are compounded by the difficulty of assessing the total number of properties at risk within each flood zone, assessing the return periods for which the measures are effective and, significantly, the quality of the damage-probability curve which is being used to calculate these figures. Although it has been possible to estimate these, the quality of the output figures is questionable.

A second approach investigated was to use the NRD and the modelled flood extents for different return periods for those properties with measures and, using the MCM, to calculate those damage values for each which would be avoided due to the measures. Again, there are a number of methodological issues associated with the approach such as the problems of using averaged values. However, the more significant problems in this method lie with its application in Appleby. The depth values which have been applied in this case have been estimated as there is no information on likely flood depth experienced. The design effectiveness of the measures is not known, so it has been assumed that they are 100% effective up to a 1 in 50 year flood. After this, no damages are saved and, perhaps most significantly, the method is reliant on the correct identification of properties within the scheme which has been very difficult to achieve in this situation and hard to validate.

The current estimates for property level measures were calculated on incomplete and unverified data, in particular data relating to the identification and location of those residential properties that participated in the scheme, as well as estimations of their risk of flooding. It is not clear whether the flood risk extent information is sufficiently up-to-date and this might be affecting specific estimations of benefits. Despite this, if these data can be improved and verified then it is hoped that the method can to provide a more accurate measure of the total potential benefits of these non-structural approaches.

B.6.3.5 Moving contents and evacuation of property

Again, this value been derived from a mix of local and national values. The best available values for Appleby are provided in the equation below:

$$\begin{aligned} CME^{RE} &= RA^{RE} \times OP^{CME} \times EF^{CME} \\ &= 38\% \times 62\% \times 21\% \\ &= 4.9\% \end{aligned}$$

The flood warning reliability and availability (RA) factor of 38% is taken from Table B.26.

The operated (OP) value was taken from the number of people who were able to take certain actions during the 2005 flood as detailed by the post-event survey.

It was necessary to adopt the national effectiveness (EF) value as detailed in Parker et al. (2007) as there were no additional data by which to refine it.

B.6.4 Discussion and recommendations

In general, the extended FWRBP method is suitable and can be applied at the local level using a range of approaches to estimate the benefits within each pathway. However, the Appleby case study has raised some significant data issues in relation to the application of the extended FWRBP method at this local scale.

The main issue concerns the use and integration of results from inconsistent datasets. Of particular significance is the selection of the EAD value. The sensitivity analysis conducted as part of this project indicates that this is one of the key variables to ensure the accuracy of the assessment. The temporal variations in data for this figure are problematic as the CFMP figures were generated for 2008, yet estimates for other benefit pathways are from newer data; hence it is questionable whether it is correct to calculate benefits as a proportion of this value. Newer estimates of EAD are possible from the SAMPs assessments, but these are based on very coarse grid data which again raises questions about the validity of using these data for such a local assessment.

These issues have been further compounded by an inability to verify both the approaches used to generate estimates and the quality of the data being provided. Some of the documents do not fully explain how estimates have been generated (for instance the CFMP). In the case of Appleby, much of the modelling work was carried out some time ago and by external consultants. This, in addition to the movement and departure of personnel, has meant that knowledge about the data, their origins and their quality have been lost. In general, it has been hard to verify locally many of the details about the data which, in turn, has necessitated an increase in the number of assumptions required (or rejection of some data) and reduced the overall quality of the assessment. The issues of data quality are magnified at this local scale.

From a spatial perspective, data have been used at a national, local and regional scale. Again, this is not ideal when dealing with such small numbers of properties (for example, 12 commercial properties having property level measures) at the local level. It means that these inconsistencies become very significant. With additional data collection at a local level in certain areas (such as flood warning or more frequent survey), the quality of the benefit assessment outputs could be improved.

Despite the data issues, the methods developed have great potential for verification (both by expert judgement and survey) and for providing a contrast and comparison to the national level approaches. Indeed, if needed, each of the 46 properties with defences could be reviewed and individually assessed for the potential damage savings (for example, more specific estimates of damage might be utilised from the MCM). No depth grid information is currently available. However, new modelling is planned and would assist in improving any of the identified data issues.

In general, although data issues dominate the Appleby case study, it illustrates a number of different approaches that could be used at this local scale and where data improvements are necessary.

Appendix C ANSR user guide

C.1 Overview

This user guide contains four sections representing features of analyses carried out using the ANSR tool. Each section is broken down into the tabs where input is required for that analysis. Tabs not included in each section do not need to be considered for that analysis.

The first section is the most basic form of analysis, a single scenario quantifying the benefits (direct property damage avoided) of resistance (warning-dependent and warning-independent), resilience, and contents moved and evacuated.

The second section shows the method for quantifying the benefits (direct property damage avoided) of ‘working with assets’ (enabling the operation of assets through flood forecasting). The activities included:

- flood defence operation such as flood gates
- community-level operations such as temporary and demountable defences
- watercourse management – activities to prevent blockages

The third section extends these analyses to include direct property damages, the wider impacts of flooding and the benefits of avoiding those impacts.

The fourth section extends the single scenario to include up to five additional investment scenarios, where investment in a given area is linked to changes in the value of a particular factor.

Throughout this user guide, the names of tabs are shown like this, and the names of pathways and factors are shown **like this**.

C.1.1 General tabs

C.1.1.1 Intro

The Intro tab provides a quick summary of all the other tabs and a version history.

C.1.1.2 Dashboard

The Dashboard tab is the main port of call for a summary of results. Its various features are discussed in the relevant sections below.

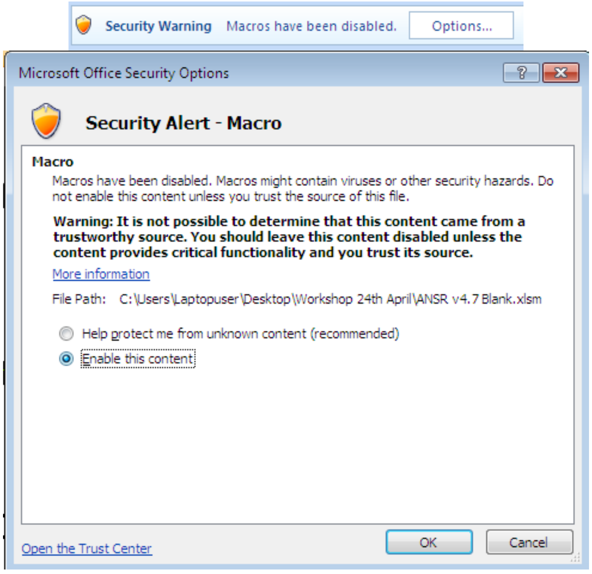
C.1.1.3 Settings

The Settings tab contains key options that change the way the spreadsheet operates. Parts of this tab are included in the appropriate section below.

C.1.2 Getting started

The ANSR spreadsheet is an XLSM file. This means it is a macro-enabled spreadsheet designed to work with Microsoft® Office 2007 and later versions. When you start, you need to ‘Enable Macros’.

In Office 2007, click ‘Options’ on the security warning that appears, select ‘Enable this content’ and click ‘OK’.



Macros have been disabled.

Security Alert - Macro

Macro

Macros have been disabled. Macros might contain viruses or other security hazards. Do not enable this content unless you trust the source of this file.

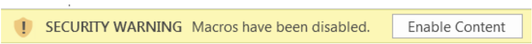
Warning: It is not possible to determine that this content came from a trustworthy source. You should leave this content disabled unless the content provides critical functionality and you trust its source.

More information

File Path: C:\Users\Laptopuser\Desktop\Workshop 24th April\ANSR v4.7 Blank.xlsm

○ Help protect me from unknown content (recommended)
● Enable this content

In Office 2013, click ‘Enable Content’ on the security warning that appears:



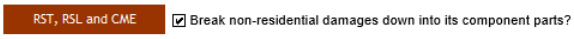
SECURITY WARNING Macros have been disabled.

In general, there is no link between the colour of a cell and its function. Cells which can be edited are hatched:

C.1.2.1 *General settings*

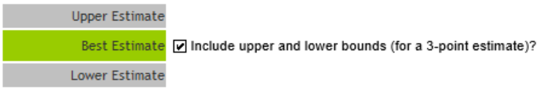
The Settings tab includes a number of settings that apply throughout the spreadsheet.

The FWRBP model, the basis for ANSR’s methodology, included a single business continuity planning (BCP) factor representing the damage avoided by businesses. ANSR breaks this down into individual non-residential, property level responses, but gives you the option to revert to a single factor:



☑ Break non-residential damages down into its component parts?

You can choose between a single ‘best estimate’ for each value or a set of three (‘upper estimate’, ‘best estimate’ and ‘lower estimate’):

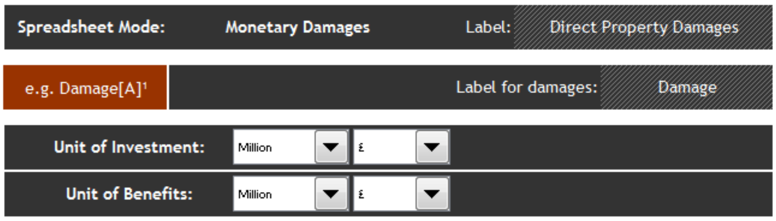


☑ Include upper and lower bounds (for a 3-point estimate)?

Dropdown boxes, using Excel's built-in data validation functionality, are not always clear to see. There is therefore an option to highlight dropdown boxes to help you spot them.

Highlight 'drop-down' boxes? No

There are also settings to define how damages are referred to. The unit of investment/benefit can also be changed, but be aware that this only has an impact on the headline rounded figures on the Dashboard tab and the values on the Investment tab. It is advisable to leave these as the default values:



Spreadsheet Mode: Monetary Damages Label: Direct Property Damages

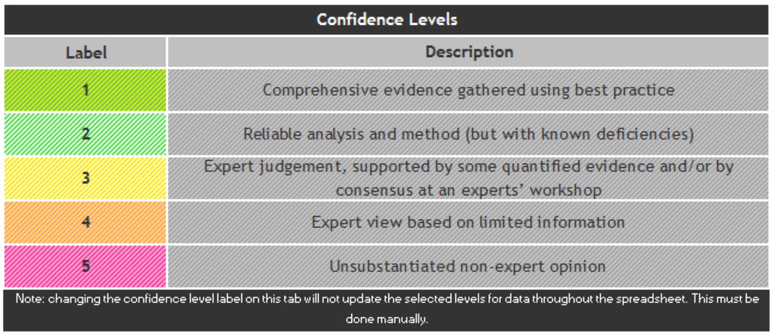
e.g. Damage[A]¹ Label for damages: Damage

Unit of Investment: Million £

Unit of Benefits: Million £

C.1.2.2 Data sources and confidence levels

On the right-hand side of most lines of data, you can add notes to indicate a data source and a 'confidence level' from one to five. You can change the definition of these confidence levels on the Settings tab (Figure C.1).



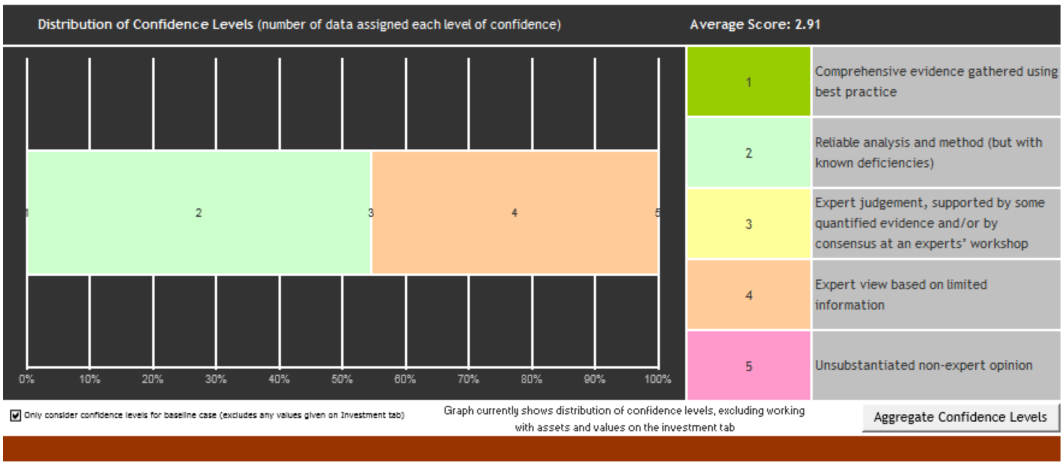
Confidence Levels

Label	Description
1	Comprehensive evidence gathered using best practice
2	Reliable analysis and method (but with known deficiencies)
3	Expert judgement, supported by some quantified evidence and/or by consensus at an experts' workshop
4	Expert view based on limited information
5	Unsubstantiated non-expert opinion

Note: changing the confidence level label on this tab will not update the selected levels for data throughout the spreadsheet. This must be done manually.

Figure C.1 Settings: Confidence level definitions

Confidence levels are aggregated and displayed on the Dashboard tab by clicking the 'Aggregate Confidence Levels' button. Rather than performing any complex analysis or weighting of confidence levels, they are simply added to give you an indication of the spread of confidence levels in your data.



Distribution of Confidence Levels (number of data assigned each level of confidence)

Average Score: 2.91

1	Comprehensive evidence gathered using best practice
2	Reliable analysis and method (but with known deficiencies)
3	Expert judgement, supported by some quantified evidence and/or by consensus at an experts' workshop
4	Expert view based on limited information
5	Unsubstantiated non-expert opinion

☑ Only consider confidence levels for baseline case (excludes any values given on Investment tab)

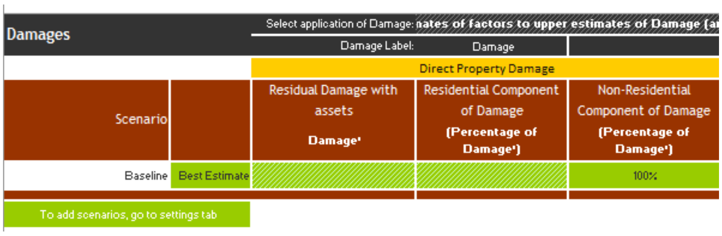
Graph currently shows distribution of confidence levels, excluding working with assets and values on the investment tab

C.2 ANSR calculation of the benefits of property level responses

C.2.1 Settings

See the general settings section above. Nothing else on the Settings tab is relevant to this basic analysis.

C.2.2 Damage Inputs



Damages

Select application of Damage: nates of factors to upper estimates of Damage (a

		Damage Label: Damage		
		Direct Property Damage		
Scenario		Residual Damage with assets Damage'	Residential Component of Damage (Percentage of Damage')	Non-Residential Component of Damage (Percentage of Damage')
Baseline	Best Estimate	▨	▨	100%

Figure C.2 Damage inputs for a basic analysis.

As shown in Figure C.2, the damage inputs for an analysis of property level responses are:

- **Residual Damage with assets** (an absolute monetary value) – a defended damage value
- **Residential Component of Damage** – he percentage of the total direct property damage accounted for by residential properties

Other inputs on this tab are not necessary for this basic analysis.

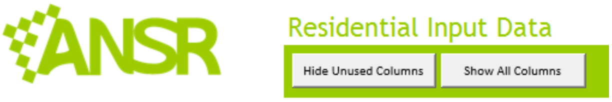
C.2.3 Res Inputs

Inputs in the Res Inputs tab are grouped by factor. This is to make it easier to compare the same input value between factors. The Res Calcs tab shows values grouped by pathway to see the complete calculation.

C.2.3.1 Options

Each factor (apart from **Response Operated**) allows you to use either a single factor (Mode: ‘Simple’) or a set of factors multiplied together (Mode: ‘Detailed’):

You can also show or hide unused columns to make it easier to work with the spreadsheet:



C.2.3.2 Response Uptake (UP)

UP % Response Uptake The percentage of properties/areas at risk that each measure has been installed or invested in Mode: Simple

			%UP	
WIR	Warning Independent Resistance	Best Estimate	0%	Pos
WDR	Warning Dependent Resistance	Best Estimate	0%	Pos
RSL	Resilience Measures	Best Estimate	0%	

Figure C.3 Inputs for Response Uptake

Response Uptake is the percentage of damage to protected properties as a proportion of the total (residential) property damage. At large scales, this could be approximated by the percentage of protected properties as a proportion of the total number of properties. By default, this is set to a single value for each of the three relevant pathways:

- **Warning Independent Resistance**
- **Warning Dependent Resistance**
- **Resilience Measures**

If you change the mode from ‘Simple’ to ‘Detailed’, you can use a number of factors multiplied together for each. Figure C.3 shows the inputs for **Response Uptake.**

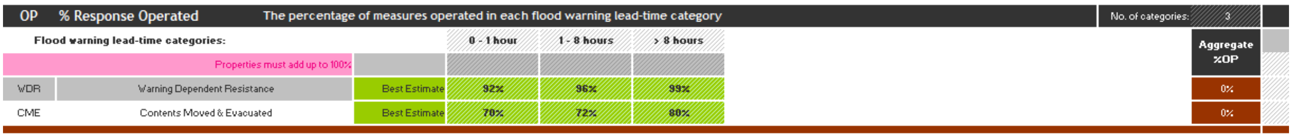
C.2.3.3 Response Operated (OP)

Response Operated is the percentage of the potential damage actually avoided. For example, for **Warning Dependent Resistance**, this is the percentage of flood guards successfully put in place. For **Contents Moved & Evacuated**, this is the percentage of the moveable inventory successfully moved.

Response Operated is the factor used to represent the available lead time and the subsequent action taken. Therefore there are two components to **Response Operated**:

- Lead time categories (for example, 0–1 hour, 1–8 hours, >8 hours), and the percentage of properties (or damage) in each lead time category. You can change the number of categories (No. of categories: 3).
- The **Response Operated** value for each lead time category for **Warning Dependent Resistance** and **Contents Moved & Evacuated**. Values are provided for this (Figure C.4), and can be used in any application unless

better data become available. This is because the percentage of properties in each lead time category links these values to a specific location.



OP % Response Operated The percentage of measures operated in each flood warning lead-time category No. of categories: 3

Flood warning lead-time categories:			0 - 1 hour	1 - 8 hours	> 8 hours	Aggregate %OP
Properties must add up to 100%						
VDR	Warning Dependent Resistance	Best Estimate	92%	96%	99%	0%
CME	Contents Moved & Evacuated	Best Estimate	70%	72%	80%	0%

Figure C.4 Inputs for Response Operated

C.2.3.4 Response Potential (PO)

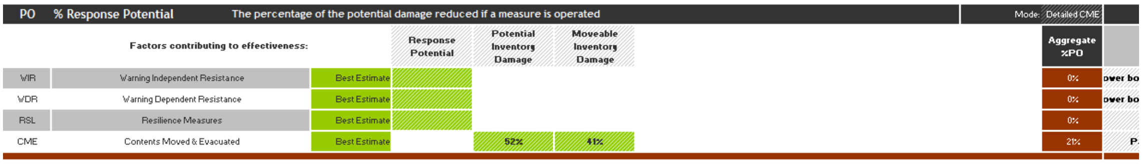
Response Potential is the proportion of the annual average damage that each pathway could avoid if properties were protected, and the response was successfully operated. The emphasis here is on the fact that it is not the maximum potential of each pathway (for example, resistance measures could avoid almost all damages for floods up to 0.6 m), but the annual average and so must take into account extreme events.

It is also inherently linked to the level of **Response Uptake.** If it is assumed that the properties protected first are those where the greatest benefit can be achieved, then further investment and correspondingly higher values of **Response Uptake** are likely to result in a reduction in the overall **Response Potential**.

By default, pathways use a single factor, apart from **Contents Moved & Evacuated**, which uses a pair of relatively well-established figures (Parker et al,.2007):

- Potential Inventory Damage – the proportion of damage to a property accounted for by damage to household inventory (as opposed to building fabric damage)
- Moveable Inventory Damage – the proportion of the household inventory damage accounted for by items which can be moved

Figure C.5 shows the inputs for **Response Potential**.



PO % Response Potential The percentage of the potential damage reduced if a measure is operated Mode: Detailed CME

Factors contributing to effectiveness:			Response Potential	Potential Inventory Damage	Moveable Inventory Damage	Aggregate %PO	
WIR	Warning Independent Resistance	Best Estimate				0%	over bo
VDR	Warning Dependent Resistance	Best Estimate				0%	over bo
RSL	Resilience Measures	Best Estimate				0%	
CME	Contents Moved & Evacuated	Best Estimate		52%	41%	21%	P

Figure C.5 Inputs for Response Potential

C.2.3.5 Warning Success (WS)

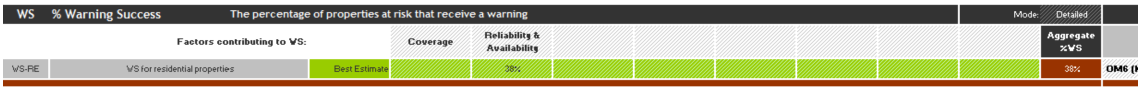
Warning Success represents the likelihood that people successfully receive a timely flood warning in order to take some action. It takes into account:

- coverage of the flood warning service – the percentage of damage/properties at risk of flooding offered a warning service
- sign-up to the flood warning service – the percentage of properties offered a warning service who are signed up to it
- effectiveness of the flood forecasting and warning service – the percentage of properties signed up to the warning service who are sent a flood warning

- availability of residents to receive, understand and act on the flood warning – the percentage of properties who are sent a flood warning who actually receive it

By default, two factors are used: **Coverage** and **Reliability and Availability.** The latter combines sign-up, warning service effectiveness and availability of residents. This is based on Parker et al. (2007), who found that a single factor matched the data available from post-flood event surveys.

Figure C.6 shows the inputs for **Warning Success**.



WS	% Warning Success	The percentage of properties at risk that receive a warning									Mode: Detailed	
	Factors contributing to WS:		Coverage	Reliability & Availability							Aggregate %WS	
WS-RE	WS for residential properties	Best Estimate		38%							38%	OM6 (I

Figure C.6 Inputs for Warning Success

C.2.3.6 *Benefit Overrides*

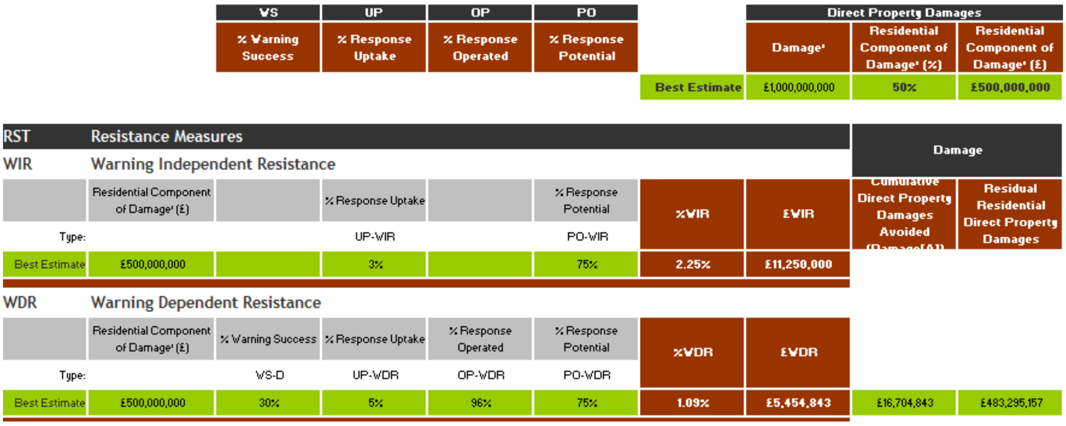
This section of the tab allows you to use a single factor for the damage reducing potential of a pathway. If you use an override, values for that pathway elsewhere on this tab do not affect the value of the pathway.

C.2.4 Res Calcs

The Res Calcs tab summarises the inputs from Res Inputs and goes through the sequence of calculations, showing how the factors for each pathway are multiplied together to obtain a single percentage value. Each pathway percentage is then multiplied by the residual damage (in sequence) to obtain the benefit for that pathway. This is subtracted from the residual damage to give a new lower damage value for the input to the next pathway in the sequence. The sequence is defined by the point in the system at which the pathway acts, that is:

- Resistance measures prevent water from entering a property.
- If water does enter a property, resilience measures reduce the damage.
- Contents moved or evacuated reduces any remaining damage

Figure C.7 shows an example pathway calculation. As the figure shows, resistance measures act slightly differently to other pathways. It is assumed that warning-dependent and warning-independent resistance measures operate at the same point in the system, so their percentage factors are added together and applied together, rather than being applied sequentially.



WS	UP	OP	PO		Direct Property Damages		
% Warning Success	% Response Uptake	% Response Operated	% Response Potential		Damage'	Residential Component of Damage' (%)	Residential Component of Damage' (£)
				Best Estimate	£1,000,000,000	50%	£500,000,000

RST	Resistance Measures							Damage	
WIR	Warning Independent Resistance								
	Residential Component of Damage' (£)		% Response Uptake		% Response Potential	%WIR	£WIR	Cumulative Direct Property Damages Avoided (Damage[A])	Residual Residential Direct Property Damages
Type:			UP-WIR		PO-WIR				
Best Estimate	£500,000,000		3%		75%	2.25%	£11,250,000		
WDR	Warning Dependent Resistance								
	Residential Component of Damage' (£)	% Warning Success	% Response Uptake	% Response Operated	% Response Potential	%WDR	£WDR		
Type:		WS-D	UP-WDR	OP-WDR	PO-WDR				
Best Estimate	£500,000,000	30%	5%	96%	75%	1.09%	£5,454,843	£16,704,843	£483,295,157

Figure C.7 Part of the Res Calcs tab, showing the calculation of benefits for resistance measures

To the right of the calculations are a series of graphs representing the gradual reduction in damage, as shown in Figure C.8.

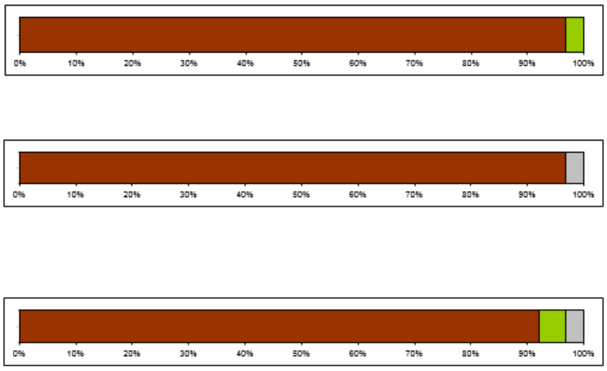


Figure C.8 Graphs showing the damage avoided by each pathway (green) and residual damage (orange)

The tab also provides a cumulative total damage avoided and a final residual damage value.

C.2.5 Non-Res Inputs and Non-Res

Non-Res Inputs and Non-Res are replicas of the Res Inputs and Res Calcs tabs for non-residential properties. The only difference is the addition of a button at the top of Non-Res Inputs which runs a macro to copy across values (including data sources and confidence values) from the Res Inputs tab.

C.2.6 Dashboard

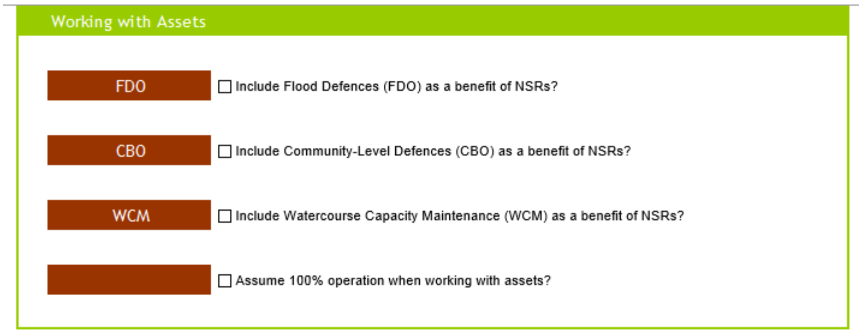
The Dashboard tab presents a summary of the residential and non-residential damage avoided by property level responses, total damage avoided and residual damage values (before and after so-called non-structural responses).

Note: investment information is also presented on the Dashboard but is not required for this type of analysis as it is only used to compare multiple scenarios. You can, however, still input this information on the Investment tab if desired.

C.3 ANSR calculation of the benefits of working with/enabling assets

C.3.1 Settings

To include one or more of the pathways representing the benefits of flood detection, forecasting and warning enabling the operation of assets, use the tick boxes on the Settings tab (Figure C.9).



Working with Assets

FDO ☐ Include Flood Defences (FDO) as a benefit of NSRs?

CBO ☐ Include Community-Level Defences (CBO) as a benefit of NSRs?

WCM ☐ Include Watercourse Capacity Maintenance (WCM) as a benefit of NSRs?

☐ Assume 100% operation when working with assets?

Figure C.9 Settings: Working with Assets options

Notes: FDO = flood defence operation

CBO = community-based operations

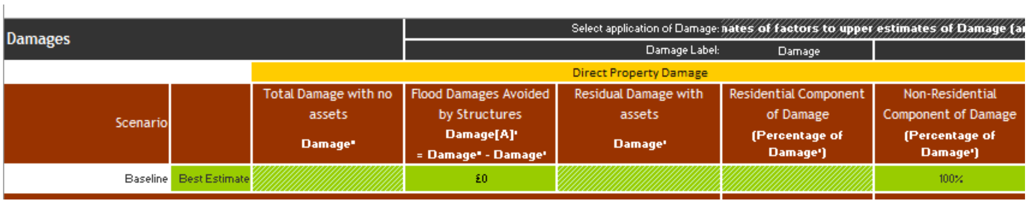
WCM = watercourse capacity maintenance

If one or more of these pathways is switched on, the Assets tab appears and the Damage Inputs tab changes.

The option to ‘Assume 100% operation when working with assets’ allows you to uplift the damage that goes into the property level responses calculation, based on some probability that assets are not successfully operated (see the Assets Inputs tab below). If this option is deselected, the Assets Inputs tab is enabled.

C.3.2 Damage Inputs

To calculate the benefits of working with assets, an additional value for the ‘Total Damage with no assets’ is needed on the Damage Inputs tab (Figure C.10). This is synonymous with undefended damages. If undefended damage values are not available, then with a revised attribution of damages (see Assets tab), a partially defended value could be used (for example, with flood gates left open or temporary/demountable defences not operated).



Damages

Select application of Damage: nates of factors to upper estimates of Damage (a

Damage Label: Damage

		Direct Property Damage				
Scenario		Total Damage with no assets **Damage'**	Flood Damages Avoided by Structures **Damage[A]'** **= Damage' - Damage'**	Residual Damage with assets **Damage'**	Residential Component of Damage **(Percentage of Damage')**	Non-Residential Component of Damage **(Percentage of Damage')**
Baseline	Best Estimate		£0			100%

Figure C.10 Damage Inputs tab with additional space for the total damage with no assets

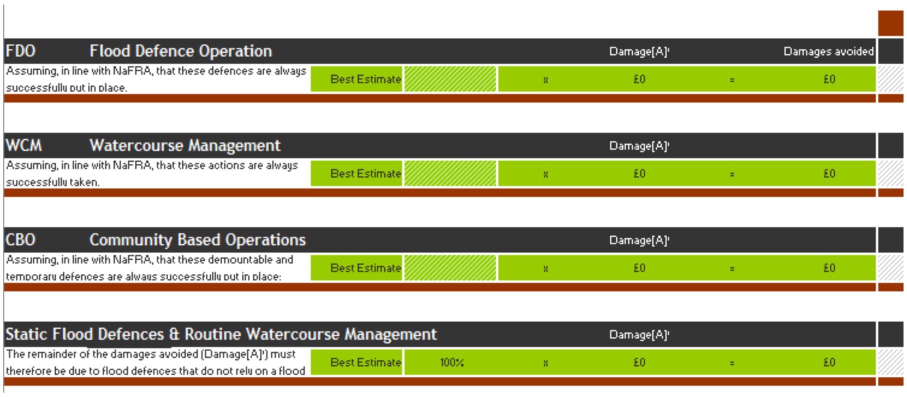
C.3.3 Assets Inputs

The Assets Inputs tab allows you to indicate the likelihood that assets will be operated, using **Response Operated** and **Warning Success** factors – like the property level responses, though the values will be different. The layout of this tab is much the same as the Res Inputs tab, with the exception that lead time categories (and the percentage of properties in each category) are taken directly from the Res Inputs tab.

These factors are then applied on the Assets tab to obtain an uplifted damage value which goes into the rest of the calculations. This is based on the assumption that current calculations of residual damages assume that assets are always operated successfully.

C.3.4 Assets

The difference between the ‘total damage with no assets’ and the ‘residual damage with assets’ (the damage avoided by assets) is attributed to each of the pathways on the Assets tab. You can assign a percentage to each pathway, and the remainder is therefore attributed to ‘static flood defences and routine watercourse management’ (Figure C.11).



FDO	**Flood Defence Operation**				Damage[A]'		Damages avoided
Assuming, in line with NaFRA, that these defences are always successfully put in place.		Best Estimate		x	£0	=	£0

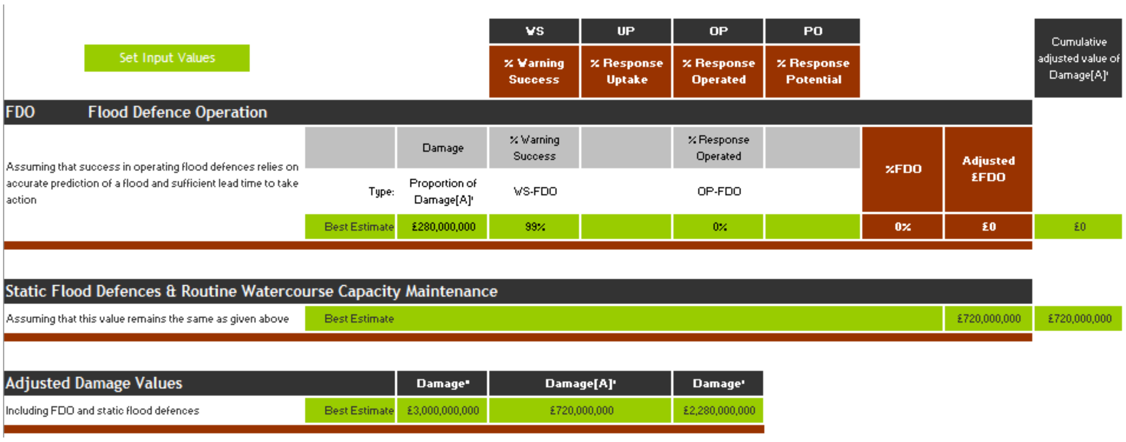
WCM	**Watercourse Management**				Damage[A]'		
Assuming, in line with NaFRA, that these actions are always successfully taken.		Best Estimate		x	£0	=	£0

CBO	**Community Based Operations**				Damage[A]'		
Assuming, in line with NaFRA, that these demountable and temporary defences are always successfully put in place:		Best Estimate		x	£0	=	£0

Static Flood Defences & Routine Watercourse Management					Damage[A]'		
The remainder of the damages avoided (Damage[A]') must therefore be due to flood defences that do not rely on a flood		Best Estimate	100%	x	£0	=	£0

Figure C.11 Assets: attributing damage values to each pathway

If the Assets Inputs tab is used (it is assumed that assets are not successfully operated 100% of the time), an additional calculation takes place (Figure C.12) to uplift the damage values that go into the property level responses calculation.



			VS	UP	OP	PO			Cumulative adjusted value of Damage[A]'
			% Warning Success	**% Response Uptake**	**% Response Operated**	**% Response Potential**			
FDO Flood Defence Operation									
Assuming that success in operating flood defences relies on accurate prediction of a flood and sufficient lead time to take action		Damage	% Warning Success		% Response Operated		**%FDO**	**Adjusted £FDO**	
	Type:	Proportion of Damage[A]'	WS-FDO		OP-FDO				
	Best Estimate	£280,000,000	99%		0%		**0%**	**£0**	£0

Static Flood Defences & Routine Watercourse Capacity Maintenance			
Assuming that this value remains the same as given above	Best Estimate	£720,000,000	£720,000,000

Adjusted Damage Values		**Damage***	**Damage[A]'**	**Damage'**
Including FDO and static flood defences	Best Estimate	£3,000,000,000	£720,000,000	£2,280,000,000

Figure C.12 Damage uplift to account for the likelihood that assets are not operated

C.3.5 Dashboard

With the ‘working with assets’ pathways enabled, additional rows appear on the main Dashboard to represent the damage avoided by enabling assets to be operated. If they do not appear, use the ‘Toggle’ button to show them.

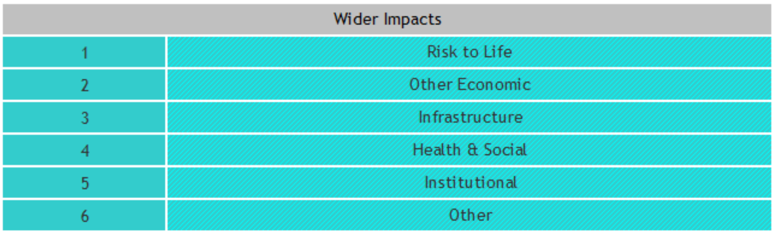
C.4 Wider impacts

ANSR includes the ability to consider the wider impacts of flooding and, by extension, the benefits which accrue by avoiding these damages. Wider impacts are included as benefit multipliers, proportionally linked to the total direct property damages.

Response Uptake, **Response Operated** and **Warning Success** are assumed to be constant for all wider impacts. You can change the **Response Potential** to account for the changes in effectiveness of each pathway under each impact category.

One important consideration is that the definitions of the pathways are quite heavily tailored to the avoidance of direct property damages, but consider whether there are responses that work to reduce the wider impacts in a similar way.

C.4.1 Settings

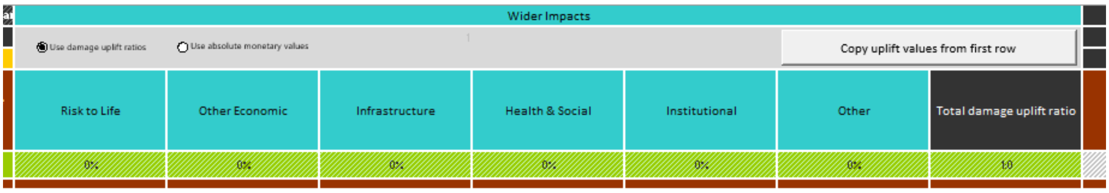


Wider Impacts	
1	Risk to Life
2	Other Economic
3	Infrastructure
4	Health & Social
5	Institutional
6	Other

Figure C.13 Settings: wider Impacts category definitions

As shown in Figure C.13, you can change the names of the six wider impacts categories. The figure shows the default categories. Note these are not necessarily quantified in the tool. For example, Risk to Life is included but explicitly **not** quantified.

C.4.2 Damage Inputs



Wider Impacts

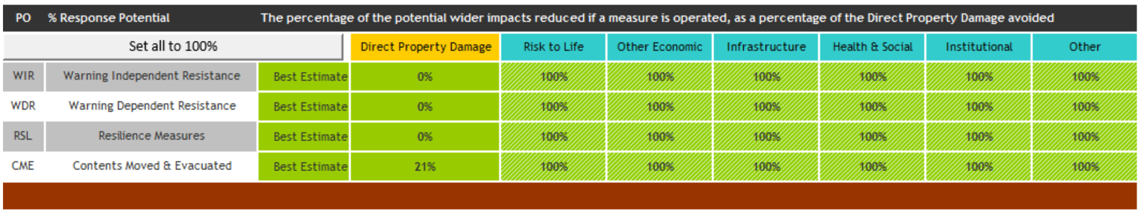
● Use damage uplift ratios ○ Use absolute monetary values

Risk to Life	Other Economic	Infrastructure	Health & Social	Institutional	Other	Total damage uplift ratio
0%	0%	0%	0%	0%	0%	1.0

Figure C.14 Wider impacts on the Damage Inputs tab

On the Damage Inputs tab you can set the wider impacts of flooding either as a damage uplift ratio (as a proportion of the direct property damage) or by inputting absolute monetary values (using the radio button, shown in Figure C.14).

C.4.3 Wider Impacts



PO % Response Potential The percentage of the potential wider impacts reduced if a measure is operated, as a percentage of the Direct Property Damage avoided

			Direct Property Damage	Risk to Life	Other Economic	Infrastructure	Health & Social	Institutional	Other
WIR	Warning Independent Resistance	Best Estimate	0%	100%	100%	100%	100%	100%	100%
WDR	Warning Dependent Resistance	Best Estimate	0%	100%	100%	100%	100%	100%	100%
RSL	Resilience Measures	Best Estimate	0%	100%	100%	100%	100%	100%	100%
CME	Contents Moved & Evacuated	Best Estimate	21%	100%	100%	100%	100%	100%	100%

Figure C.15 Inputs on the Wider Impacts tab

As discussed above, on the Wider Impacts tab, you can set the **Response Potential** of each property level response for each wider impact category as a percentage of their **Response Potential** for direct property damages.

Below these inputs is the full set of calculations for the benefits achieved by avoiding wider impacts. There is also a dropdown menu so you can choose which scenario's results to view (see scenarios below).

C.4.4 Wider Impacts (Assets)

The Wider Impacts (Assets) tab performs the same function as the Wider Impacts tab, but for calculating the benefits of working with assets. The values you set on the Wider Impacts (Assets) tab are the attributions of impacts to each pathway.

C.4.5 Dashboard

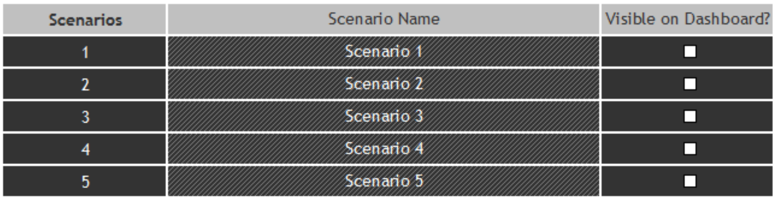
Results from the wider impacts calculations are presented on the Dashboard to the right of the direct property damage calculation.

C.5 Investment scenarios

ANSR allows you to consider the impact of changes in investment on the values of factors in the equations. These changes are estimated by representing the relationship between investment and factor values through a curve defined by:

- the minimum investment (relative to current investment) required to achieve any benefit (so-called fixed costs)
- the current investment and current value of the factor
- the maximum possible value of the factor (relative to the current value)

C.5.1 Settings



Scenarios	Scenario Name	Visible on Dashboard?
1	Scenario 1	☐
2	Scenario 2	☐
3	Scenario 3	☐
4	Scenario 4	☐
5	Scenario 5	☐

Figure C.16 Settings: scenario settings

You can turn scenarios on or off (and change their names) on the Settings tab (Figure C.16).

C.5.2 Damage Inputs

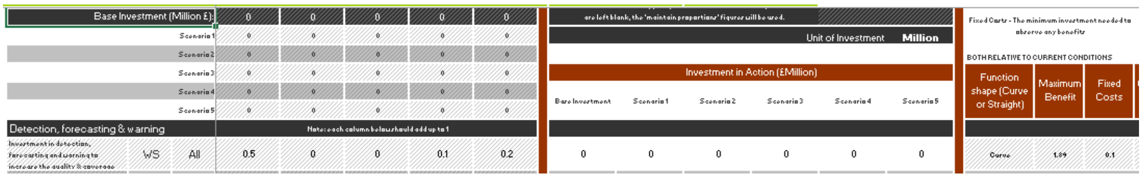
Multiple scenarios can be defined by setting different values for the damages on the Damage Inputs tab. Scenarios appear on the Damage Inputs tab when turned on using the Settings tab. The damage values required are the same as the baseline case.

C.5.3 Investment

The Investment tab allows you define the key input values required for a scenario assessment (Figure C.17):

- levels of investment for each scenario (including the baseline), split into a number of broad investment areas
- attribution of investment from these broad investment areas to specific investment activities; each of these investment activities is directly linked to a factor in the equations

- an investment–benefit function defined by the maximum possible value of the factor (as a multiplier of its baseline value) and the minimum possible investment to achieve any benefit (as a proportion of the baseline investment)



Base Investment (Million £):			0	0	0	0	0
Scenario 1			0	0	0	0	0
Scenario 2			0	0	0	0	0
Scenario 3			0	0	0	0	0
Scenario 4			0	0	0	0	0
Scenario 5			0	0	0	0	0
Detection, forecasting & warning			Note: each column below should add up to 1				
Investment in detection, forecasting and warning to increase the quality & coverage	WS	All	0.5	0	0	0.1	0.2

are left blank, the 'maintain proportions' figures will be used.

Unit of Investment **Million**

Investment in Action (£Million)

Base Investment	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
0	0	0	0	0	0

Fixed Costs - The minimum investment needed to observe any benefits

BOTH RELATIVE TO CURRENT CONDITIONS

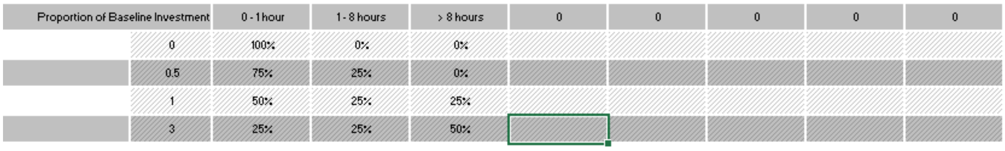
Function shape (Curve or Straight)	Maximum Benefit	Fixed Costs
Curve	1.89	0.1

Figure C.17 Investment tab: investment values (top left), attribution of that investment to a particular factor (bottom left) and definition of the investment–benefit function (bottom right)

C.5.4 %OP

The **Response Operated** factor is a special case of a link between investment and benefits because of the distribution of properties into lead time categories. The %OP tab allows you to define how that distribution changes under the different scenarios, for example, representing how you can increase lead times by investing in the flood warning service.

As with other areas of investment, the investment level itself is defined on the Investment tab. The %OP tab lets you define the distribution of lead time categories for different levels of investment, as shown in Figure C.18 and Figure C.19.



Proportion of Baseline Investment	0 - 1 hour	1 - 8 hours	> 8 hours	0	0	0	0	0
0	100%	0%	0%					
0.5	75%	25%	0%					
1	50%	25%	25%					
3	25%	25%	50%					

Figure C.18 Inputting the percentage of properties in each lead time category for different levels of baseline investment

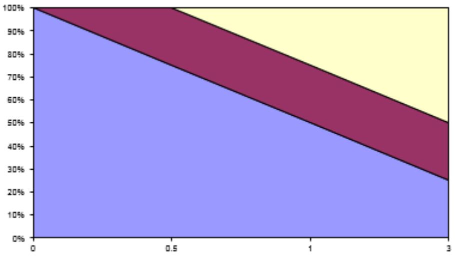


Figure C.19 Graphical representation of the change in lead time distribution, as shown on the %OP tab

C.5.5 Dashboard

Results from the scenarios are presented on the Dashboard tab and the scenarios appear there, when turned on using the Settings tab.

Appendix D Data table

Factor	**National value**	**Data source**	**Local variation and notes**	**Potential data sources**
Undefended damage	£3 billion	Estimated by Parker et al. (2008), based on information on the Defra website[1] and Defra (2001)	Entirely dependent on the study area	SAMPs or an MDSF2 run for the study area without defences. Alternatively, if the study is quantifying the benefits of enabling assets, then an MDSF2 run with assets not operated (for example, flood gates left open) can be used to obtain a partially undefended damage value. The proportion of damage avoided by active flood defences would have to be changed (for example, to 100%) to reflect this.
Residual (defended) direct property damage	£1 billion	As above. Used as an approximation for demonstration purposes here. More accurate national values could be obtained from current NaFRA modelling.	Entirely dependent on the study area	MDSF2, NaFRA or any suitable depth-damage calculation (for example, ISIS Damage Calculator)
Residential component of damage	52%	Estimate based on NaFRA. More accurate national values could be obtained from current NaFRA modelling.	Entirely dependent on the study area	As above.

Factor	**National value**	**Data source**	**Local variation and notes**	**Potential data sources**
Proportion of damage avoided by active flood defences	28%	Expert judgment by Parker et al. (2008)	Entirely dependent on the study area	Modelling can be carried out (for example, using MDSF2) to calculate this value for a study area, for example, by running MDSF2 with flood gates 'open' (crest levels set to ground level) and other assets not activated.
Proportion of damage avoided by community-based operations	1%	Expert judgment by Parker et al. (2008)	Entirely dependent on the study area	Modelling can be carried out (for example, using MDSF2) to calculate this value for a study area, for example, by running MDSF2 with temporary and demountable defences not in place.
Proportion of damage avoided by watercourse management	10%	Expert judgment by Parker et al. (2008)	Entirely dependent on the study area	Modelling can be carried out (for example, using MDSF2) to estimate this by creating hypothetical blockage scenarios (or other sensitivity analysis on channel capacity) and estimating the likelihood that these scenarios will occur.
Percentage of properties which receive a warning (reliability and availability)	30%	Estimated by multiplying: • 79% coverage taken from Environment Agency KPI900 • 38% 'reliability and availability' from Parker et al. (2007)	This factor has a significant impact on the results and can vary substantially between different communities and their nature.	Coverage can be estimated by comparing properties at risk of flooding with flood warning areas. The percentage of properties signed up, reliability of the warning process and availability of residents to receive the warning require more research.

Factor	National value	Data source	Local variation and notes	Potential data sources
Distribution of properties in lead time categories	0–1 hour lead time: 13% 1–8 hours: 70% >8 hours: 17%	Summary of all Flood Warning Level of Service spreadsheets. The categories are aligned with available data on the percentage operated (see below).	The distribution of properties in lead time categories is dependent on the specific study area.	The appropriate FWLoS spreadsheet(s) can be used to find the lead times for individual or groups of communities.
Uptake in resistance measures	8%	Percentage of respondents who indicated they had put flood boards/barriers in place in post flood event surveys from summer 2007, January 2007, October 2006 and August 2006.	Uptake can be anything from 0 to 100%, depending entirely on the specific study area. Uptake should represent the % of damage that protected properties represent (relative to the total study area damage), not just the % of properties with protection.	During a depth-damage calculation of the study area (or using WAAD data from MCM), divide the damage attributed to properties with protection by the damage attributed to all properties.
Uptake in passive (warning-independent) resistance measures	3%	A property level protection manufacturer indicated that the split between active and passive resistance measures is 60:40, adding up to the 8% value above.	Uptake in resistance measures can be of active and/or passive measures, but the total for both cannot exceed 100%. Properties are assumed to have either active or passive resistance, as a single active measure makes the property effectively warning-dependent.	
Uptake in active (warning-dependent) resistance measures	5%			
Effectiveness of resistance measures (average damage avoided if they are installed)	75%	Thurston et al. (2008) Average of upper and lower bounds of 84% and 65%.	Effectiveness can vary significantly depending on the specific local conditions, specifically the depth of flooding at the full range of possible flood events. In the Forest Row and Aylesford case studies, effectiveness	During a depth-damage calculation of the study area (or using WAAD data from MCM), calculate the reduced damage with resistance measures installed (for example, set damage for depths up to 0.6 m as £0).

Factor	National value	Data source	Local variation and notes	Potential data sources
			was found to be over 90%, as flood depths were low (that is, within the depth at which resistance measures are effective) even for extreme events.	Effectiveness is unprotected – protected divided by unprotected damage for properties with protection.
Percentage of active resistance measures successfully operated (given that a property receives a warning and has the measure installed)	0–1 hour lead time: 92% 1–8 hours: 96% >8 hours: 99%	Priest and Parker (2012) identified these values from post-flood event surveys as the percentage of properties which take effective action. It is assumed that if a property has resistance measures, their first 'effective action' would be to put those measures in place, so those values are an effective proxy for the percentage operated.	These factors should be applicable at any location, although the high values suggest that it includes action taken regardless of flood warning. These values are made locally applicable with the percentage of properties in each lead time category.	Future or a more extensive range of post-flood event surveys could be used to improve these data and find more appropriate categories that are more in line with the available lead time data (that is, up to two hours, rather than one).
Uptake in resilience measures	2%	No evidence available. Estimated at the FIM Investment Review expert workshop.[2]	As with resistance measures, uptake can be anything from 0 to 100%, and is entirely dependent on the study area.	See uptake in resistance measures.
Effectiveness of resilience measures	50%	Estimated by the project team (Parker, Priest, Clarke, 12 January 2012).	The effectiveness depends on the specific portfolio of resilience measures installed, but is likely to be less variable than resistance measures. Whereas resistance measures are effective up to a maximum depth and then ineffective, resilience measures are more likely to have some level of effectiveness at any depth of	Follow a similar method to the effectiveness of resistance measures. Thurston et al. (2008) based their method on the findings of the Association of British Insurers for the ability of individual resilience measures to reduce flood damages.

Factor	National value	Data source	Local variation and notes	Potential data sources
			flooding, so their effectiveness may be less location-specific.	
Effectiveness (maximum potential damage avoided) of moving and evacuating contents	21%	Parker et al. (2007) found that 52% of damage to a property is 'inventory' (rather than building fabric), and that 41% of that inventory damage is moveable, so a maximum of 21% of damage can be avoided by moving and evacuating contents.	This factor should be applicable for any location, although variations could occur if properties in an area have an unusually high or low proportion of moveable inventory relative to the remaining property damage.	Not applicable
Percentage of the potential damage avoided by moving and evacuating contents which is avoided in the time available	0–1 hour lead time: 70% 1–8 hours: 72% >8 hours: 80%	Priest and Parker (2012) identified these values from post-flood event surveys.	These factors should be applicable at any location, although the high values suggest that it includes action taken, regardless of flood warning. These values are made locally applicable with the percentage of properties in each lead time category.	Future or a more extensive range of post-flood event surveys could be used to improve these data and find more appropriate categories that are more in line with the available lead time data (that is, up to two hours rather than one).

Notes:

[1] http://www.defra.gov.uk/environ/fcd/default.htm [accessed by Parker et al. on 11 October 2007].

[2] An expert workshop was held on 26 October 2012 as part of the Environment Agency's Flood Incident Management Investment Review project.

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