EVIDENCE REVIEW FOR PROPERTY FLOOD RESILIENCE PHASE 2 REPORT

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GLOSSARY

Flood risk: an expression of the combination of the flood probability (or likelihood) and the magnitude of the potential consequences of the flood event. The higher the likelihood and the greater the impact of flooding, the higher the level of flood risk.

Floodplain: any low-lying area of land next to a river or stream, which is susceptible to partial or complete inundation by water during a flood event.

Fluvial flooding: flooding from a river or other watercourse.

Groundwater: water that collects or flows beneath the Earth's surface, filling the porous spaces in soil, sediment, and rocks. Groundwater originates from rain and from melting snow and ice and is the source of water for aquifers, springs, and wells. The upper surface of groundwater is the water table.

Hazard: a situation (physical event, phenomenon or human activity) that has the potential to produce harm or other undesirable consequences to some person or thing

Integrated Strategy: requires the use of both structural and non-structural measures to address potential flood risks.

Kitemark(ed) flood protection: flood protection products that have been independently tested (against BSI's PAS1188-2014) and proved fit for purpose.

Overtopping (of defence measures): when flood water reaches levels that are higher than the flood defence level and flows over the top of the barrier or similar.

Property Flood Resilience: methods by which people and their property can become less vulnerable to the physical and mental impacts of flooding. These include: stopping water entering a property; or significantly reducing the time for recovery when it does; or a combination of these). Also termed 'property level flood resilience (PLFR)'.

Resilience: the capacity that people/groups/structures may possess to withstand or recover from emergencies

Resilience (to flooding): sometimes known as 'wet-proofing', resilience relates to how a building is constructed in such a way that, although flood water may enter the building, its impact is minimised, structural integrity is maintained, and repair, drying & cleaning and subsequent reoccupation are facilitated.

Resistance (to flooding): sometimes known as 'dry-proofing', this relates to how a building is constructed to prevent flood water entering the building or damaging its fabric.

Return period: average interval of time, in years, between which events occur that equal, or exceed, a given magnitude

Risk: the probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril over a specified time period (Risk is normally calculated as Probability × Consequence).

Risk management: the systematic process of risk assessment, options appraisal and implementation of any risk management measures to control or mitigate risk

Water entry strategy: measures designed to make properties more resilient to the effects of flood water, if it cannot be prevented from entering.

Water exclusion strategy: a combination of measures designed to prevent rising flood water from entering properties.

Weighted Annual Average Damage method: A strategic level estimate of flood risk damages calculated using the 'Multi-Coloured Handbook' (Penning-Rowsell *et al.* 2005). The Weighted Annual Average Damages (WAAD) figure gives an indicative estimate of direct costs to residential properties, non-residential properties and agriculture. It includes the benefit offered to residential and non-residential properties by flood protection schemes but does not include the benefit from flood warning schemes.

(SEPA definition/explanation, from: http://apps.sepa.org.uk/nfra/pva/pdf/pva_000019.pdf (accessed 26/09/2017)

LIST OF ABBREVIATIONS

ABI	Association of British Insurers
CLG	(Department of) Communities and Local Government
Defra	Department for Environment, Food and Rural Affairs
DMM's	Damage mitigation measures
ECAWG	Economics of Climate Adaptation Working Group
ICPR	International Commission for the Protection of the Rhine
PFR	Property Flood Resilience
PLP	Property level Protection (former name for one type of PFR)

EXECUTIVE SUMMARY

Background

Flood Re was established to promote the availability and affordability of flood insurance whilst supporting the transition to risk-based and affordable flood insurance for UK households at high risk of flooding. In order for the goal of affordability to be achievable, there is a need to manage down the risk to these properties. One way to reduce risk is to install measures at a property level, often termed property flood resilience (hereafter PFR). This report reflects findings from Phase 2 of a three phase project; it is designed to assist Flood Re to establish an evidence base for the value of PFR in order to help inform decisions about the PFR support to homeowners that could/should be provided by Flood Re in future. The findings of an evidence review, including synthesis of the existing literature and selected additional analyses of data extracted from the evidence sources, are presented in answer to the question, "How effective are property level resistance and resilience measures in reducing loss due to damage and time to repair damage resulting from flooding for UK households and their insurers?"

It is anticipated that the completed Phase 3 evidence review will be of benefit to both Flood Re and the direct insurers to inform pricing, premium incentives, terms and conditions, claims handling and customer communications. The evidence gathered will also be helpful to other stakeholders such as Defra and CLG (and their equivalents in the devolved administrations), as well as insurance intermediaries and insured/uninsured households.

Existing Evidence

A total of 2,271 literature sources were identified, considered against relevance criteria and then scored against sub-questions; 51 sources were judged to have empirical/modelled evidence relevant for the question and have been scored for relevance before evidence from selected sources was synthesized and summarized in the report. Some initial conclusions are drawn and clear evidence gaps have been identified. Suggestions for further data gathering are provided for investigation in Phase 3, improving upon the existing evidence base.

A wide range of appropriate measures has been identified in the literature, along with guidelines and 'rules of thumb' that allow experts to specify measures for properties based on a range of characteristics both of the floods themselves (source, speed of onset, duration) and the properties they affect (construction type, attachment, occupants). Choice of appropriate measures and packages of measures have been based largely on theoretical considerations such as structural stability and expert judgement and are widely accepted in the UK and internationally. Several 'standard' packages of measures have been defined and used by UK research studies. The specification of alternative low cost packages or individual measures is an emerging trend that needs further exploration.

Estimates of the performance of the measures in limiting damages for the UK is also largely based on expert judgement and desktop accounting, as there is currently insufficient real world data available to establish an empirical view. Based on these theoretical models, where measures are appropriate and implemented correctly, studies all agree that the potential to limit damage and disruption by employing appropriate measures is seen to be substantial. Up to 100% of the damage cost is saved for properties that succeed in keeping water out, whereas with full packages of water entry measures the saving is typically lower but still substantial (more than half). Real case study examples of successful schemes are available, as are some counter examples from which lessons on success factors have been derived. International empirical evidence, based on properties that have been flooded after installing measures, also confirms the UK theoretical literature. For example, German communities achieved contents savings of 95% on application of measures, and succeeded in keeping water out of 62% of properties. This was across a portfolio of property where water exclusion may not have been appropriate, may have been overtopped, not fully implemented or failed. Limiting damage can also be demonstrated to help in reducing time for repair and recovery after flooding, which is an important consideration for both households and insurers.

The benefits associated with limiting damage and disruption have associated costs: these vary depending on the type of measures installed and anticipated depth and type of flood. Studies that consider cost benefit ratios universally conclude that measures are cost beneficial for a subset of properties, but disagree on the details of flood frequency where measures would break even. There is consensus that a comprehensive set of measures (of some kind) would be cost beneficial for properties expected to flood frequently (up to 40-year return period or 0.025 probability of flooding in a given year). Studies agree that manually deployed water exclusion measures are generally the most cost beneficial, and that the pre-defined full package of internal resilient adaptation is the most costly option and least likely to pay back. Consensus exists in the literature that the cost of internal resilience is lower if undertaken as part of other works and specifically flood reinstatement. The cost benefit of resistant measures is seen as less time sensitive and they are suitable to be installed pro-actively. Beyond this studies differ, but individual measures and lower cost packages of measures (some of which are cost neutral) have shown potential to be cost beneficial across the range of flood likelihoods as infrequent as 1 in 200 years (0.005 probability).

These findings are subject to shortcomings in the available studies that stem from a number of limitations: these are summarised below. This leads to the suggestion that, with better input data and a wider consideration of packages of measures, the number of properties that could be considered within the cost beneficial subset could be better understood and may provide justification for improved benefit/cost ratios.

Limitations of Existing Evidence

Evidence gaps for performance of measures include data on the reliability of measures encompassing failure to deploy, inappropriate specification of measures, failure of measures and inadvertent removal of measures during recovery or other works.

Evidence gaps for direct damage avoided include up to date evidence on the real cost of claims to be avoided. Most studies use estimated damage data that has been informed by analysis of historical claims. Some of these estimates have been shown in this report to underestimate losses in comparison with actual claims data from the 2007 events.

There are also critical gaps in the evidence regarding other potential claims items: these can be classified as indirect or intangible benefits. Furthermore, there is virtually no evidence on potential co-benefits, nor conflicts that may arise when installing measures. Alternative accommodation costs are identified in the literature as the largest component of this suite of avoided damage types, linked to the increased speed of reoccupation for resilient properties. Relevant data on indirect costs such as cost of alternative accommodation suggests that this is a substantial cost borne by insurers. Analysis of other indirect and intangible benefits also indicates substantial societal costs could be saved through adoption of measures, although these would not affect claims insurance costs. Greater understanding of the benefits of PFR on indirect costs is needed. However, due consideration has never been given to other potentially substantial co-benefits to insurers: for example, reduction in escape of water claims, (also termed domestic water nuisance: e.g. burst pipes, leaking appliances and water tanks) which between 2014 and 2016 on average constituted around 4 times the average annual cost of insurance claims from flooding.

Data used in the literature on the cost of resilient measures for the UK market is limited and out of date in most of the studies reviewed. Data used for resistant products is also limited to a range of commonly analysed measures or packages of measures. The most recent studies use data based on real schemes that were implemented up to 2011. Technology is constantly evolving and studies do not consider the latest innovations, the economies of scale involved in increasing numbers of installations nor competitive pressures on pricing.

The evidence collated so far has largely been generated for the purposes of economic analysis over long timescales with national datasets. As such, some issues with application to the primary question have been identified, for example the use of the Weighted Annual Average Damage method. Sensitivity analysis carried out in this report suggests that using a more precise method with more accurate input data would materially change benefit/cost estimates. Self-evidently, assumptions about the timing of adaptation take-up also impacts upon expected portfolio gains and losses from PFR but there are no studies that take into account this factor. Indicative analysis by this review suggests that the cost benefit ratio for individual property would not change significantly but that the proportion of property benefitting from measures could be much lower.

Interim Conclusions

Without further evidence gathering Flood Re could usefully examine the options to encourage take up of measures in highest risk properties (e.g. within the Environment Agency's 30 year return period outline) and to ensure implementation of cost neutral measures at reinstatement following a flood for all properties ceded to Flood Re.

Phase 3 Recommendations

A larger cohort of properties with measures installed is now available to study in the UK as several major flood incidents have occurred since the most recent studies were conducted. Some of these have occurred in areas of the UK where PFR schemes have been taken up in numbers that are more significant. Further data gathering and analysis should, therefore, be undertaken to enhance the current evidence base.

Detailed insurance claims data from more recent flooding incidents should be gathered and used to enhance the evidence base. Key areas to investigate in more detail include:

- The real cost of resilient reinstatement from schedules and actual costs incurred;
- Potential losses avoided with improved estimation for different flood types, depths and building characteristics;
- Actual performance of measures from claims made by properties previously made resilient; and
- Indirect costs borne by insurers and the link to recovery time.

Collation of data from relevant agencies, such as local authorities and water companies, regarding implemented schemes could enhance the evidence base regarding:

- The real cost of PFR measures including barriers and resilient measures;
- Performance of implemented schemes;
- Locations of properties with measures.

These agencies should be consulted to explore the potential to gather improved evidence.

Improved benefit/cost analysis is recommended which relies less on the 'averaging' approaches employed within the current literature. This could either involve the use of stochastic modelling to enhance the existing approaches, or instead could leverage more advanced modelling approaches such as those used by Flood Re. Both approaches would allow for more valuable conclusions to be drawn from the new evidence gathered and the benefits to the portfolio of properties ceded to Flood Re. These approaches would also provide a basis for understanding the potential for benefits of PFR to build up under a range of deployment/adoption strategies.

INTRODUCTION

Flood Re was established to support the transition to risk based but affordable flood insurance for UK households at high risk of flooding. In order for the goal of affordability to be achievable over the next 20 or so years, there is a need to manage down the risk from flooding to these properties. One way to reduce risk is to install risk reduction measures at a property level, an approach often termed flood resistant/resilient measures, or property flood resilience (hereafter PFR). PFR is seen as part of the UK's integrated strategy for management of flood risk, not only for properties in areas without planned community level defences, but also for those where such schemes are in place, thus recognising that they are still subject to residual risk. Flood Re, therefore, wishes to examine the potential to:

- Reduce future loss and damage by supporting the uptake of measures; and
- Reflect the risk reduction achieved through installed measures in reduced cost of insurance to households.

Flood Re's primary requirement is to develop an in-depth understanding of the state of knowledge regarding property level measures, to:

Establish an evidence base for the value of property level flood resistance and resilience measures that will in future help inform decisions about the support to homeowners that could/should be provided by Flood Re in decisions about 'building back better'.

This requirement is to be achieved through an incremental process of evidence synthesis followed by evidence enhancement over 3 phases. The first phase, a short scoping review has already been reported. This report covers the second phase in the form of a full evidence assessment. Phase 3 will encompass gathering of selected primary data and further analysis to fill the evidence gaps. Ultimately, the evidence will lead to a cost benefit analysis of available options that can inform the choices of support and incentives offered by the Flood Re scheme and other insurers in the market. This evidence base, when complete, will also be of benefit to a wider group of stakeholders including policymakers, lenders, damage management professionals, local authorities, community advisers and communities themselves.

Phase 1 and 2 considered the evidence required to make a financial assessment and to perform a suitable benefits/cost analysis of the evidence needed to encompass:

- Type of measures;
- Decision factors around installation of measures;
- Cost of measures and loss avoided through implementation of measures (direct damage, indirect damage and intangibles) as shown in Figure 1.

In phase 3, when considering how to support and incentivise uptake, the evidence base will also ideally consider:

- Acceptability of different measures in terms of householder preferences and resources;
- Categories of measures that could/should be provided as part of insurance reinstatement and those that could/should be supplied or supported in other ways and at other times;
- Distribution of benefits across stakeholders including social equity considerations of alternative mechanisms to support uptake;
- Differential effectiveness of supporting uptake via alternative mechanisms such as universal changes in reinstatement practice, premium incentives, lower excess, optional resilience add on, penalties such as cover exclusions, loans, grants, etc;
- Key remaining barriers to uptake including emotional barriers to measure adoption and ways of overcoming these.

This evidence review phase 2 report incorporates the result of the initial scoping review (phase 1) to determine the amount and range of existing evidence sources available to address these evidence needs.

Figure 1: Evidence requirements

Decision factors	**Loss prevented**	**Cost of measures**	**Value of measures to Insurers/Flood Re**
• Flood Type , • Building type • Flood probability • Required effectiveness • Occupants • Delay in recovery • Level of damage	• Effectiveness/ performance • Direct damage costs • Indirect loss (alternative accommodation) • Intangibles • Co-Benefits (security, fire safety)	• Survey costs • Installation • Operation and maintenance • Replacement • Flood warning costs • Delay in reinstatement	• Flood Re • Time value • Cost of capital • Customer service • Reduced demand

METHOD

The scoping review method is described in full in the report scoping review for “building back better” followed guidance on the provision of scoping reviews by the Joint Water Evidence Group (Collins *et al.*, 2014). This requires the careful selection of an agreed set of questions comprising a primary question related to the aim of the study and secondary questions for judgement of relevance and scoring.

PRIMARY QUESTION: How effective are property level resistance and resilience measures in reducing loss resulting from flooding for UK households and their insurers?

Sub themes

- The range and types of measures available to protect high flood risk domestic properties eligible for cover under the Flood Re scheme;
- Indication of the types of measures and minimum packages of measures most suitable for installation in different combinations of house/flood typology;
- The level of direct damage prevention likely to be achieved by the range of measures;
- The costs of installation of measures, particularly the additional cost of installing measures as part of the reinstatement process following flood events;
- The value of direct intangible benefits and of indirect benefits (including co-benefits) of installing measures.

Relevance scoring

The 315 publications identified as likely to be most pertinent were scored against the agreed sub themes to capture the scope of evidence and select the most important sources for summary in this report. Papers were examined for conformance with six criteria:

- Does the source contain information on the type and range of measures available?
- Does the source identify minimum or recommended packages of measures?
- Does the source address measures for different house types and flood scenarios?
- Does the source indicate the (likely) level of, or value of, direct damage prevented?
- Does the source contain estimates of cost of installation or reinstatement?
- Does the source include estimates of indirect, intangible or co-benefits?

Each of the above criteria was then designated as follows:

‘No’ (does not contain evidence of this criterion); ‘Yes’ (contains evidence); ‘YesYes’ (contains empirical evidence).

Table 1: summary of literature scoring

	Type and range of measures	Minimum packages indicated	Different house / flood types indicated (with or without empirical value)	Level and/ or value of damage prevention indicated (with or without empirical evidence)	Cost of installation/ reinstatement indicated (with or without empirical value)	Direct / indirect-intangible/ co-benefits benefits indicated	Total
Contains non-empirical evidence	159	13	89	81	40	82	132
Contains empirical evidence	Na	Na	22	28	41	Na	51
Total Contains evidence	159	13	111	109	81	82	183

The scope of the total evidence base was summarized by its relevance to the sub themes, as shown in Table 1, demonstrating where the largest gaps are likely to be found. At this point the quality and strength of the evidence had not been assessed.

Overview of scoping

Title and abstract filtering was followed by removal of duplicates the scoping review found 315 relevant documents. (A detailed breakdown of sources and filtering was given in Appendix 2 of the scoping review report).

The results of the scoring revealed that 183 documents scored above zero, in that they included some relevant evidence on one or more of the sub themes.

Evidence scoring (empirical/modelled studies)

After the initial scoping review was conducted following the guidance by the Joint Water Evidence Group (Collins et al, 2014) the review found 51 relevant documents with empirical/modelled evidence from all search categories. The identified documents were then scored according to three selected subthemes:

- The level of direct damage prevention likely to be achieved by the range of measures;
- The costs of installation of measures, particularly the additional cost of installing measures as part of the reinstatement process following flood events;
- The value of direct intangible benefits and of indirect benefits (including co-benefits) of installing measures.

The evidence assessment scoring was based on the following assessment criteria:

- Whether the evidence source is peer reviewed by authentic sources or not?
- Whether the data (cost and benefit) included in the document is unique or has been derived from other sources?
- What is the geographical distribution of the evidence base? (Whether it is UK or Europe based, study from the rest of the world or just general study which does not include any specific area.)
- What is the sample size of the data that is used to inform the evidence base?
- How sound is the methodology used for adequate representation of the data/information to produce the evidence base?

Quality Scoring

The criterion of peer review was included to assess the quality of documents determined by peers or experts in the field through careful evaluation, published by professional scholarly society, association or University department, well cited and found in scholarly databases, and based on original research. Most of the documents (except 3) are peer reviewed. The index created for the scoring of the documents scored the peer reviewed documents higher than non-peer reviewed documents to give more importance to quality of publication. The three publications that are not peer reviewed were included in the database because of their wider acceptance in both academic and industrial fields of research.

The uniqueness of data was identified by examining whether the data shown in the selected document was new and not adopted from other source, or data was acquired from an authentic source and evidence provided based on the data was new and never been published in any other source. Some of the publications are based on deductions from theoretical information gathered from other sources; however, those qualitative deductive sources of information are unique in terms of outputs. Such documents are also considered as new or having unique data. There are some documents which based their analysis on previously acquired data and added some new data or information for the analysis, and produced unique results were considered to be providing some unique perspective, while others which based their analysis completely on previously published data are considered to be non-unique and assigned scores accordingly.

For geographical distribution of the study the location of the study areas was considered and the scoring was straight forward. As the scoping study is UK based and the evidence base requirement of Flood Re (UK based) is also UK specific, the highest score was assigned to studies which are geographically based in the UK followed by European studies and then anywhere else in the world. Lowest score was given to studies with no specific geographical location.

As for the sample size, scoring is generally based on higher scores for larger samples of data; however there are some studies which were unique in their contribution to knowledge with a lower number of samples. Studies using case study, or deductive theoretical observation and scoping studies, cannot be compared with studies with large data samples (for example, those using questionnaire surveys) in terms of numbers, therefore those documents are scored lower to maintain consistency in scoring. In order to accommodate the importance of such studies with lower score in sample size, due to the methodology used, the criteria of judgmental score was established which considered the overall value addition to the existing knowledge base rather than quantity.

The judgemental score was based on soundness of the methodology used in the documents. Soundness of methodology includes the use of systematic approach and established procedures to gather data, accepted in the scientific community and well applied in the field of research. The documents which conformed to all the above mentioned criteria were assigned the highest score followed by those with substantial limitations and those not clear. Table 2 (below) illustrates the scoring index and the order or stages in which review and scoring was performed.

Table 2. Scoring index and order of review

Criteria	Scoring (ascending with number)
Peer Review	
Unknown/ No	1
Yes	2
Uniqueness of Data	
No Unique data	1
Some Unique data	2
Unique data	3
Geographical distribution	
General data/ no country specific	1
Rest of the world	2
Europe	3
UK	4
Sample size	
Small (less than 100)	1
Medium (100-1000)	2
Large (More than 1000)	3
Judgmental score/ soundness of methodology	
Not clear	1
Clear with limitations	2
Sound and well applied	3

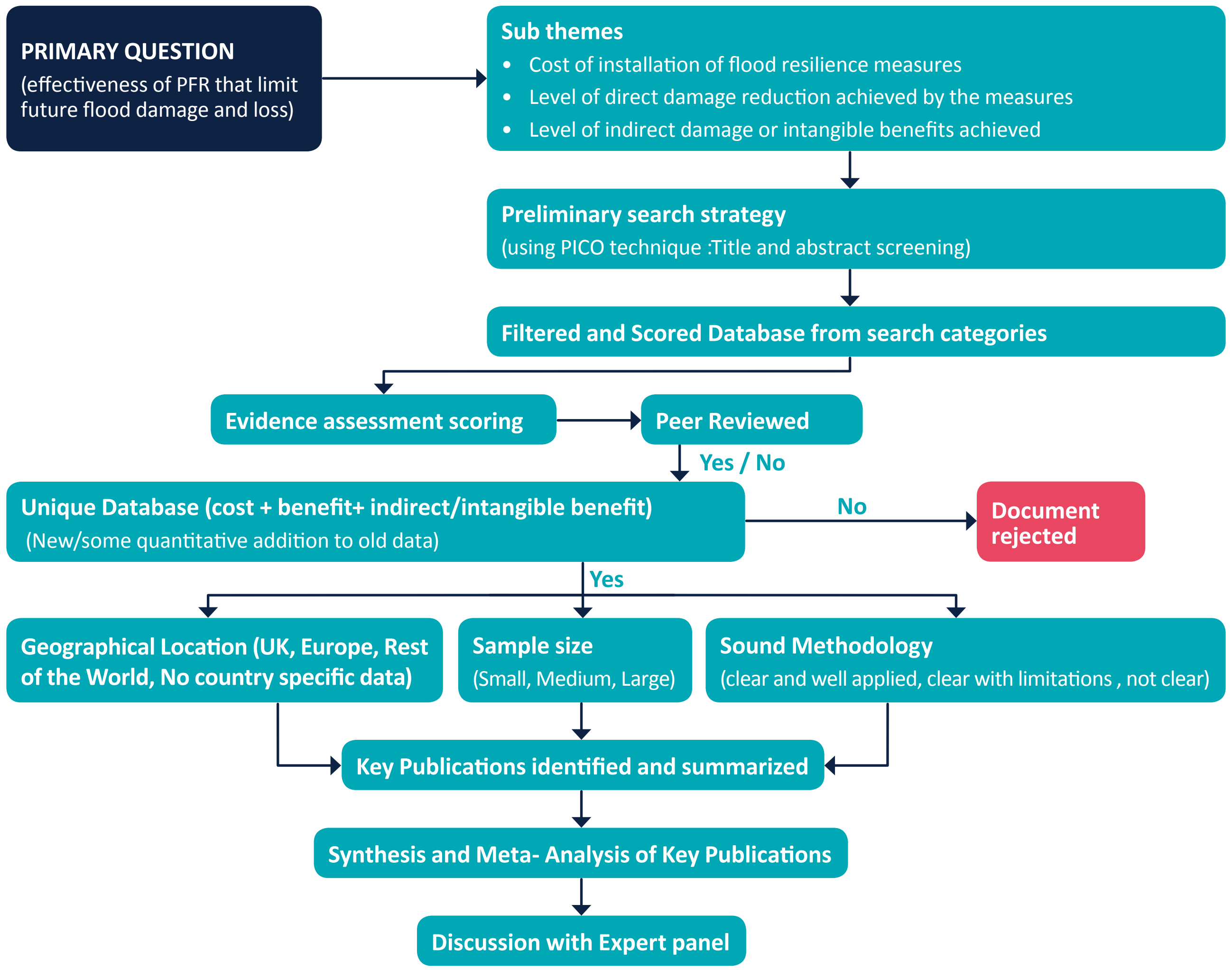
Order of scoring

The criteria for inclusion of a key publication into the database after the primary search was performed were:

- Whether the source is peer reviewed or not to maintain authenticity of the data; and
- Whether the document source is adding any new data source to the existing knowledge base.

The documents which did not add any new data source and used existing databases for new results were eliminated at this stage from the review. Documents which provided new quantitative evidence of: cost of installation of property flood resilience (PFR), some types of which were formerly referred to as ‘property level protection’ or ‘PLP’; measures/ packages in general or as part of reinstatement packages; damage avoided as a result of installation of mitigation packages or prevention likely to be achieved; and finally any evidence of direct intangible benefits were considered to be unique in their data sources. Publications which produced analyses using data sourced from existing published literature, and which provided a new addition to the existing knowledge base were also taken to be unique data source in their own right. These publications were also included in the key publication list. Once the uniqueness of data was confirmed, the documents were further scoped to identify their geographical coverage, the sample size of the data used and whether a justified well established methodology was used to secure the given results. Special importance was given to studies which were UK based. As for dealing with the samples, there was the issue of reducing bias in sample size. Studies using different methodology (such as case study, interviews or deductive analysis) had a much lower sample size than those used through questionnaire survey. For those studies, therefore, the scoring was lower but it did not have any effect on the final scores, as these studies scored highly on judgemental score or soundness of methodology. This method also helped in keeping consistency within the scoring system. Figure 2 shows the flow of processes that helped in scoping and identifying key documents for the study.

Figure 2: Flowchart of quality scoring of evidence sources



RESULTS

Results from the scoring of empirical evidence are summarised in Table 3 and the detailed quality scoring of empirical evidence sources is presented in Appendix 4. The results of the synthesis and meta-analysis of sources against all sub themes are presented below, in the order of the sub themes with the primary question addressed as the final section of the results. Detailed analyses are presented in the appendices. Further evidence sources accessed after presentation of initial results to address specific evidence gaps are listed in Appendix 10.

Table 3: List of key publications providing empirical evidence

Literature	Cost of installation	Damage avoided	Indirect/Intangible benefits	Total Weighted Score
ABI, 2003/2006	☒	☒	☐	26
Office of the Deputy Prime Minister, 2003	☒	☒	☒	34
Kreibich, 2005	☒	☒	☐	29
Multihazard Mitigation Council, 2005	☐	☒	☒	26
Messner *et al.*, 2007	☐	☐	☒	11
Green *et al.*, 2006	☐	☒	☐	11
Hawkesbury-Nepean Floodplain Management Steering Committee, 2007	☒	☒	☐	22
Bichard and Kazmierczak, 2009	☒	☒	☐	30
Wassell *et al.*, 2009	☒	☒	☒	39
Joseph *et al.*, 2011	☒	☐	☐	13
JBA Consulting *et al.*, 2012	☒	☒	☒	40
Highfield and Brody, 2013	☐	☒	☐	12
Joseph, 2014	☒	☒	☒	43
Hudson *et al.*, 2014	☒	☒	☐	28
May *et al.*, 2014	☒	☒	☐	28
Owusu, 2014	☐	☐	☒	11
Dhonau and Rose, 2016	☒	☐	☐	12
FEMA, 2015	☒	☐	☐	11
Poussin *et al.*, 2015	☐	☒	☐	13
Joseph *et al.*, 2015	☐	☐	☒	13
National Flood Forum Blue Pages, 2016	☒	☐	☐	12
Lamond *et al.*, 2016b	☒	☒	☐	26
Royal Haskoning, 2012	☒	☒	☒	37

Measures - Range and Types

Measures to limit damage from flooding at an individual property level can be broadly divided into two approaches:

- planning to keep the floodwater outside the property, sometimes termed resistance, protection, dry proofing or water exclusion measures; and
- accepting that water will enter the property, sometimes known as resilience, wet proofing or water entry.

Both types of approach are covered within this report, but increasingly it is being recognised that, since water exclusion can never be entirely guaranteed and most property owners and occupiers will want to control water entry to some extent, it may be useful to consider both approaches in a holistic property level resilience approach. Figure 3 below shows a categorization of measures and demonstrates the vast number of options that need to be considered in designing a scheme for an individual property.

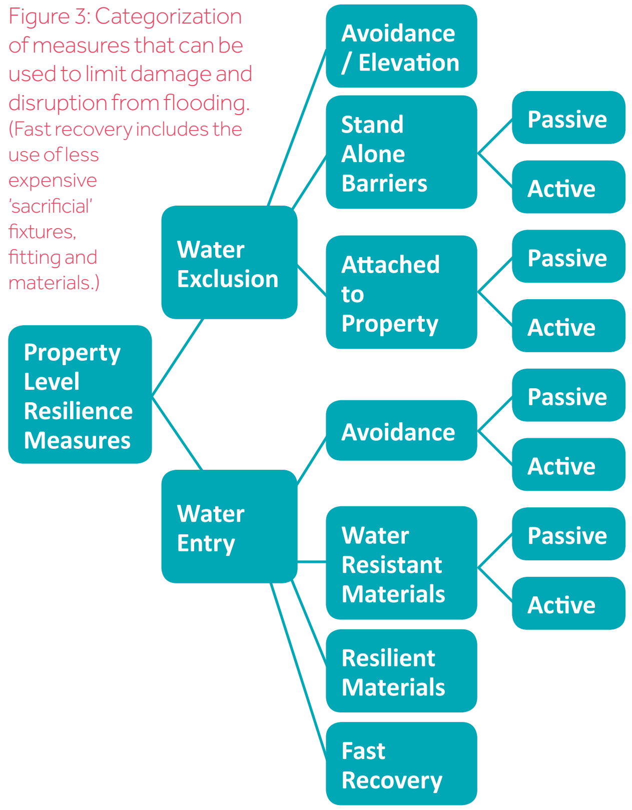


Figure 3: Categorization of measures that can be used to limit damage and disruption from flooding. (Fast recovery includes the use of less expensive 'sacrificial' fixtures, fitting and materials.)

Within each of the approaches further sub-categorisation is useful. Water may be kept well away from the building fabric by landscaping or stand-alone barriers, or water may be prevented from entering the property by attaching barriers to water entry points such as doors and low-level windows and treating other water entry points (such as walls and service entries). Once it is accepted that water may enter a property, then contents and services can be protected from damage: using avoidance principles; using water resistant materials such as plastics or ceramic tiles; or resilient materials such as stone, permeable tiles and concrete. Finally, where it is not possible to limit damage to a building element, a cheap 'sacrificial' approach that allows for fast recovery may also save time and money for owners, occupiers and their insurers.

There are limitations to each approach and it is important to recognize that, under certain circumstances, the measures will not prevent all damage. Water exclusion requires coherent packages of measures to be installed in order to prevent water from entering the property. Water entry approaches can be more flexibly applied as damage can be limited to many elements on an individual basis.

It is not possible to specify an ideal resilience approach that will fit all circumstances. This is because factors including flood type, expected frequency and depth, speed of onset, lifestyle and owner/occupier capacities and preferences need to be considered in planning an approach to limit damage to a particular property. Homeowner preferences, although outside the scope of this scoping review, are a major decision factor in practice; there are, however, some general principles that have been accepted in the industry. Examples of packages are outlined within Table 7: Summary of flood repairable packages from Lamond *et al.* (2016b)

The majority (159) of the 183 retained sources had some evidence on the range and type of measures useful for preventing damage in individual properties.

Key sources that summarise the widest range of measures include Dhonau and Rose (2016), NFF (2016) and Lamond *et al.* (2016b) as these are up to date and incorporate the findings from earlier studies, as well as entries from product providers. Typical measures are depicted in Figure 4 below, taken from Dhonau and Rose (2016): this shows a range of water exclusion and water entry strategies in situ.

For the evidence review lists of measures were taken from both Dhonau and Rose (2016) and Lamond *et al.* (2016b) to underpin the meta-analysis that is presented in Appendix 1. Each measure has an appropriate flood depth indicator, together with an approximate cost banding; utilising information drawn from the above publications, combined with (ABI, 2003, ABI, 2006) and (Garvin *et al.*, 2005).

Finally, other evidence sources published in 2016 and later were checked in case new measures were listed but none were found that were not captured by the previous two reviews.

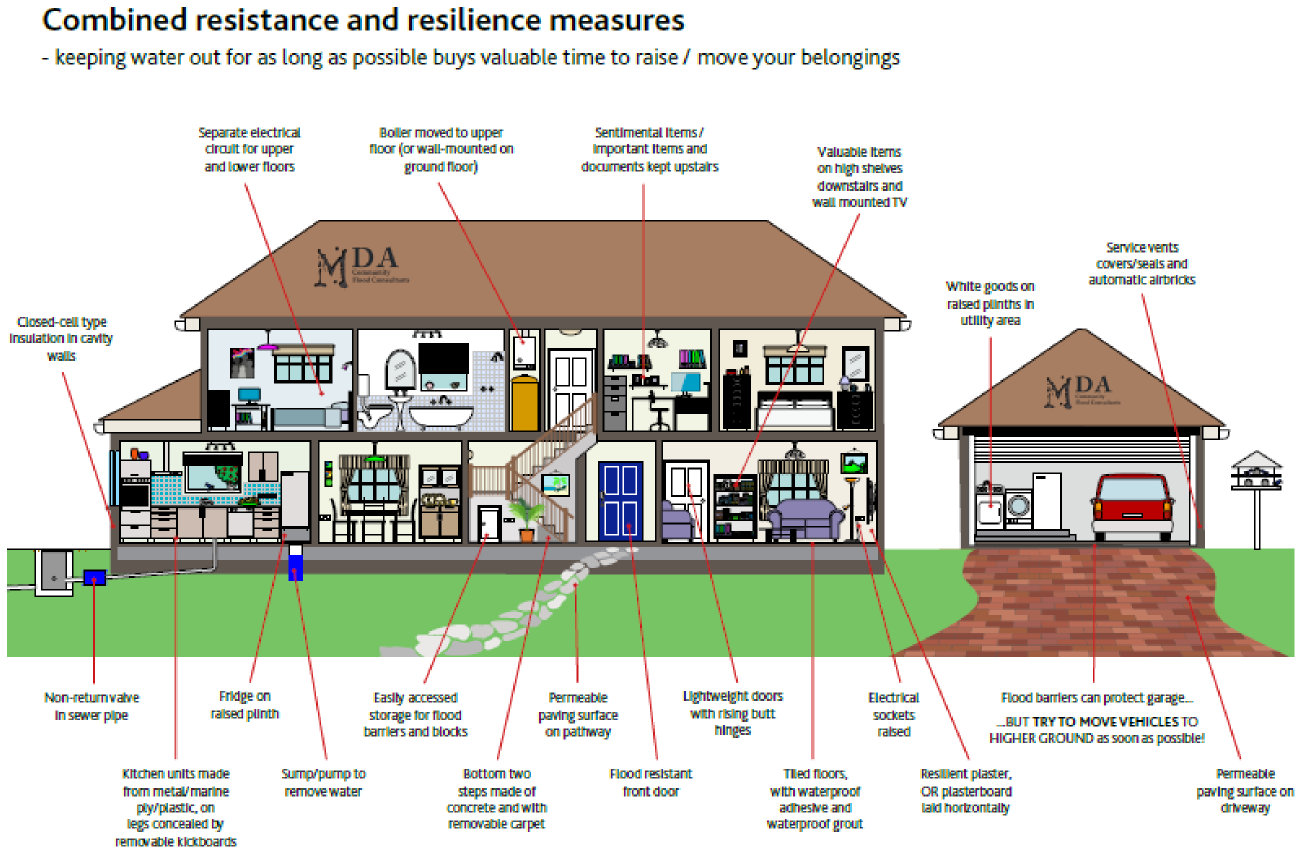


Figure 4: Combined resistance and resilience measures from Dhonau and Rose (2016) - image used with kind permission from Mary Dhonau.

Packages – varying house types/ flood types

Over half (111) of the retained studies give insight into the different flood typologies and house types in relation to choosing measures. However, most of these are not empirically based and only 22 contain empirical evidence. The general preference expressed by homeowners and professionals alike is to attempt to keep water out in the first instance (Lamond *et al.*, 2017, and others). It is on this basis that recommendations for water exclusion measures have predominated. However, keeping water out is not always possible or desirable.

A widely accepted standard is given by the British Standards Institution (BSi) (2015) based on Bowker *et al.* (2007) that water can be excluded up to 300mm, partially excluded above that height but water to be allowed in over 600mm to protect structural integrity (see Figure 5). There is also guidance on effective delivery of measures published by Defra, the Scottish Government and the Environment Agency (see for example Defra, 2014).

Figure 5: Rationale for design strategies, from Bowker *et al.* (2007) p 46

	Design water depth*	Approach	Mitigation measures
Resistance/ Resilience**	Design water depth above 0.6m	Allow water through property to avoid risk of structural damage. Attempt to keep water out for low depths of flooding. 'Water Entry Strategy'***	• Materials with low permeability up to 0.3m • Accept water passage through building at high water depths • Design to drain water away after flooding • Access to all spaces to permit drying and cleaning
Resistance/ Resilience**	Design water depth from 0.3m to 0.6m	Attempt to keep water out, in full or in part, depending on structural assessment. If structural concerns exist follow approach above***	• Materials with low permeability up to 0.3m • Flood resilient materials and designs • Access to all spaces to permit drying and cleaning
Resistance/ Resilience**	Design water depth up to 0.3m	Attempt to keep water out 'Water Exclusion Strategy'	• Materials and constructions with low permeability
Avoidence		Remove building/development from flood hazard	• Land raising, landscaping, raised thresholds

Notes:
* Design water depth should be based on assessment of all flood types that can impact on building
** Resistance/resilience measures can be used in conjunction with avoidence measures to minimise overall flood risk
*** In all cases the 'Water Exclusion Strategy' can be followed for flood water depths up to 0.3m

This standard is somewhat consistent with international guidance from Ingargiola *et al.* (2012) and is based on the limitations of the water exclusion approach. Therefore instances where water entry measures may be more suitable include the following:

- Depth of flooding - Due to structural considerations, water exclusion approaches are not generally recommended for flooding that is expected to be deep. Although the definition of 'deep' varies in the literature, the current British Standard uses the precautionary principle based mainly on hydrostatic pressure, and defines 'deep' as greater than 0.6m for masonry and 0.3m for other construction types (Bowker *et al.*, 2007).
- Groundwater flooding – Although it may be possible to create a water resistant flooring system that excludes groundwater flooding there are structural considerations that may make this undesirable. Guidance in this area is based around basement waterproofing technology that should be accompanied by a structural assessment (Bowker *et al.*, 2007.
- Speed of onset – if measures require deployment then they may not be suitable in circumstances where flooding arises rapidly and warnings times are short.
- Velocity of flooding – Hydrodynamic forces may cause structural issues at lower depths than the BS recommendations (British Standards Institution (BSi), 2015).
- Duration of flooding – Most walls will allow water through eventually unless steps are taken to treat the wall surface (Beddoes and Booth, 2015). In these circumstances the water exclusion approach may need to be carefully considered.

- Attached property – If a property is attached to an adjoining structure that has a different approach to limiting damage, is of different construction or is at a different elevation then it may not be possible or sensible to try to exclude water from the property.
- Historic/Character properties - There may be constraints on the type of measures acceptable for use on character property: for example, Historic England mentions that the application of closed cell spray insulation within a timber frame structure is not appropriate (an open-cell type is required, to avoid timber decay) (Historic England (formerly Eng Heritage)/ Pickles *et al.*, 2015).
- Occupant considerations – if deployment is required then there may be limitations due to the availability and capacity of residents to deploy measures in a timely fashion (JBA Consulting, 2012).
- Non-standard construction, poor quality/porous brick, poorly maintained structures – the standard approach of protecting openings and providing pumps (JBA Consulting, 2012) may be subject to failure if properties will allow water through the walls and the water exclusion approach may be more costly or not feasible.

Water entry approaches are more flexible in their application because they can be applied piecemeal. Water entry approaches are often seen as a last resort to be adopted when water exclusion approaches are inappropriate. As such they have traditionally been recommended for deep fluvial flooding because they can be applied to deal with higher expected flood levels. However, this is a matter of recent debate and an emerging view is that they may also be appropriate in the other scenarios listed above: rapid onset; high velocity; attached property; groundwater flooding; and non-standard construction.

The confidence around which maximum flood levels can be predicted and resulting design depth is also a consideration. Measures are usually designed to operate to the maximum expected flood level; however, the possibility for measures to be overtopped by deep floods always exists. In some circumstances the presence of water exclusion measures that are overtopped could increase the damage if they result in retention of water within the property after a flood has subsided externally. Within the subcategories of water entry approaches, avoidance strategies (particularly passive avoidance) are usually subject to design depth limitations but do not generally increase damage when they fail. Equally the height to which water resilient or water resistant finishes are applied is a critical success criterion.

Suitability of measures as they relate to different property types, particularly those that are likely to be common in the Flood Re portfolio, is an area with fewer evidence sources. Studies in the UK have explored a variety of different property type and age categories (See Appendix 3). However, the property types prevalent in the 350,000 properties potentially eligible to be underwritten by Flood Re is not contained in the literature. Many studies have based their categorisations on the groupings used in the Multi-coloured Manual (hereafter MCM) (Penning-Rowsell *et al.* 2005) which in turn rely on the information available in the National Receptor Database. An alternative approach is based on construction typologies, for example ABI (2006), Wassell *et al.* (2009) and Lamond *et al.* (2016b). Understanding of the predominant property types that have submitted claims in previous flood events is also provided by Wassell *et al.* (2009), together with some reflections on the types of measures suitable for installation in property of different types. Davis Langdon (2011) estimated the proportion of property that could benefit from measures (See Table 4). However, this was based on unspecified information sources, accompanied by 'professional judgement': therefore some of these assumptions bear greater scrutiny, and a similar (properly evidenced) table would be a valuable addition to the evidence base.

The number of studies that specify minimum or example packages is even lower at 13 studies. Most of these are studies produced for the UK government: for example, both JBA *et al.* (2012) and Royal Haskoning (2012) studies as well as two PhD theses (Owusu, 2014, Joseph, 2014). Many of the packages employed are based on information contained in a key ABI/BRE publication (ABI, 2003). Analysis of the 13 studies is presented in Appendix 2. On the whole, studies have explored fairly similar packages of measures under 6 main headings: manual resistance; automatic resistance; resilience with and without a concrete floor; combinations of the four resistant and resilient packages. An example is shown in Table 5.

Table 4: Applicability of measures by property type from Davis Langdon (2011)

#	Measure sub-type	pre 1919 semi- or terrcd	1919- 1980 semi- or terrcd	1980-2010 semi- or terrcd	post 2010 semi- or terrcd	pre 1919 dtchd	1919-1980 dtchd	1980-2010 dtchd	post 2010 dtchd	pre 1919 flat	1919-1980 flat	1980-2010 flat	post 2010 flat
1	Dense screed	10%	50%	50%	50%	10%	50%	50%	50%	5%	9%	8%	5%
2	Chipboard -> treated timber floorboards	FALSE	FALSE	50%	50%	FALSE	FALSE	50%	50%	FALSE	FALSE	8%	5%
3	New floor with treated timber joists	90%	50%	50%	50%	90%	50%	50%	50%	45%	9%	8%	5%
4	Solid concrete floor	90%	50%	50%	50%	90%	50%	50%	50%	45%	9%	8%	5%
5	Raise floor above likely flood level	100%	100%	100%	FALSE	100%	100%	100%	FALSE	50%	18%	15%	FALSE
6	Closed cell cavity insulation	3%	36%	53%	53%	3%	36%	53%	53%	2%	6%	8%	5%
7	Water resistant plaster	FALSE	50%	100%	100%	FALSE	50%	100%	100%	FALSE	9%	15%	10%
8	Chemical damp-proof course	84%	21%	3%	FALSE	84%	21%	3%	FALSE	42%	4%	0%	FALSE
9	Water resistant doors and windows	40%	40%	50%	10%	40%	40%	10%	10%	20%	7%	2%	1%
10	Wall-mounted boiler	10%	10%	10%	10%	10%	10%	10%	10%	5%	2%	14%	9%
11	Move washing machine to first floor	90%	90%	90%	90%	90%	90%	90%	90%	FALSE	FALSE	FALSE	FALSE
12	Raised, built-under oven	50%	50%	50%	50%	50%	50%	50%	50%	25%	9%	14%	9%
13	Move electrics above flood level	100%	100%	100%	100%	100%	100%	100%	100%	50%	18%	15%	10%
14	Move service meters above flood level	100%	100%	100%	100%	100%	100%	100%	100%	50%	18%	15%	10%
15	Plastic kitchen / bathroom units	100%	100%	100%	100%	100%	100%	100%	100%	50%	18%	15%	10%
16	Flood resistance package, fit & forget	100%	100%	100%	100%	100%	100%	100%	100%	50%	18%	15%	10%
17	Flood resistance package, manual activation	100%	100%	100%	100%	100%	100%	100%	100%	50%	18%	15%	10%

Table 5: typical packages of measures (after Owusu, 2014)

Flood Protection Package	Individual Measures	Source
Manual resistance measures	Demountable Door Guards Manual Airbrick and Vent Covers Sewerage bungs/toilet pan seals Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump	DEFRA (2007). DEFRA (2008). AECOM (2011)
Automatic resistance measures	Automatic door guards Smart airbricks and vents Non-return valves on main sewer pipe Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump	
Resilience without flooring	Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water resistant alternative Mount boilers on wall Move washing machine to first floor Replace ovens with raised, built-under type Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/ bathroom units with plastic units	DEFRA (2007). DEFRA (2008). AECOM (2011)
Resilience with flooring	All the above, plus: Replace floor with solid concrete plus all measures above	DEFRA (2007). DEFRA (2008). AECOM (2011)

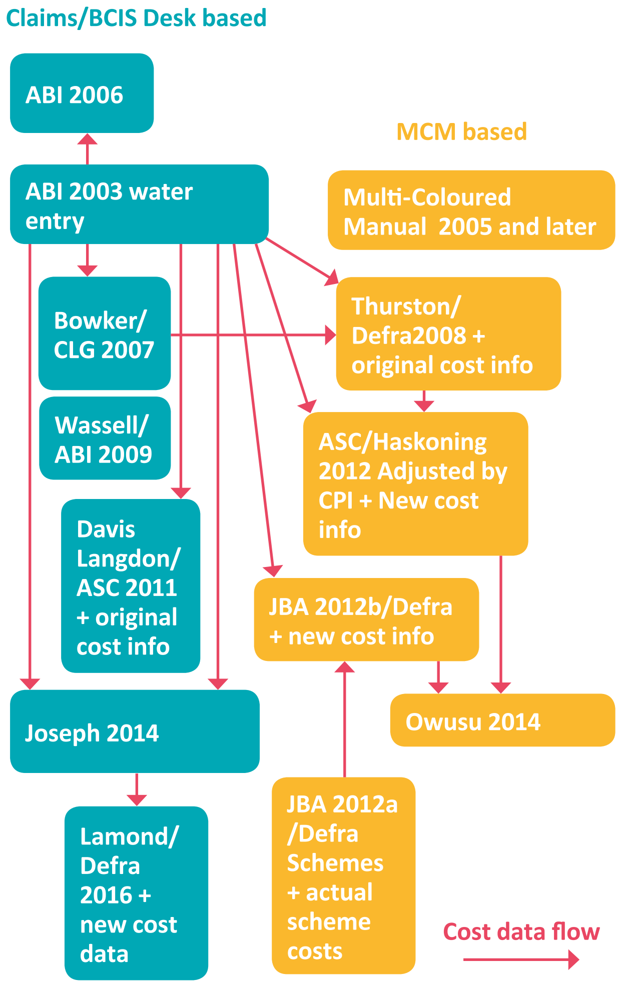
In seeking consistency, it may be argued, the studies have not incorporated some of the emerging technologies (such as full height flood doors) and may have consistently chosen over-costly and arguably inappropriate resilience measures (such as lime plaster for a modern building). Exceptions include Lamond *et al.* (2016b) as this deliberately sought to explore different (ie lower cost) resilience packages (shown in Table 7); and Davis Langdon (2011) in which each resilience measure was treated as a separate item. The packages in Lamond *et al.* (2016b) include cement and sand render (instead of lime plaster) in more modern construction types and also explored the use of membrane technology and internal finishes such as tiling.

Examination of different assumptions about property typologies and suitability of approaches would allow for a better understanding of the potential to reduce the cost and disruption from flood damage. Furthermore exploration of different resistant and resilient packages would be beneficial.

Installation costs

Costs of installation are considered by 81 sources. Around half of these (41) offer some empirical/modelled evidence; however, there are links between many of the main studies in that they use cost data provided by a very limited number of original sources. This is illustrated in Figure 6, which shows two principal studies in this area the ABI (2003, 2006) and Bowker (2007).

Figure 6: Cost data flows in UK studies



Further refinement and detail have been provided by Wassell *et al.* (2009) and Joseph (2014) (using RICS Building Cost Information Service (BCIS)) on several packages of measures; from JBA *et al.* (2012) for installed property water exclusion measures (average £5k); by Keating *et al.* (2015) for a variety of schemes including administration and survey costs; and by Lamond *et al.* (2016b) for resilient packages. Cost information for individual products and water exclusion products is also available from The Homeowners Guide to Flood Resilience (Dhonau and Rose, 2016). This guide has built on previous reviews and studies: for example, the National Flood Forum Blue Pages (2016) and guides from the Construction Industry Research and Information Association, and it is regularly updated. Costs have also been estimated by Davis Langdon (2011), Thurston *et al.* (2008) and Bowker *et al.* (2007) using the base data within the assessment by the ABI (2003).

On the whole, studies demonstrate that the cost of different measures differ widely: some measures are very low to no cost, whereas others are much more costly. While many commonly employed measures have been costed there are inconsistencies in the estimates related to assumptions underlying costings. Cost estimates are generally based on desk based accounting principles, whereby quantities of materials and labour are specified for a particular package and property type and these are subsequently costed. Recent studies such as JBA *et al.* (2012) have also provided cost ranges in recognition that estimates are not precise and may vary with timing and quality of workmanship.

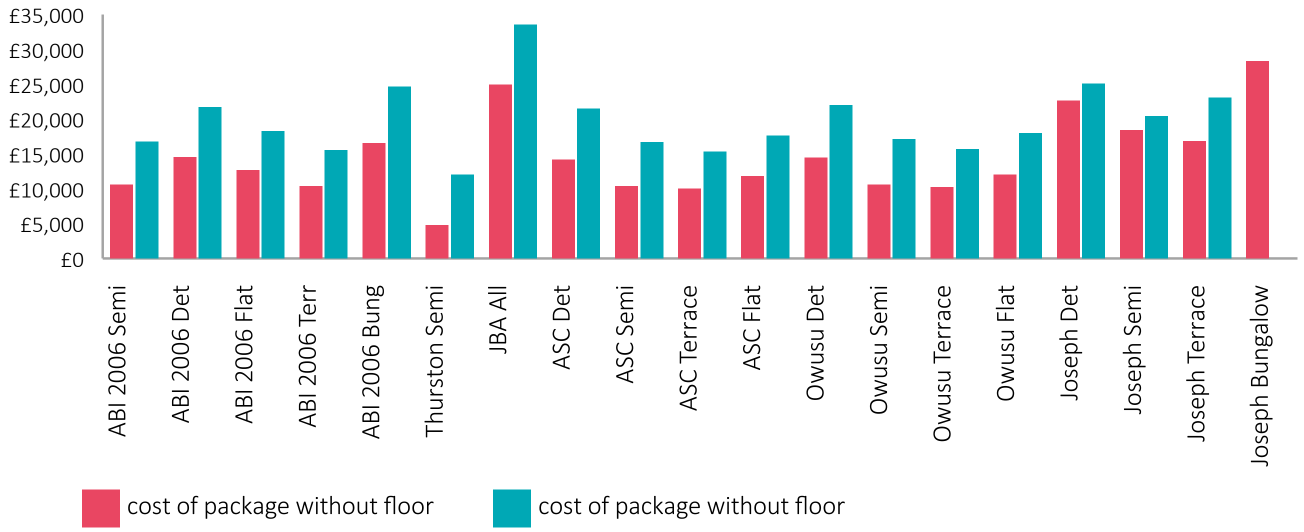
There is variation even when packages are ostensibly quite similar: for example, estimated costs of automatic resistance packages vary from £5,000 to over £9,000 for a terraced property (see Table 6). JBA *et al.* (2012) provide some contextualization on water exclusion measures from actual installations within the Defra pilot schemes that occurred prior to 2011: this seems to imply costs for resistance measures may be falling over time and so their cost estimates may be more reliable than other studies. However, the estimates for maintenance costs provided by JBA *et al.* (2012) add significantly to the cost estimates for automatic measures. More detailed breakdown of costs are provided in Appendix 5.

Table 6: cost estimates for resistance packages (with VAT, surveys and maintenance where study provided

	Detached	Semi-detached	Terrace	Flat	Bungalow
Automatic					
JBA *et al.* (with maintenance)			8,616		
Royal Haskoning (with maintenance)	16,325	11,638	9,245	9,370	
Joseph	10,200	6,700	5,200		10,800
Owusu	7,572	6,928	5,250	5,393	
Manual					
JBA *et al.* (with maintenance)			3,484		
Royal Haskoning (with maintenance)	5,180	4,802	3,911	3,954	
Joseph	6,400	4,000	3,800		6,800
Owusu	3,663	2,630	2,568	2,630	

The differences in costs of resilience packages is even greater, though given the differences in the assumptions made this is unsurprising. For example, meta-analysis of costs for a typical resilience package (without concrete floor) across studies varies from £5,000 to £25,000. Depending on assumptions around time of installation (during reinstatement or spontaneously) and property type (see Figure 7).

Figure 7: Costs of resilient packages



(and the future cost saved if there is a need to replace a cheap carpet, as opposed to an expensive carpet, for a second time also needs to be considered in the overall assessment of benefit/cost). Assumed size, value and layout of property are also key factors. Wassell *et al.* (2009) and Joseph (2014) took the approach of re-specifying actual reinstatement work schedules in a resilient manner, thereby improving the understanding of costs of resilient reinstatement.

The issue of additional cost as part of reinstatement is complicated by the huge variety of existing internal finishes, fixtures and fittings given that insurers will normally replace on a 'like for like' basis (Lamond *et al.*, 2016b). For example, replacing cheap carpet with tiling represents a much higher extra cost than does replacing expensive carpet with tiling

One item that stands out as hugely variable in terms of cost of 'like for like' replacement is the kitchen (Joseph *et al.*, 2011). In a property that prior to flooding had high-quality fittings and fixtures, a traditional 'like for like' reinstatement of the kitchen units alone was costed at £30k.

Table 7: Summary of flood repairable packages from Lamond *et al.* (2016b)

Package Number: A1
House Type 1: Semi-detached
Net Internal floor area: 49m2

Repairable Package
Salt resistance added to lime plaster
Retain timber floor and door
Removable carpets and vinyl flooring
Rising butt hinges for internal doors
Removable kitchen cabinet doors
Acrylic bath panel and wall mounted vanity unit
Raised sockets + Non return valve

Cost of package: £11,420
Like for like comparison: £8,950
Additional cost of repairability: £2,470

Package Number: A2
House Type 2: Mid-Terraced
Net Internal floor area: 37m2

Repairable Package
Sand and cement render
Closed cell insulation
Retain concrete floor and timber door
Quarry tiles and ceramic tiles to floor
Rising butt hinges for internal doors
Removable kitchen cabinet doors
Raised sockets + Non return valve

Cost of package: £7,420
Like for like comparison: £5,530
Additional cost of repairability: £1,890

Package Number: B7
House Type 7: Semi-detached
Net Internal floor area: 48m2

Repairable Package
Water resistant wall boards
Closed cell insulation
Retain timber floor
Replace door with UPVC
Ceramic tiles to floor
Rising butt hinges for internal doors
Removable kitchen cabinet doors
Raised sockets + Non return valve

Cost of package: £10,930
Like for like comparison: £7,410
Additional cost of repairability: £3,520

Package Number: C8
House Type 8: Mid-Terraced
Net Internal floor area: 72m2

Repairable Package
Cavity membrane and sacrificial gypsum (horizontal)
Closed cell insulation
Retain concrete floor
Replace external doors with UPVC
Removable carpets and ceramic tiles to floor
Rising butt hinges for internal doors
Removable kitchen cabinet doors
Raised sockets + Non return valve

Cost of package: £12,540
Like for like comparison: £7,770
Additional cost of repairability: £4,770
Cost without membrane: £3,230

Further understanding of likely differences can be seen by breaking down the cost of resilience (based on the ABI data used by most studies). This is shown in Figure 8 and it can be seen that the majority of the costs are represented by four items: replacing the floor with concrete; replacing chipboard kitchen with plastic; water resistant doors and windows; and replacing (gypsum) plaster with lime plaster.

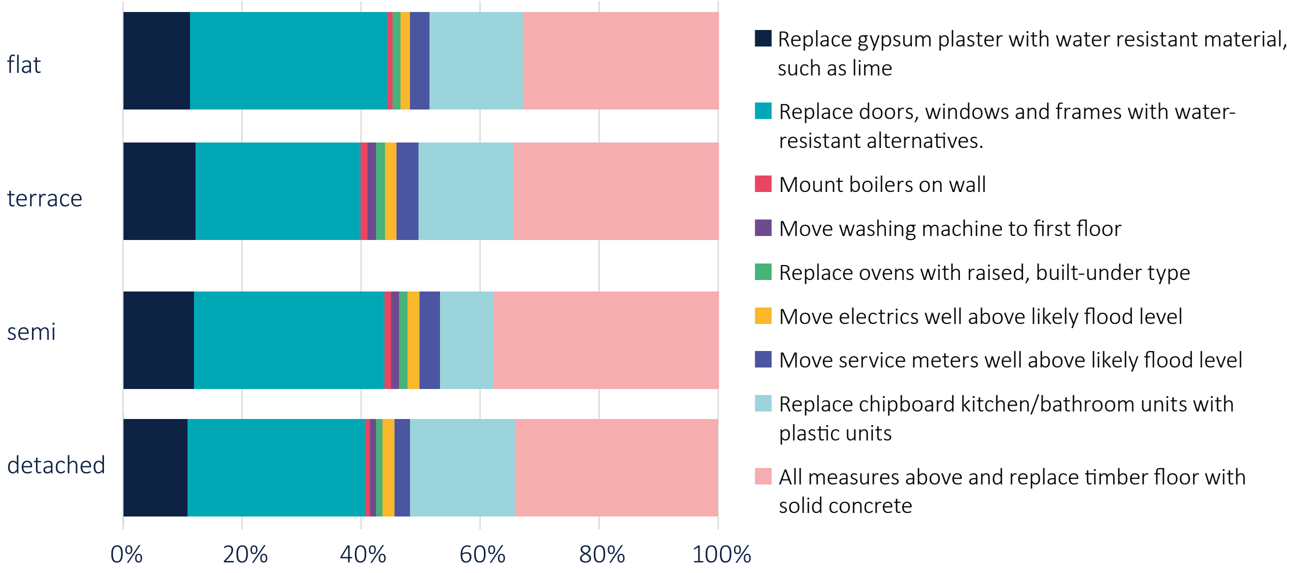
Although lime is a resilient option it is not the only approach available when replacing gypsum plaster; the use of lime plaster is costly, as it requires specialist skills, and many alternatives were covered by the recent low cost resilience project (Lamond et al, 2016b). The analysis showed gypsum plaster can generally be replaced with resilient alternatives that are cheaper than lime: for example, resilient sand and cement, with a waterproof additive to increase resilience if required. If a property already has lime plaster then reinstatement with lime would not in itself be considered an additional cost, but a salt resistant additive can be added at minimal extra cost. Lamond *et al.* (2016b) consulted with industry experts who concluded that replacing gypsum plaster with lime was unlikely to be appropriate for flood resilience alone, but could be appropriate in historic property for other reasons.

Specially designed water resisting front doors are estimated by Dhonau and Rose (2016) as being 'Medium to high' cost (£1500 – 5000 each at 2014 price base). If existing doors require replacement then, as part of a resilient approach, Lamond *et al.* (2016b) estimated that the additional cost of standard UPVC doors could be as little as £600 for two doors.

Replacing the timber floor with concrete is seen as a major measure only appropriate for frequently flooded property and only if existing timber flooring is in need of replacement.

Kitchens are a much more expensive item on average than the assumed cost in ABI figures; however, the extra cost of a resilient kitchen may be lower than the ABI estimate. The kitchen installed in the BRE resilient house was £2,000 more than a non-resilient equivalent (personal communication).

Figure 8: Percentage of extra resilience costs represented by components of typical resilience packages



Based on this analysis, assumptions often adopted that resilient repair would include the use of lime plaster, replacement of timber floor with concrete floors and cost of flood resistant windows, may be overstated. The extra expense of resilient doors and kitchens may also be costed too high. On this basis the average extra cost of resilience appears to have been generally over estimated. While Lamond *et al.* (2016b) provides a good start in terms of alternative packages, further work addressing a suitable subset of common alternatives is warranted.

Barriers and other products to exclude water are often easier to cost as they are not replacing existing items; however, a wide variety of barriers is currently available at different price points, even among Kitemarked products, and no studies have evaluated the suitability and justification for using less or more costly products. The range of costs of both water exclusion and water entry measures needs further investigation.

Appropriate surveys of the building itself, as well as consideration of the anticipated flood depths/frequencies, are necessary precursors to the selection of appropriate and effective flood resistance and/or and resilience solutions (Thurston *et al.*, 2008) and thus form an essential element of the overall costs. The outlay required for such surveys can vary greatly, however, as discussed in detail by Keating *et al.* (2015) who provide the following estimates for residential properties:

- Threshold survey: £25–50 per property;
- Building survey: £200–400 per property;
- Post-construction survey: £55–75 per property.

These same figures were used by Royal Haskoning (2012) in deriving an average value of £450 per property as the financial cost of surveys within their model. The above figures, however, apply only where a large number of surveys are procured as a 'bulk order', such as those performed as part of the resilience grant pilots (Defra, 2008b). Where such economies of scale are not available, as in the case of individual residential properties, much higher costs could be anticipated: Defra (2008a) estimated this as being 'up to £1,000' per property. ABI (2003) estimated the additional cost of a resilience survey during the reinstatement process as £300 with a further £300 for keeping records of the measures. Audit and monitoring surveys are also required to improve the likely performance of measures in the event of a flood.

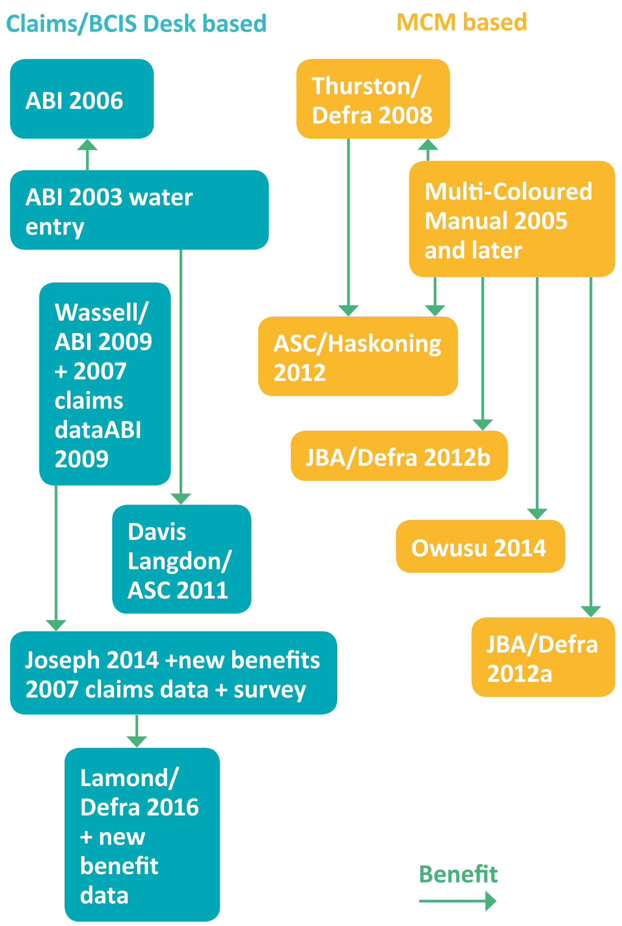
The various components of a property level measure package cannot be assumed to have an indefinite product life: both Royal Haskoning (2012) and JBA *et al.* (2012) adopt a 20 year default (which is consistent with that used by the Environment Agency for partnership funding in England). The whole life cost of any measure needs to include an element for its appropriate maintenance. The details will vary according to type, as measures such as automatic flood doors are in constant daily use and are therefore exposed to much higher levels of wear and tear than manual measures, which are deployed intermittently (JBA Consulting, 2012). The models used by both Royal Haskoning (2012) and JBA *et al.* (2012) use the following annual rates (these being included as a discounted cost over the 20 years for which the packages were appraised):

- Automatic resistance 5%;
- Manual resistance 2%;
- Resilience 2%.

Direct damage prevention

The potential to limit damage is one of the cornerstones of evidence required for evaluation of costs and benefits. Multiple studies (109) have considered the damage limitation potential of measures and from a number of perspectives. Empirical evidence around (actual) performance of measures in limiting damage is more elusive in the literature, occurring in just 28 studies. In the UK the studies are of two types: those that use the Weighted Annual Average Damage method (hereafter WAAD) and the damage curves contained with the MCM; and those that use an individual property approach based on desk based or claims data and make recommendations for property at different return periods and depths. Appendix 8 summarises the features of the UK cost benefits studies, and the flows in the avoided damage data is shown in Figure 9.

Figure 9: Flow of avoided damage data



Under assumptions of performance of measures, these methods can be used to evaluate the likely savings from damage limitation. In general, all of the studies indicate potential for significant damage prevention by installing measures.

Underlying assumptions such as economic or financial models, the choice of discount and reliability factors, inclusion of 'contents' or 'inventory' clearly have the potential to make a difference to the estimated losses avoided. These assumptions will be discussed further in Appendix 11. However, the method of "damage prevention" relies on the use of a traditional "depth-damage curve" to calculate the damage that would have occurred without any resilience/resistance measures in place. The accuracy of the estimation of "damage avoided" is therefore limited to the accuracy of the underlying depth-damage curves.

Depth Damage relationships

Depth damage curves show the average cost of damage for properties flooded in a single event to a range of different depths. They can be averaged over a whole portfolio of risk/property types or presented for different types of property and durations of flooding.

An example of a depth damage curve is shown in Figure 10 taken from Thurston *et al.* (2008) and based on the depth damage figures embedded in the 2005 edition of the MCM. These figures are regularly updated and the 2010 version of the MCM was used in other studies. The MCM tables are broken down by property types and for two flood durations; however, when these depth damage curves are compared to actual claims data it would appear that MCM underestimates the cost of damage actually borne by insurers.

Alternatives to the MCM data include the ABI (2003) study, which contains damage limitation estimates from expert assessments and was used by studies such as Davis Langdon (2011). Other studies, for example Joseph (2014) have estimated damage avoided using recent

insurance claims data taken from loss adjusters' records of the 2007 flood. These have been coupled with desktop analyses of reinstatement costs by quantity surveyors within the adjustment profession (for example, Wassell *et al.*, 2009). These, arguably, may be seen as more realistic for the purposes of estimating the financial value of insurance loss avoidance and limitation. The amount of loss avoided is also subject to expert assumptions whereby resistance is assumed to prevent the majority of buildings and contents losses until they are overtopped (0.6m in Figure 10 below) whereas resilience measures do not protect contents but are successful in preventing some damage at greater depths of flooding.

Damage avoided is obtained by subtracting the damage curve with measures from the curve without measures. Comparison of the different depth/damage data (Figure 11) demonstrates that using claims data from 2007 would give higher avoided damage estimates than the 2010 MCM estimates because the level of claims without measures is larger in claims data than in MCM estimates. The differences are greatest at shallow depths, representing a high proportion of expected claims, and for larger properties.

Figure 10: Depth damage curves adapted for packages of resistant and resilient measures from Thurston *et al.* (2008)

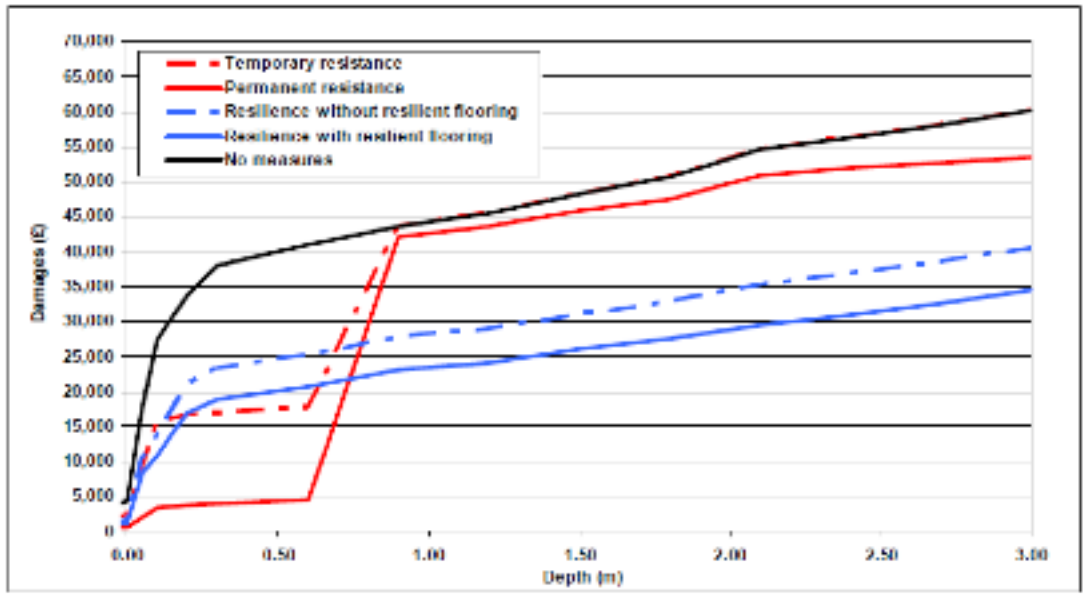


Figure 11: Comparison of 2007 claims data with MCM (building costs, long duration)

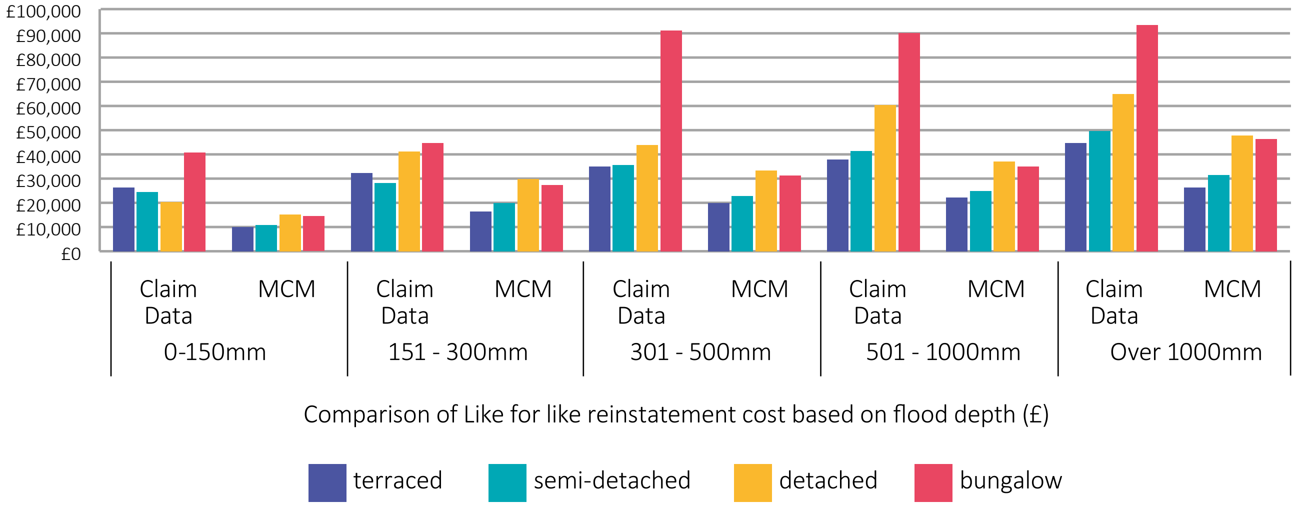
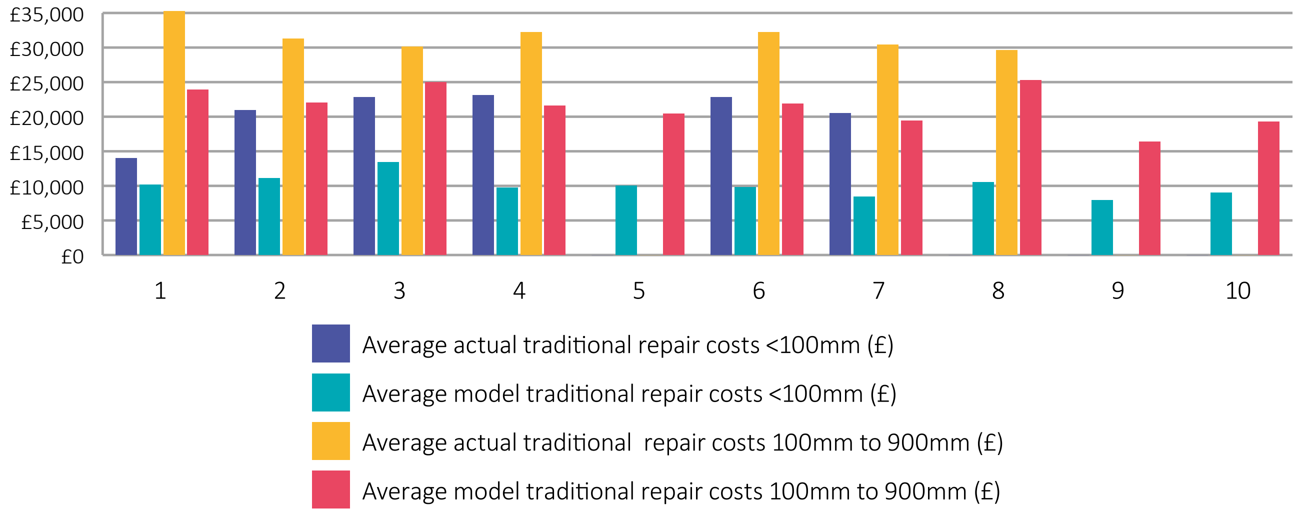


Figure 12: comparison of actual vs modelled claims costs (data from Wassell *et al.* 2009)



It is also possible to compare claims data with desktop estimates based on 'typical' properties as presented in Wassell et al. (2009): this shows that claims data typically exceed these desk based estimates, as shown in Figure 12. Wassell et al. (2009) offers several reasons for this discrepancy: uplift due to high demand just after a flood; variation in property within broad property classes; and unrealistic assumptions about the height to which properties are stripped out. This can be well understood when the variability of claims is examined as they were in Joseph et al. (2011) where it was highlighted that differences in the quality of fittings (particularly the kitchen, as discussed above) can create wide variability in claims cost for similar property.

Further analysis of 2007 claims data is presented in Appendix 12 and shows expected patterns of claims increasing with duration and property size, as well as some interesting patterns around the costs for different construction types. The claims data from the extreme floods of 2007, though useful, is not necessarily typical and investigation of more recent claims data is recommended.

Expected damage avoided calculation

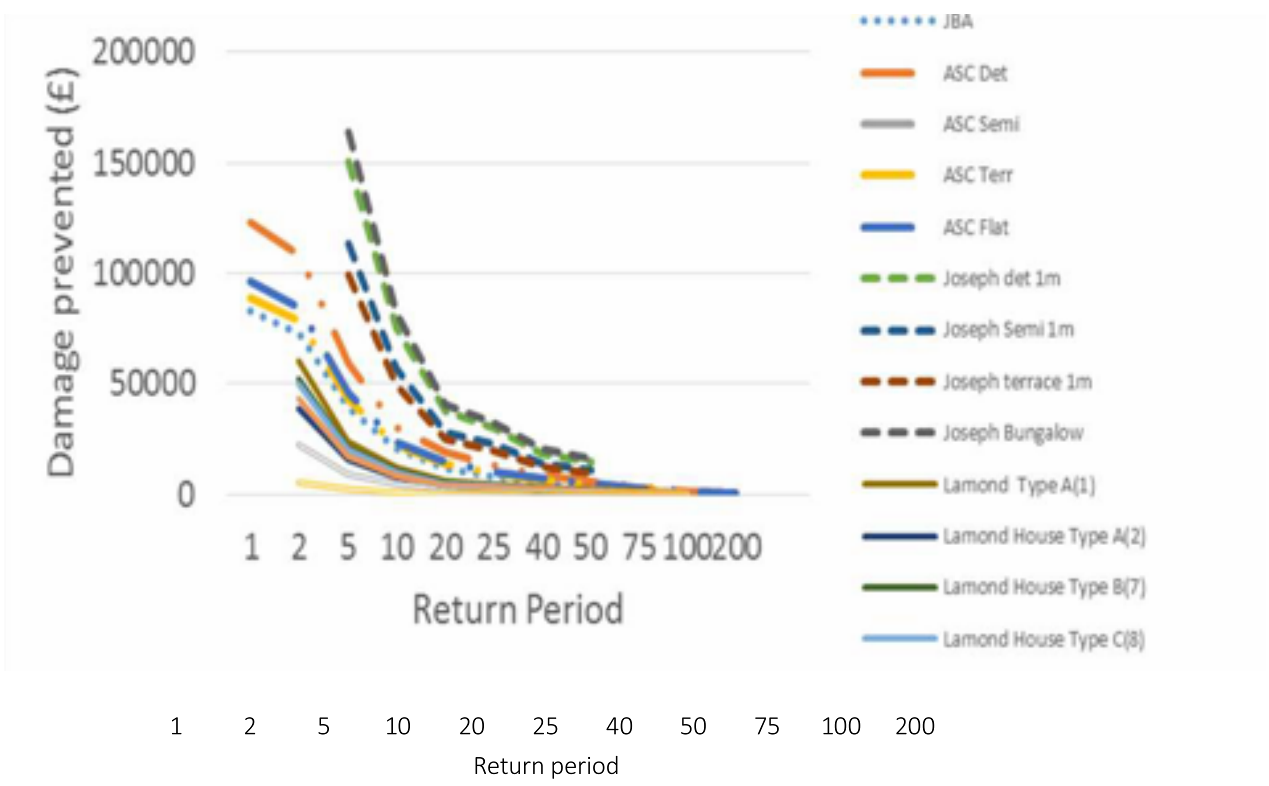
The depth damage data is then converted into expected damage avoided over a specified time period (usually 20-25 years). Expected damage avoided is based on the damage avoided in a single event but it is adjusted by the number of floods likely to occur during the specified period. The avoided damage is discounted over time and can be calculated for different depths of flooding. Averaging across properties in a portfolio with different expected likelihoods of flooding can be achieved using either the MCM's WAAD method, or other deterministic methods based on the expected frequency and depth of flooding for the relevant portfolio.

Stochastic methods of assessing the benefit/cost relationship, such as those commonly used within the insurance industry, have not typically been used in studies carried out to date. These approaches are able to consider the full range of flooding frequency, impacts and potential benefits of resistance/resilience measures. This type of analysis can in turn provide insights into the likelihood of achieving a given level of benefit over time.

The WAAD method (explained in Appendix 11) is designed for avoided damage for all properties within a given floodplain, based on aggregated data universally available for the UK and is acknowledged to be quite imprecise. It therefore makes generalisations and averaging assumptions that may not be appropriate when evaluating options for a set of properties that have flooded. For example, the method decreases the expected damages through an averaging procedure, based on analysis of previous floods, that recognizes that many of the properties in the 200 year floodplain will not suffer damage in a flood situation (and will therefore not make an insurance claim). The actual damage for a property that has flooded will be higher than the expected damage for an average property in the 200 year floodplain, as the fact that the property has flooded confirms the property is not raised out of the floodplain or protected from flood damage in some other way. As stated in the MCM (Penning-Rowsell *et al.*, 2005), where better estimates of risk are available they should be used. Insurers (including Flood Re) have additional sources of information to draw upon, including their own claims records, and may, therefore, have an adjusted estimate of the risk applying to an individual property and their particular property portfolios as a whole.

Some studies have assumed that the return period is precise, i.e. that a property with a 0.2 annual probability of flooding will flood on average once every five years and to a known depth. This approach is suitable for assessment at an individual property level but could also be scaled

Figure 13: Damage avoided from resilience packages by return period over 20/25 years (discounted). Shows an example of the difference in avoided damage estimates across the UK studies carried out to date.



up to a portfolio for which the risk profile is well defined. Potentially it could also be used to upscale using some of the assumptions embedded in the WAAD (eg the average depth of flooding for a flood of given return period). However, the Flood Re portfolio does not conform to many of the typical characteristics reflected within the WAAD assumptions, as it reflects a particularly concentrated portfolio of risky properties.

For example, Joseph (2014) used the following equation (see Figure 13.1) to calculate annual damage avoided. By contrast, Davis Langdon (2011) does not clearly specify the calculations used, however, they do state that: The general Economics of Climate Adaptation Working Group (ECAWG) (2009) methodology of calculating annual losses based on annual exceedance probability multiplied by corresponding losses can be directly applied to the analysis in this study.

This implies a similar calculation to Joseph (2014); the study also used property risk profiles (for a case study area) based on AEP bandings from 0.1 to 5% at two different depth levels, without using WAAD averaging methodology.

Performance of measures in limiting damage

While the above calculation gives the potential damage avoided by installing measures, predictions of the damage that will be avoided also need to take into account the performance of measures in limiting direct damage. Usually in desktop studies for resistance packages it is assumed that buildings and contents are protected, whereas for resilience packages the contents are not protected but some items of 'inventory' may be saved.

However, measures may not prevent all damage due to a range of issues including non-deployment; overtopping; flooding from other sources; or failure of measures. Rate of deployment may also be influenced by a number of factors: for example, personal flood experience or memory of flooding can lead to better knowledge and motivation to act in the event of a flood (Terpstra, 2011). Some evidence has been presented that suggests effective communication, suitably selected measures, community PFR schemes, emergency plans and preparedness drills can also have an impact (May *et al.* 2014). Estimation of performance is proffered by a variety of studies including the JBA (2012) evaluations of cost effectiveness of 'PLP' (see table 8), which used a fault tree analysis to generate reliability estimates for manual and automatic resistance measures (77% and 90% respectively) and some sensitivity analysis has been carried out. Experimental testing of measures (such as Kitemark testing) in simulated flood conditions is another source of evidence of likely performance. This is an area where evidence is limited to a smaller subset of measures that are commonly employed; it has the potential (if synthesized) to improve the understanding of reliability and suitability of measures for different flood types.

A consensus emerges that the concerns around impact of poor performance does not negate the potential to make savings by employing measures. The scale of the effect on savings of real performance is, however, currently under-researched.

Figure 13.1: Equation used by Joseph (2014) to calculate annual damage avoided.

The ECD avoided, which is the gross benefit (GB) of resistance measures, is expressed mathematically as:

$$GB_f = \sum p * \left(\frac{1}{1+\delta}\right)^y * d_y \text{ .... equation 15}$$

Where;
GB_f, denotes the avoided damage at flood return period f
p' denotes the annual flood probability for return period f
f' denotes the flood return period in year
y' varies from 1 to 20-years (the rationale behind the 20-years is that, it is anticipated that renovation would have been carried out within 20-years, for instance kitchen units
would have been replaced within this period)
d_y denotes the value of avoidable damages in the year y'

Table 8: Reliability assessment of PLP (from JBA 2012)

Factor	A - Automatic Measures	B - Manual Measures
Equipment not lost or misplaced	N/A	95%
Products in good working order - well maintained and correctly stored	90%	95%
Flood warning received	N/A	90%
Measures installed correctly	N/A	95%
Probability factor	**90%**	**77%**

The factors used and the overall reliability factors derived are shown in Table 8 above.

Although there are, as yet, no widespread published UK surveys that allow effectiveness of measures to be estimated from performance in real events, there is some relevant international work (for full list see Appendix 9). For example, in Europe there are studies on real damage avoided based on household surveys after flood events (eg. Kreibich *et al.* (2005); Kreibich *et al.* (2011); Poussin *et al.* (2014); and Hudson *et al.* (2014)). A study in Germany (Kreibich 2005) indicated that different precautionary measures reduced the damage ratio (defined as the ratio of damage to insured value) for buildings by between 46% (for flood adapted use) and 53% (flood adapted interior fittings). The mean damage reduction for buildings with fitted water barriers was lower than expected (60-80%) since they were overtopped by extreme flooding. The ratio of damage reduction was in reality only 29%. The damage ratio for buildings with waterproof sealed cellar walls and stable foundations indicated reduction of damage by 24% as there was little effect on contents damage. In monetary terms the mean damage reduction for contents was around EUR 9,000, and for buildings around EUR 30,000 (where these included either adapted use or adapted interior fitting). Although no quantitative evidence on indirect intangible benefits were mentioned, the flood experience motivated a significantly large of the at-risk population to undertake one or more preventive measures (42%) and it was recommended that such activities should be further stimulated with help of financial incentives and information campaigns. Another study in Germany, Hudson *et al.* (2014) reported that water barriers can be considered as a successful measure and provide a cost benefit ratio of 22.3, assuming a flood affects a building every year and there is a lifetime discount of 3%. However, a flood adapted choice of interior fitting is seen as more effective in reducing the vulnerability of buildings in cases of particularly deep flooding in which water barriers are overtopped. In monetary terms the reported savings range between EUR 14,385, EUR 11,302 or EUR 8,551 for flood adapted use, flood adapted interior fittings and water barriers respectively. More recently Kreibich *et al.* (2011) observed that German communities achieved contents savings of 95% on application of measures, and succeeded in keeping water out of 62% of property.

A study by Poussin *et al.* (2015) in France also estimated the potential of damage savings and cost-effectiveness of specific flood damage mitigation measures implemented by residents. In this study the variables explain a significant difference in means between the damage ratios for buildings and home contents for respondents who had, or had not, undertaken specific mitigation measures. The study provided empirical insights that implementation of combination of mitigation measures can improve effectiveness of damage reduction (can be up to 84% in damage ratio reduction). The range of damage reduction in absolute terms is between EUR 2,923 – 18,971. The average effect of damage was found to vary considerably between regions and type of damage, as well as closeness to source of flooding and characteristics of building. Nonetheless, the cost benefit analysis shows most (9 out of 11) of the mitigation measures are very cost effective or moderately cost effective, especially in high risk areas.

Evidence from the USA (Highfield and Brody, 2013) provides some empirical evidence of the degree to which mitigation activities such as retrofitting buildings or constructing small flood control projects significantly reduces flood losses. For example, effective benefits were seen from site level structural protection strategies for structures in vulnerable locations by mitigation activities such as elevating buildings, constructing barriers, channel modifications, dry and wet proofing. Savings of, on average $4,175 per community per year were reported. Buildings in higher risk zones realized the highest damage reduction.

Also from the USA, a report from the Multi Hazard Mitigation Council (2005) included a cost benefit analysis of different FEMA (Federal Emergency Management Agency) hazard mitigation grants and estimated the future savings from expenditures on mitigation activities carried out in community contexts. The best estimates of cost benefit ratio differentiated by grant activities and by community on avoided damage ranged between 0.66 - 12.5. The study also reported some of the benefits associated with intangible indirect effects in relation to displacement cost for a 100-year flood event. It was identified that the impact of grants not only reduced the building damage but also helped in reduction of power outage and reduced casualties. Overall the net benefits seen from such investments are empirically positive.

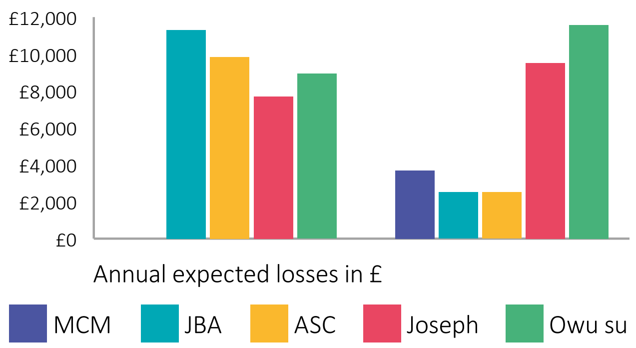
Further theoretical studies from the USA include FEMA (2015): this recognized that structural elevation can be the most effective measure for flood damage and insurance premium reduction. However, the report focused on those buildings that cannot be elevated and provided some more indicative evidence on cost of installation of mitigation measures and reduction in insurance premium with two case studies of these buildings could not. The potential premium reduction ranged between $537 for a one storey and $4,906 for a two-storey building located in a high flood risk zone. The cost of installation of measures for the one storey building was estimated to be between $6,300 and $9,500, with an estimated time to recover costs of 12-18 years. For the two-storey building the cost of around $72,000 to $108,000 included infilling of the basement and adding a second storey. The estimated time to recover mitigation cost was around 12-22 years.

An Australian study by Hawkesbury-Nepean Floodplain Management Steering Committee (2007) indicated the cost of installation for mitigation measures can increase the total cost of a standard two storey building by up to 5%. With a water depth of up to 1.2 metres over the ground floor level a house with relevant measures installed can save an estimated value of up to AU$20,000 on fixtures and structure, up to AU$30,000 on contents and approximately AU$50,000 on total damage. When this is compared to an average AU$17,000 investment for two-storey and around AU$6,000 for single storey buildings, making such buildings flood resistant appears to be cost effective for properties at significant risk.

The value of direct intangible benefits and of indirect benefits (including co-benefits) of installing measures

While direct damage prevention is usually the primary concern when installing measures, there are also many indirect and intangible benefits. For example, reduced alternative accommodation costs represent an indirect but tangible saving; a reduction in time to reinstate property, and the preservation of items of sentimental value constitute direct intangibles items; and a reduction in feelings of stress would be an indirect intangible benefit. A comprehensive breakdown of different benefits (damage and loss avoided) is contained in the MCM and Joseph (2014) among others. Meta-analysis of the UK studies is presented in Appendix 7. The list of damages considered is shown in Table 9 and the estimated values are in Figure 14, although not all of these would be covered by insurance. Insured indirect and intangible benefits (under a domestic buildings and contents policy) would form a small but significant part of this group of benefits, mainly relating to the costs of alternative accommodation and extra costs of travel, living costs related to displacement from normal living space.

Figure 14: Estimate of intangible and indirect damages in UK studies



The ability to claim indirect costs under this heading would depend on the direct underwriters' terms and conditions and might vary by company. Alternative accommodation, which forms the bulk of this cost, would normally be included under typical UK household buildings policies and could be quite substantial. Studies often include estimates of, or observations on, direct intangible and indirect benefits of damage prevention (82 studies) but these are generally not specifically aimed at estimating such benefits from the point of view of insurance. Specifically on intangible elements, key studies at a household level include the leading Defra study (Tunstall *et al.*, 2004) that was long used as the basis for economic appraisal of community schemes (willingness to pay to remove stress of flooding £253 per annum), whereas Owusu (2014) (£795 per annum) and Joseph (2014) (£653 per annum) are based on household level decision making. At a societal level alternative values have also been estimated by JBA *et al.* (2012) (£1,065 per annum per person). Joseph (2014) gives a strong analysis of temporary accommodation costs, both insured and uninsured, based on the 2007 dataset with average of over £7,000. This was based on 2,309 households' dataset, out of which 29 households were not relocated to alternative accommodation. The minimum cost of alternative accommodation in the dataset is £590.26, while the maximum is £29,625.19.

Table 9: indirects and intangibles quantified by UK studies

	Indirects		Intangibles
1	Telephone expenses**	1	Ill health
2	Extra expenses on food**	2	Mental stress of flooding
3	Unpaid leave	3	Fear of further flooding
4	Extra travelling expenses**	4	Avoidance of stress
5	Emergency Services cost	5	Loss of items of sentimental value (eg family photos, diaries etc)
6	Cost of absence from work	6	The general practitioner care cost*
7	Alternative accommodation (AA)**	7	Lost utility because of restricted activities
		8	Pain and suffering
		9	Anxiety about the future
		10	Concern and inconvenience to family members and others

*practitioner care costs would normally be considered indirect rather than intangible – therefore moved in Figure 14

**likely to be covered by insurance

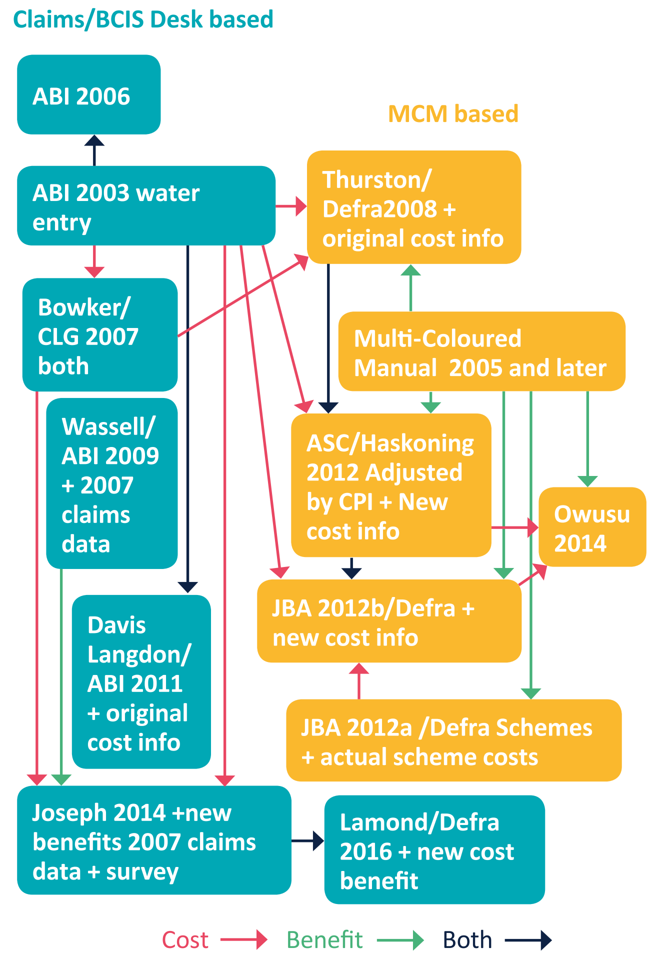
Both the indirect and the intangible costs are related to time spent displaced after a flood, since studies show that stress and mental health issues are related to length of evacuation (Lamond, 2014): the question of reduced time to reoccupation due to mitigation measures is, therefore, highly important. Studies generally assume that successfully deployed resistant measures will result in zero displacement, therefore reducing indirect and intangible costs to zero. For resilient measures, there are no studies that quantify the increased speed of reoccupation. Anecdotally, the most successful full scale resilience adoption allows reoccupation of the affected property within 24 hours, thus obviating the need to relocate (occupants can often stay upstairs while any repairs are carried out to address specific residual problems).

Co-benefits (such as benefits from crime reduction and reduced losses from escape of water claims, thermal efficiency due to air tightness) and potential conflicts (eg risks of increased dampness) have been theorised but scarcely evidenced or valued. For example, data from the ABI between 2003 and 2016 indicates that escape of water claims constitute almost four times the annual average cost of flood claims over the same period. It would appear unlikely that resistance measures would lead to any reduction in escape of water claims but the effect of flood resilience measures could result in a significant and previously un-costed co-benefit. Unpicking the distribution of benefits from the available evidence would enable a better understanding of the case for minimizing intangible and indirect costs and maximising co-benefits for the insurance industry and others.

How effective are property level resistance and resilience measures in reducing loss due to damage and time to repair damage resulting from flooding for UK households and their insurers?

There have been several UK studies that combine PFR cost evidence as outlined above, with the expected risk reduction benefits allowing for future flooding potential. Cost benefit analyses have been produced for property level measures over a variety of time windows (such as the lifetime of measures) but this is often limited to discounted benefits over 20 years. The combined data flows are shown in Figure 15.

Figure 15: Combined data flow s for UK cost benefit studies



These studies have generally concluded that measures are cost beneficial for a subset of properties at risk, but conclusions differ on the benefit thresholds in terms of return period and package of measures installed. Table 10 summarises the range of conclusions around the degree of flood risk that justifies a given set of mitigation measures and allows for overtopping of water exclusion barriers and damage expected in the water entry cases. For the first three studies using the WAAD method, this is based on averaging across different flood depths anticipated at given likelihood levels. For Joseph (2014) the estimation is given for different depths of flooding.

For example, a study for Defra (JBA Consulting *et al.*, 2012) found "compelling evidence for the cost effectiveness of manually deployed flood resistance measures, with high benefit cost ratios and high Partnership Funding Outcome Scores for typical flood thresholds of up to 2.5% annual exceedance probability (AEP) (1 in 40 year)". Passive resistance and resilience measures have generally been found to be less cost beneficial than manually deployed resistance. However the low cost resilience packages defined by Lamond *et al.* (2016b) potentially represent a change in thinking around cost of resilience. Studies differ in terms of assumptions of performance and the range of benefits included in the evaluation. In part this is due to different stakeholder perspectives, and their respective perception of perceived benefits. Evolution of estimates and the choice between economic and financial appraisals, choice of time window and discounting factor will also make a large difference. Thus Joseph (2014) concluded that, from a household perspective, benefits outweigh costs as much for properties with lower levels of risk (i.e. higher return period).

Table 10: Summary of cut off return periods for cost beneficial installation of measures

Flood Likelihood		Annual Probability	50%	20%	10%	7%	5%	4%	3%	3%	2%	1%	1%
		Retun Period (Years)	2	5	10	15	20	25	30	40	50	100	200
Manual resistance	Bung	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Det	JBA*	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Det	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic
	Det	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Flat	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic
	Semi	Thurston	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Semi	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic
	Semi	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Terr	JBA*	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Terr	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic
	Terr	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
Automatic resistance	Bung	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Det	JBA*	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Flat	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	Thurston	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Terr	JBA*	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Terr	ASC**	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Terr	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
Recoverable without floor	Bung	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	JBA*	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic
	Flat	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	Thurston	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic
	Semi	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Threshold	Uneconomic	Uneconomic
	Terr	JBA*	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Terr	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Terr	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Threshold	Uneconomic	Uneconomic
Recoverable with floor	Bung	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Threshold	Uneconomic	Uneconomic
	Det	JBA*	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Det	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Threshold	Uneconomic	Uneconomic
	Flat	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	Thurston	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Semi	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Threshold	Uneconomic	Uneconomic
	Terr	JBA*	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Terr	ASC**	Beneficial	Beneficial	Threshold	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic	Uneconomic
	Terr	Joseph***	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Threshold	Threshold	Uneconomic	Uneconomic

*Retrospective retrofit
**Economic model
***With intangibles

Key
Beneficial
Threshold
Uneconomic

Figure 16 and 17 presents the expected cost benefits ratio at different return periods. Despite differences in the cost benefit ratios all the studies concur in the finding that cost benefit declines rapidly with return period. Properties that flood frequently show high benefit ratios for all packages and only the cheapest packages continue to be cost beneficial at high return frequencies over 50 years.

Figure 16: Benefit cost ratio curves (flood resilience packages) by return period

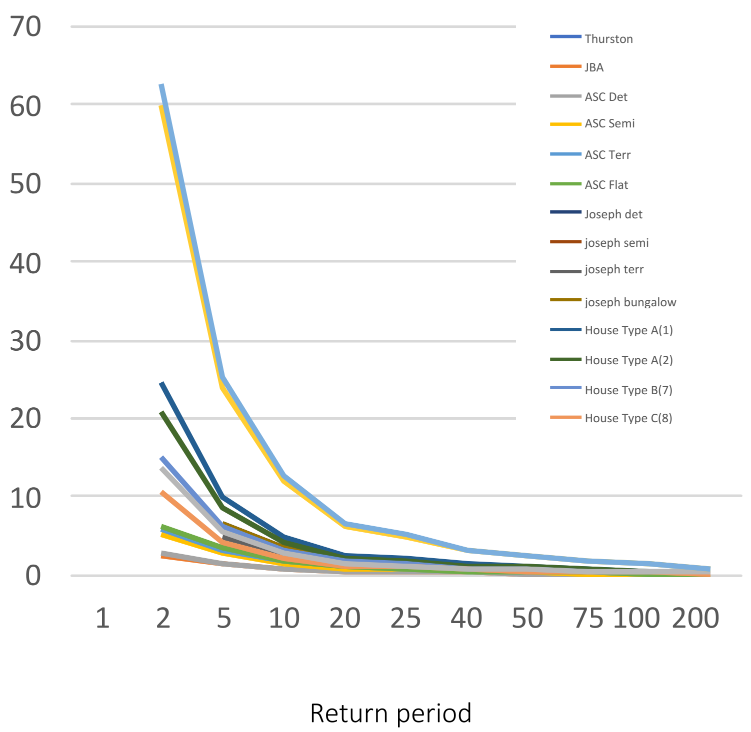
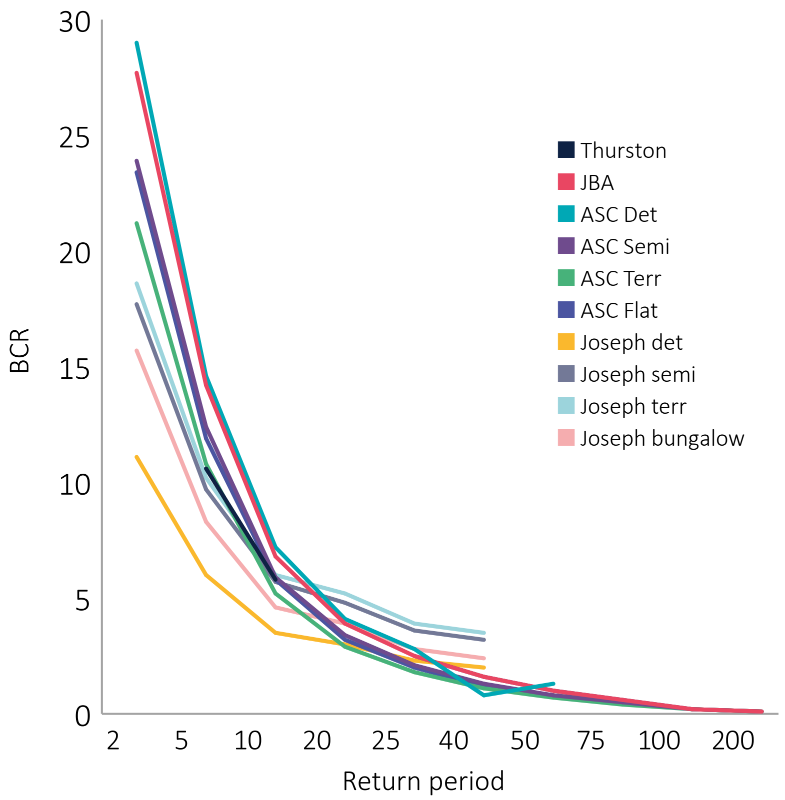


Figure 17: Benefit cost ratio curves (manual flood resistance) by return period



INTERIM CONCLUSIONS AND FURTHER QUESTIONS

Interim conclusions

There is a substantial body of literature that presents evidence of one sort or another related to the primary question. The overwhelming weight of this existing evidence is that property level measures have the potential to reduce damage and losses from flooding and that the time to recover can also be reduced. Installation of measures also has the potential to reduce the indirect costs of alternative accommodation and associated expenses. Studies also generally agree that the benefits of installing appropriate measures can outweigh the costs (based on various assumptions) for a subset of properties at risk of regular flooding.

Key findings are summarised in the sections below.

Water exclusion versus water entry option

Keeping water out of property using manually operated measures is generally cost beneficial for properties with a return period of up to 40-50 years (2% annual likelihood of flooding).

Using automatic measures to exclude water is seen as more reliable in operational terms but less cost beneficial, as the costs of automatic measures have been estimated as higher.

Limiting damage to different elements and packages of elements on the inside of property once water is allowed to enter the building can be cost beneficial at lower levels of risk, at up to 200 years return period (0.005% annual likelihood of flooding).

Fully resilient packages that minimise internal damage to near zero are generally estimated to be more expensive and less cost beneficial than water exclusion packages.

Previous UK studies have generally used a limited, high cost, subset of packages for resilience and neglected some of the latest developments in water exclusion measures.

Cost estimation

Average cost of water exclusion packages explored ranges from £2.5k - 16.5k. Average cost of resilience packages can be from negligible to £35k at reinstatement. Cost varies with size and type of property, as well as the level and type of flooding. Cost of resilience is lowest during reinstatement or other works to a property; it also varies with the standard and type of existing internal finishes. Water entry measures are less dependent on time of installation.

Many studies slightly underestimate the cost of the commonly defined packages of resilience measures at reinstatement. This could be related to consideration of suitable inflation indices and inflation in costs during high demand due to recovery period.

Data on cost of manual resistance packages is more constantly updated but may be artificially pegged to a pre-defined suite of measures. Estimated costs of products has declined over time and new products are still being introduced.

If water exclusion products deteriorate then a scheme may fail, therefore appropriate maintenance is important. Ongoing inspection/ replacement/ maintenance costs require better consideration.

Studies have used a limited range of measures and have not fully considered the implications of using either cheaper or more expensive options.

Items warranting greater focus include: flood doors as opposed to automatic barriers; flood resilient doors and windows; replacement kitchens; plaster treatments; tanking/membranes; and waterproofing of walls.

Benefits Estimation

Comparison of actual claims cost with estimated losses shows that many studies substantially underestimate the cost of repair/damage to be avoided. This is particularly severe at low depths of flooding. Household indirect expenditure including alternative accommodation costs also requires more consideration.

Use of methods that average over properties at different risk levels and low estimates for repair of property results in estimates of benefits to insurers that can be too low and make measures appear less cost effective than they could be.

Recent estimates of intangible benefits are higher than the Defra standards; co-benefits such as improved security and reduced escape of water claims have not been explored. Potential conflicts with other building performance aspects have also been largely ignored.

Selective investment in 'building back better' in appropriate cases, therefore, has the potential to reduce average reinstatement costs for insurers and, therefore, limit the long term future need for Flood Re. Additional uninsured benefits would be felt by owners, occupiers and society as a whole. These uninsured benefits are, however, currently under-researched.

Limitations and areas for further research

After evaluation of the evidence, it appears that the majority of UK studies have used widely accepted methods that are more appropriate for evaluating economic benefits to society rather than financial benefits for insurers. This has led to a number of shortcomings when trying to relate to costs and benefits for the insurance community. In particular, the averaging across national portfolios of property with poorly defined and smoothed risk profiles is not appropriate for judging the decision for individual or small groups of property with a known flood risk.

Assumptions on performance of measures are currently based on a small number of published empirical studies and limited expert opinion. However, with the increase in installed measures, and the occurrence of several flood events since the last major evaluation in 2014, together with further analysis of already existing datasets and ongoing initiatives in the industry, it may now be possible to arrive at improved estimates of likely performance.

Further work on the costing issues around resilience (water entry) is warranted, focussing upon a suitable subset of common alternatives. The 'stand-alone' products designed to exclude water are typically easier to cost, but no studies have yet evaluated the suitability and justification for using less or more costly products from the range available.

Finally, unpicking the distribution of benefits from the available evidence would enable a better understanding of the case for minimizing intangibles and indirect cost for the insurance industry. Most current studies have not adequately explored the complexity of insurance terms and conditions and the indirect costs faced by insurers. Co-benefits such as the impact on escape of water claims have also been largely ignored and could be material.

NEXT STEPS - PHASE 3 RECOMMENDATIONS

A larger cohort of properties with measures installed is now available to study in the UK as several major flood incidents have occurred since the most recent studies were conducted. Some of these have occurred in areas of the UK where PFR schemes have been taken up in numbers that are more significant. Further data gathering and analysis should be undertaken to enhance the current evidence base.

Detailed insurance claims data records from more recent flooding incidents should be gathered and used to enhance the evidence base. Key areas to investigate in more detail include:

- The real cost of resilient reinstatement from schedules and actual costs incurred;
- Potential losses avoided with improved estimation for different flood types, depths and building characteristics;
- Actual performance of measures from claims made by properties previously made resilient; and
- Indirect costs borne by insurers and the link to recovery time.

Collation of data from relevant agencies such as local authorities and water companies regarding implemented schemes could enhance the evidence base regarding:

- The real cost of PFR measures including barriers and resilient measures;
- Performance of implemented schemes;
- Locations of properties with measures.

These agencies should be consulted to explore the potential to gather improved evidence.

Improved benefit/cost analysis is recommended which relies less on the 'averaging' approaches within the current literature. This could involve the use of stochastic modelling approaches to enhance the existing approaches, or instead could leverage more advanced modelling approaches such as those used within the insurance industry. Both approaches would allow for more valuable conclusions to be drawn from the new evidence gathered and the benefits to the portfolio of properties ceded to Flood Re. These approaches would also provide a basis for understanding the potential for benefits of PFR to build up under a range of deployment/adoption strategies.

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APPENDIX 1: Meta-analysis of range and type of measures available

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Treatment for walls**	**Depth indicator**	**Cost indicator**	**Treatment for walls**
1000mm possible; 600mm typical	L/M	Use closed cell (waterproof) insulation	Any	low	Closed-cell type insulation (to replace mineral insulation in cavity walls) (aka Sprayed polyurethane foam or SPF)
			Any	low	Cavity wall – use insulation materials that are water resistant/low absorption (expanded polystyrene sheets, EPS water-resistant beads, or semi-rigid self-draining mineral wool slabs/batts that will not collapse on wetting) with stainless steel fixings
			Any	low	Replace corroded timber frames with treated timber
			Any	low	Replace corroded steel frames with galvanised steel equivalents
			Any	low	Seal between wall, floor and partitions (continue concrete seal 0.5m up walls)
Variable	VH	Tanking (internal) including cavity drain membrane systems			
			Any depth possible; 600mm typical	M	Use cement based moisture-resistant plasterboard (eg Aquapanel) or waterproof board (eg Marmox Multiboard)
1000mm possible; 300mm typical	M	Wall sealant			
			Any depth possible; 600mm typical	M	Use cement based moisture-resistant plasterboard (eg Aquapanel) or waterproof board (eg Marmox Multiboard)
1000mm possible; 300mm typical	M	Wall sealant			

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Treatment for walls**	**Depth indicator**	**Cost indicator**	**Treatment for walls**
1000mm possible; 300mm typical	M/H	Render / external tanking			
1000mm possible; 300mm typical	L/M	Water resisting airbricks/ permanent airbrick covers			
					Use cellulose-fibre reinforced gypsum for areas with short duration floods (eg Fibrerock)
			High	low	Fix plasterboards horizontally on timber framed walls rather than vertically (aka Sacrificial plaster board/dry-lining)
			Any	low	Removable timber cladding material
			Any	low	Cement Render/cement sand render/water-resistant cement-based plaster coated on to internal walls then skimmed
					Lime based plaster/ hydraulic lime coating with porous paint on top of plaster, to allow water vapour to pass out as drying proceeds
			Any	low	Avoid (non-breathable) vinyl wall-coverings, use microporous paint temp finish, then breathable paper (affixed with breathable adhesives)
			High	Low (if replacing expensive carpeting)	Ceramic/porcelain tiles (with water-resistant grout and adhesives, as used in swimming pools).
			Any	low	Avoid (non-breathable) vinyl wall-coverings, use microporous paint temp finish, then breathable paper (affixed with breathable adhesives)
			High	Low (if replacing expensive carpeting)	Ceramic/porcelain tiles (with water-resistant grout and adhesives, as used in swimming pools).

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Treatment for walls**	**Depth indicator**	**Cost indicator**	**Treatment for walls**
Med	Low (pump only) Medi-um-high (system)	Built-in sump and pump systems	Med	low	Sump and pump system (with alarm in case pump fails)
VH	Tanking (internal) including cavity drain mem-brane systems	Variable	VH	Tanking (internal) including cavity drain membrane systems	Variable
			Any	low	Avoid fitted carpets, parquet and laminate flooring: use ceramic tiles, loose fitting rugs; removable carpets (e.g. fixed with Velcro or hooks-&-eyes set into floors)
			1000mm possible; 600mm typical	M/H	Vinyl/thermoplastic tiles replaced by ceramic tiles (vinyl sheet flooring can be retained)
			Any	low	Quarry tiles, coated to prevent staining / water absorption
			Any	low	Cement-rich floor screed
			Any	low	3mm epoxy resin waterproof floor treatment added to concrete floor screed
			Any	low	Susp floors - preservative-treated joists/ floorboards
			Any	low	Susp floors (brick and block?) - need to create low point/well in soil or sub-floor (ie SUMP) to collect water then pump out
			Any	low	Ensure effective connection between the damp-proof membrane for the floor and the damp proof course in the wall

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Treatment for walls**	**Depth indicator**	**Cost indicator**	**Treatment for walls**
			Any	low	If oak blocks finishes on concrete need replacing, use tiles. If oak blocks set in bitumen need replacing, then use screed and new finish on top.
			Any	low	For suspended floors, if oak floorboards need replacement, then use (cheaper) treated timber.
			Any	low	Remove ash-bedding from underneath quarry tiles in Victorian houses (retains moisture and impedes drying out)
			Any	low	Clear and repair air bricks/vents to suspended timber ground floors (aids drying out process via airflow imps)
					Treated floorboards, WBP plywood, screed or tiles to replace chipboard
			Any	low	Closed cell insulation in boards for floors
			Any	Bespoke	Design floor levels and exit routes to shed water once flood has receded to minimise standing water

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Water compatible kitchen fittings**	**Depth indicator**	**Cost indicator**	**Water compatible kitchen fittings**
			Med	low	Sump and pump system (with alarm in case pump fails)
			Low	low	Fit kitchen units with extendable plastic or stainless steel feet or support on raised brick/ stonework (for floods <50mm deep only)
					Replace ovens with raised, built under type
					Oven/microwave mounted part way up wall (shoulder height/eye-level)
			Any	low	Specify the least expensive kitchen possible and to expect to replace it (aka Sacrificial approach)
			Any	low	Free standing removable units (eg pitch pine), then carry upstairs when flood warning rec'd.
					Use Belfast sink on brick base, not a 'sink unit'
			Any	low	Limit number of base units and have removable doors so only bottom carcases need replacing
			Med	low	Avoid built in appliances and have strong work surfaces that can support appliances during a flood
			Low	low	Removable kick boards – wrapped around units avoiding end sections that extend to the floor
			Med	low	Better to have a table and/or high-level 'breakfast bar' than a (fixed) island.
			Any	low	Avoid kick heaters and use radiators instead.

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Water compatible bathroom fittings (ground floor/ basements)**	**Depth indicator**	**Cost indicator**	**Water compatible bathroom fittings (ground floor/basements)**
			Any	low	Waterproof tile adhesive and water-resistant grout for tiled walls
			Any	low	Some acrylic baths have integral encapsulated (ie waterproofed) base-boards (cost same as normal acrylic baths).
				M/H	Have a wet room rather than shower tray.
			Any	low	Use of an anti-siphon toilet
			High	low	No vanity unit around wash-hand basin use wall mounted cupboards/shelves
			Any	M/H	Gravity drained toilets (grnd floor) replaced with pumped system

Resistant			Resilient (recoverable)		
Depth indicator	Cost indicator	Building Services	Depth indicator	Cost indicator	Building Services
	Bespoke	Through-wall service connections raised >900mm above the ground floor level	High	low	Through-wall service connections raised >900mm above the ground floor level
			Med	low	Raised electrics sockets, this has a dual purpose, as more accessible for older/less mobile people when raised.
			High	low	Electric cables drop from first-floor level down to sockets at high level on walls;
			Any	low	Central heating pumps and controls raised above max expected flood level; and any pipe insulation below expected flood level replaced by closed-cell type
			Any	low	Central heating control unit moved upstairs, so radiators serving upper floor(s) can still be used (ground floor underfloor heating only will be affected by flood water).
			Any	low	Wall-hung fires >1m above flood level (dep on exp'd flood depth)
			Any	low	Raise meters 1m above expected flood level, and use plastic housing.
			Any	low	Boiler mounted above max expected flood level
			Any	Low	Seal radiators with polyethylene sheeting
			Any		Use enamelled radiators, which wipe clean after flood.
			Any	Bespoke	Use demountable radiators.
			Med		Use an enamelled finish woodburning stove (cast iron rusts after a couple of floods)
			Low	M	Raise woodburner up on robust metal support.

Resistant			Resilient (recoverable)		
Depth indicator	Cost indicator	Building Services	Depth indicator	Cost indicator	Building Services
	L	Sealing cracks / weep-holes / service inlets and service entry and exit points; duct sealing products			
			Any	low	Where possible, incoming telephone lines/cable services/ and internal control boxes should be raised above the expected flood levels.
			Any	low	A house can be wired so that the ground floor ring main can be switched off, leaving supply to the upper floors still available; likewise, smaller vulnerable circuits can be isolated.
			Any	low	Place services including electrics in easy to access conduits to allow draining and drying
	L	Non-return valves (NRVs) for appliance waste-pipes	Any	low	Anti-backflow valves (NRVs) to sewer pipework AND dishwasher/washing machine pipes.
			Any	low	Water supply pipework insulation can be replaced with flood resistant closed cell material below the expected flooding level.
	Bespoke	Outside fuel tanks raised on concrete plinth (standard plastic bunds float, pipes then fracture)		Bespoke	Outside fuel tanks raised on concrete plinth (standard plastic bunds float, pipes then fracture)

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Doors/windows/ staircases**	**Depth indicator**	**Cost indicator**	**Doors/windows/ staircases**
1000mm possible; 300mm typical			1000mm possible; 300mm typical		
1000mm possible; 300mm typical		windows / garages	1000mm possible; 300mm typical		Covers / barriers for appliance vents / airbricks / pet-flaps
1000mm possible; 300mm typical		Covers / barriers	1000mm possible; 300mm typical		Free standing barriers for larger areas (eg driveways)
1000mm possible; 300mm typical	M/H	for appliance vents /			
		airbricks / pet-flaps	Med	Bespoke	Water compatible steps/stairs (partly or fully eg Resilient staircase of solid timber/ steel/ concrete
		Free standing barriers	Med	Low	Separate piece of carpeting for bottom-most stairs, removable when flood warning received - then nail back down (but looks like normal fitted stair carpet).
		for larger areas	Any	Bespoke	If normal staircase has to be replaced, use open-tread type made of oak. (Half the wood, so cost-neutral at rebuild stage).
		(eg driveways)	Any	low	Replace internal doors with solid hardwood doors (caution - avoid cheap 'oak-style' doors)
		Water-resisting external	Any	low	Consider installing cheapest possible doors to be sacrificial.
		doors / windows	Any	low	Removable /light weight internal doors/Replace door hinges with rising butt hinges. These allow doors to be lifted off.
			Any	Med	Internal hollow cellular-fill type doors - replaced with solid timber types (and paint these before hanging, with water-resistant paint, to ensure sides and bottom fully covered)
			Any	low	Retain traditional solid wood doors, on rising butt hinges, and use on trestles to support furniture etc

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Doors/windows/ staircases**	**Depth indicator**	**Cost indicator**	**Doors/windows/ staircases**
			Any	low	For wooden windows and external doors - use oil-based or waterproof stains, paint or varnish timber
			Any	low	Replace doors, windows, skirting boards, architraves, doorframes and window frames with fibreglass (GRP), PVC-U or similar
High	M-H				
			Any	low	Replace skirting boards with ceramic tiles
			Any	low	Treat wood skirting, primed on ALL sides
			Any	low	Oak skirting held with screws, removable.
			Any	low	Use of toughened glass in doors/windows / cabinets (reduce damage from floating debris)
			Any	low	Use non-corrosive door/window hardware fittings (eg stainless)
		Hopper style windows with fixed lower panels below the likely flood depth. (caution ensuring adequate low level escape routes)	Low	low	Wall cupboards/built-in-wardrobes - rebuild off floor with plastic legs, concealed by removable plinth
			Any	Low	Use PVC wall cupboards instead of timber
			Any	low	Bookcases formed of fixed brackets but with easily removed shelving.
			Any	low	Oak exterior doors oiled repeatedly with linseed oil

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Misc – permanent/ automatic**	**Depth indicator**	**Cost indicator**	**Misc – permanent/automatic**
All	L/M	Anti-backflow valves for sewer pipes (backwater valves)	All	L/M	Anti backflow devices on foul drainage
1000mm possible; 300mm typical	L/M or bespoke	Flood alarms	1000mm possible; 300mm typical	L/M or bespoke	Flood alarms
1000mm possible; 300mm typical	L	Sealing around external doors / windows	1000mm possible; 300mm typical	L	Sealing around external
1000mm possible; 300mm typical	L/M	Re-pointing	Any	Low/med	doors / windows
1000mm possible; 300mm typical	Bespoke only	Bolt-down manhole covers	1000mm possible; 300mm typical	Bespoke only	Re-pointing Ext walls - Re-point brickwork with a mix of 1:2:9 – cement: lime: sand mortar (far more likely to survive flood conditions without need for repair)
1000mm possible; 300mm typical	VH/H	Auto-barriers	Low	low	Bolt-down manhole
1000mm possible; 300mm typical	Medium-high to Very high (depending on length required / groundworks involved)	Permanent barrier walls with demountable gates / concealed gates / permanent swing gates			covers
Low level only	Medium-high to High	Raised porch / threshold			Plinths (or equivalent methods) for white goods.
1000mm possible; 300mm typical	M	Brick-facing using engineering bricks			

Resistant			Resilient (recoverable)		
Depth indicator	**Cost indicator**	**Misc – temporary/ manual/ contents protection**	**Depth indicator**	**Cost indicator**	**Misc – temporary/manual/ contents protection**
Low level only	L/M	Modern versions of sandbags	Low level only	L/M	Modern versions of sandbags
1000mm possible; 300mm typical	L	Toilet seals / bungs	1000mm possible; 300mm typical	L	Toilet seals / bungs (to prevent sewage ingress)
1000mm possible; 300mm typical	L	Pipe bungs/seals	1000mm possible; 300mm typical	L	Pipe bungs/seals to prevent sewage ingress)
Low level only	L/M	Free-standing pumps	Low level only	L/M	Free-standing pumps
Low level only	L	Water-tight covers for furniture / appliances	Low level only	L	Water-tight covers for furniture / appliances
Low level only	L	Steel telescopic/ adjustable trestles	Low level only	L	Steel telescopic/adjustable trestles
Low level only	L	Plastic trestles	Low level only	L	Plastic trestles
All	L (home-made)/L (ready-made)	Emergency Flood Kits / 'Grab Bags' (ready-made)	All	L (home-made)/L (ready-made)	Emergency Flood Kits / 'Grab Bags' (ready-made)
All	L	Sack trucks	All	L	Sack trucks
All	No cost	Relocate valuables	All	No cost	Relocate valuables

APPENDIX 2: Meta-analysis of minimum packages indicated.

(13 publications)

1. Assessment of Literature sources noted as including information on packages of measures. Items in red deemed unsuitable for inclusion in meta-analysis.

1	Committee on Climate Change 2012. Assessing the economic case for property level measures in England - final report (9x1055). Peterborough: Royal Haskoning. Packages selected based on thorough review of previous UK studies.
2	Davis Langdon 2011. Research to identify potential low-regrets adaptation options to climate change in the residential buildings sector. London: Adaptation subcommittee, Commission for Climate Change. Packages selected based on thorough review of previous UK studies.
3	ICA DataGlobe. 2013. Building resilience rating tool [Online]. ICA DataGlobe. Available: http://www.icadataglobe.com/resilience-rating/ [Accessed 13th December 2016. THIS IS AN ONLINE TOOL INTENDED FOR INDIVIDUAL USE, NOT A REPORT
4	JBA Consulting, May, P. & Chatterton, J. 2012. Establishing the Cost Effectiveness of Property Flood Protection: FD2657 - Final report. London: Defra. Packages selected based on thorough review of previous UK studies and experience with Defra Pilot studies.
5	May, P. 2012. Evaluation of the Defra Property-level Flood Protection Scheme: 25918 - Summary Report. Environment Agency. THIS IS AN EVALUATION OF THE PROJECT ALREADY INC ON LINE 4, HENCE N/A)
6	Joseph, R.D. 2014. Development of a comprehensive systematic quantification of the costs and benefits (CB) of property level flood risk adaptation measures in England. PhD, University of the West of England. Packages selected based on thorough review of previous UK studies.
7	Keating, K., May, P., Pettit, A. & Pickering, R. 2015. Cost estimation for household flood resistance and resilience measures. Bristol: Environment Agency. Packages selected based on thorough review of previous UK studies.
8	Lamond, J., Rose, C., Joseph , R. & Proverbs, D. 2016. Supporting the uptake of low cost resilience: Summary of technical findings (FD2682). London: Defra. Packages selected through review of current studies and expert consultation with project board
9	May P., Emonson P., Jones B., Davies A. 2014. Post-installation effectiveness of property level flood protection Defra. (THIS IS A FURTHER EVALUATION OF THE REPORT INC AT LINE 4, HENCE NO NEW INFO)
10	Owusu, S. 2014. Public attitudes towards flooding and property level flood protection (PLFP) uptake. PhD, Heriot-Watt University. Packages selected based on thorough review of previous UK studies.
11	The Concrete Centre 2010. Basements for housing. Benefits and solutions for sustainable housing. The Concrete Centre. THIS IS NOT ABOUT FLOOD RESIST/RESIL PACKAGES, BUT CREATING NEW BASEMENTS HENCE N/A
12	Thurston, N., Finlinson, B., Breakspear, R., Williams, N., Shaw, J. & Chatterton, J. 2008. Developing the Evidence Base for Flood Resistance and Resilience - R&D Technical Report FD2607/TR. London: Defra.Packages selected based on thorough review of previous UK studies.
13	Tricker, R. & Algar, R. 2008. Scottish building standards in brief. Mechanical & Electrical Supplement. THIS IS NOT ABOUT FLOOD RESIST/RESIL PACKAGES, BUT BLDG STDS RE NEW/ALTERED BLDGS HENCE N/A

2. Summary of packages by publication

	Resistant package	Resilient package
1	**Manual:** Demountable Door Guards Manual Airbrick and Vent Covers Sewerage bungs/toilet pan seals Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump **Automatic:** Automatic door guards Smart airbricks and vents Non-return valves on main sewer pipe Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump	**Resilience without flooring:** Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water-resistant alternatives. Mount boilers on wall Move washing machine to first floor Replace ovens with raised, built-under type Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/bathroom units with plastic units **Resilience with flooring** Replace timber floor with solid concrete AND Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water-resistant alternatives. Mount boilers on wall Move washing machine to first floor Replace ovens with raised, built-under type Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/bathroom units with plastic units

	Resistant package	Resilient package
2	**Manual:** Demountable Door Guards Manual Airbrick Covers Sewerage bungs/toilet pan seals Repointing external walls up to 1.0m above ground level with water resistant mortar 'Fit and forget': **Automatic door guards** Smart airbricks Non-return valves on main sewer pipe Repointing external walls up to 1.0m above ground level with water resistant mortar	**Resilience:** Install dense screed Replace chipboard flooring with treated timber floorboards Install a new floor with treated timber joists Install a solid concrete floor Raise the floor above likely flood level Use closed cell cavity insulation to prevent water wicking in walls. Use water resistant plaster Install a chemical damp-proof course Install water resistant doors and windows Install a wall-mounted boiler Move washing machine to first floor Specify a raised, built-under oven Move electrics above flood level Move service meters above flood level Specify plastic kitchen / bathroom units
3	See note	

	Resistant package	Resilient package
4	**Automatic:** Automatic door guards. Self-closing airbricks. Non-return valves on utility and sewer pipes. Re-pointing external walls up to 0.6m above ground level with water resistant mortar. Silicone sealant around service and cable entry points. Sump pump. Waterproof external walls. **Manual:** Demountable door barriers. Manual airbrick and vent covers. Sewerage bungs and toilet pan seals. Re-pointing external walls up to 0.6m above ground level with water resistant mortar. Silicone sealant around service and cable entry points. Sump pump. Waterproof external walls.	**Resilience with resilient flooring:** Resilient plaster up to 1m, resilient doors, windows and frames, resilient kitchen, raised electrics and appliances, and concrete/sealed floors. **Resilience without resilient flooring:** Resilient plaster up to 1m, resilient doors, windows and frames, resilient kitchen, raised electrics and appliances.
5	See note	

	Resistant package	Resilient package
6	**Manual:** Demountable Door Guards Manual Airbrick and Vent Covers Sewerage bungs/toilet pan seals Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump **Automatic:** Automatic door guards Smart airbricks and vents Non-return valves on main sewer pipe Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump	**Resilience without flooring:** Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water resistant alternatives Hanging internal doors with rising butt hinges Mount boilers on wall Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/bathroom units with plastic units of water resistant panels Replace MDF panel with water resistant panels Decoration to allow re-wiring **Resilience with flooring:** Replace timber floor with solid concrete AND Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water resistant alternatives Hanging internal doors with rising butt hinges Mount boilers on wall Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/bathroom units with plastic units of water resistant panels Replace MDF panel with water resistant panels Decoration to allow re-wiring

	Resistant package	Resilient package
7	**Standard resistance:** Two demountable door guards and two airbrick covers Premium resistance: Two flood-proof doors, two airbrick covers and external wall render/bricks (20 m)	**Standard resilience:** Resilient plaster, removable doors, internal wall rendering, resilient kitchen, raised electrics and appliances Premium resilience: Concrete/sealed floors, resilient plaster, removable doors, internal wall rendering, resilient kitchen, raised electrics and appliances

	Resistant package	Resilient package
8		**A1 Semi- det** Salt resistance added to lime plaster Retain timber floor and door Removable carpets and vinyl flooring Rising butt hinges for internal doors Removable kitchen cabinet doors Acrylic bath panel and wall mounted vanity unit Raised sockets + Non return valve **A2 Mid-terr** Sand and cement render Closed cell insulation Retain concrete floor and timber door Quarry tiles and ceramic tiles to floor Rising butt hinges for internal doors Removable kitchen cabinet doors Raised sockets Non return valve **B7 Semi-det** Water resistant wall boards Closed cell insulation Retain timber floor Replace door with UPVC Ceramic tiles to floor Rising butt hinges for internal doors Removable kitchen cabinet doors Raised sockets Non return valve **C8 mid-terr** Cavity membrane and sacrificial gypsum (horizontal) Closed cell insulation Retain concrete floor Replace external doors with UPVC Removable carpets and ceramic tiles to floor Rising butt hinges for internal doors Removable kitchen cabinet doors Raised sockets + Non return valve

	Resistant package	Resilient package
9	See note	
10	**Manual resistance** Demountable door guards Airbrick cover Sewerage bung Toilet pan seal Sump pump Silicone gel around opening **Automatic resistance:** Waterproof external walls Automatic door guards Self-closing airbrick Non-return valves 110mm soil waste pipe NRV 40mm utility waste pipe NRV 12mm overflow pipe	**Resilience without flooring:** Replace gypsum plaster with water resistant material Replace doors, windows, with water-resistant alternatives Mount boilers on wall Move washing machine to first floor Replace ovens with raised, built- under type Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard Kitchen/bathroom units with plastic units **Resilience with flooring:** Replace timber floor with solid concrete Replace gypsum plaster with water resistant material Replace doors, windows, with water-resistant alternatives Mount boilers on wall Move washing machine to first floor Replace ovens with raised, built- under type Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard Kitchen/bathroom units with plastic units

	Resistant package	Resilient package
11	See note	
12	**Temporary resistance:** Manually installed door guards and air brick covers, sump/pump and remedial works to seal water entry points.	**Resilience without resilient flooring:** Resilient plaster (up-to 1m), lightweight internal doors, resilient windows and frames, resilient kitchen, raised electrics and appliances.
	Permanent resistance: Permanent floodproof external doors, automatic air bricks and external wall render / facing, sump/ pump and remedial works to seal water entry points.	**Resilience with resilient flooring** Concrete/sealed floors, resilient plaster (up-to 1m), lightweight internal doors, resilient windows and frames, resilient kitchen, raised electrics and appliances.
13	See note	

APPENDIX 3: Summary of property typologies

Categories	Common types							
Type	**Detached**	**Semi detached**	**Terraced**	**Flat**	**Bungalow**			
Attached Walls	0	1	2	3 or more				
Age	Pre 1919	1919-1939 OR 1944	1939 OR 1945-1964	1965-1974	1975-1985	Utility	Post 1985	
Wall Type	Solid masonry	Empty Cavity	Timber frame	Concrete frame	Steel frame	Insulted cavity	External insulation	System built
Floor Type	Suspended Timber	Solid concrete	Suspended concrete	Concrete Part L				
Occupied Basement	Yes	No						
Size	Small <70m2	Medium 70-110	Large >110					
No of storeys	1	2	3+					
Listed	Grade 1	Grade 2	Historic property	No				

APPENDIX 4: Scoring of empirical evidence sources

The following section describes the scoring of the key publications identified based on the sub themes:
The level of direct damage prevention likely to be achieved by the range of measures;
The costs of installation of measures, particularly the additional cost of installing measures as part of the reinstatement process following flood events;
The value of direct intangible benefits and of indirect benefits (including co-benefits) of installing measures.

Table A3.1 : The level of direct damage prevention likely to be achieved by the range of measures

REF	Peer Review No-1, Yes-2	Uniqueness of data (no-1, some-2, unique data-3)	Geographical distribution (General-1, rest of the world-2, Europe-3, UK-4)	Sample size (small less than 100-1, medium 100-1000-2, large >1000-3)	Judgemental score/ soundness of methodology (1-not clear, 2-clear with limitations, 3-sound and well applied)	Total Score
Association of British Insurers, Assessment of the cost and effect on future claims of installing flood damage resistant measures. 2003, Association of British Insurers: London.	2	3	4	1	3	13
Bichard, E. and A. Kazmierczak, Resilient Homes; reward-based methods to motivate householders to address dangerous climate change. 2009, University of Salford: Salford.	2	3	4	3	3	15
Green, C., *et al.*, An assessment of the additional flood losses associated with groundwater flooding: a report to Hampshire County Council and Winchester City Council. 2006, Flood Hazard Research Centre, Middlesex University: Enfield.	1	3	4	1	2	11
Highfield, W.E. and Brody, S.D. Evaluating the effectiveness of local mitigation activities in reducing flood losses. Natural Hazards Review, 2013. 14(4): p. 229-236.	2	3	2	3	2	12
Hudson, P., *et al.*, Evaluating the effectiveness of flood damage mitigation measures by the application of propensity score matching. Natural Hazards and Earth System Sciences, 2014. 14(7): p. 1731-1747.	2	3	3	3	3	14
JBA consultants & May, P. 2012. Evaluation of the Defra Property-level Flood Protection Scheme: 25918. Bristol: Environment Agency.	2	3	4	3	3	15
Joseph, R. D., Development of a comprehensive systematic quantification of the costs and benefits (CB) of property level flood risk adaptation measures in England, in Architecture and the Built Environment. 2014, University of the West of England: Bristol.	2	3	4	3	3	15
Joseph, R., *et al.*, An analysis of the costs of resilient reinstatement of flood affected properties: A case study of the 2009 flood event in Cockermouth. Structural Survey, 2011. 29(4): p. 279-293.	2	3	4	1	3	13
Kreibich, H., Thieken, A.H., Petrow, Th., Muller, M. and Merz, B., Flood loss reduction of private households due to building precautionary measures – lessons learned from the Elbe flood in August 2002. Natural Hazards and Earth System Sciences, 2005. 5: p. 117-126 .	2	3	3	3	3	14
Lamond, J., Rose, C. B., Joseph, R. & Proverbs, D. 2016. Supporting the uptake of low cost resilience: summary of technical findings (FD2682). London: Defra	2	3	4	1	3	13
May P., Emonson, P., Jones B., Davies A., Post-Installation Effectiveness of Property Level Flood Protection 2014, Defra.	2	3	4	2	3	14
Multihazard Mitigation Council, NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities 2005, National Institute of Building Sciences Washington D.C.	2	3	2	3	3	13
Office of the Deputy Prime Minister 2003. Preparing for floods - interim guidance for improving the flood resistance of domestic and small business properties. London: ODPM.	2	3	4	1	2	12
Poussin, J.K., W.J.W. Botzen, and J. Aerts, Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters. Global Environmental Change-Human and Policy Dimensions, 2015. 31: p. 74-84.	2	3	3	2	3	13
Wassell, P., *et al.*, Resilient Reinstatement : The costs of flood resilient reinstatement of domestic properties. 2009, Report from Cunningham Lindsey and Crawford & Co: London	2	3	4	2	3	14
Hawkesbury-Nepean Floodplain Management Steering Committee 2007. Reducing vulnerability of buildings to flood damage - Guidance on building in flood prone areas. New South Wales, Australia: Hawkesbury-Nepean Floodplain Management Steering Committee.	2	3	2	1	3	11

Table A3.2: The costs of installation of measures, particularly the additional cost of installing measures as part of the reinstatement process following flood events

REF	Peer Review No-1, Yes-2	Uniqueness of data (no-1, some-2, unique data-3)	Geographical distribution (General-1, rest of the world-2, Europe-3, UK-4)	Sample size (small less than 100-1, medium 100-1000-2, large >1000-3)	Judgemental score/ soundness of methodology (1-not clear, 2-clear with limitations, 3-sound and well applied)	Total score
Association of British Insurers, Assessment of the cost and effect on future claims of installing flood damage resistant measures. 2003, Association of British Insurers: London.	2	3	4	1	3	13
Bichard, E. and A. Kazmierczak, Resilient Homes; reward-based methods to motivate householders to address dangerous climate change. 2009, University of Salford: Salford.	2	3	4	3	3	15
Dhonau, M. and C.B. Rose. Homeowners' Guide to Flood Resilience 5th edition. 2016 Available from: http://goo.gl/8MSUDQ http://knowyourfloodrisk.co.uk/.	1	3	4	1	3	12
Hudson, P., *et al.*, Evaluating the effectiveness of flood damage mitigation measures by the application of propensity score matching. Natural Hazards and Earth System Sciences, 2014. 14(7): p. 1731-1747.	2	3	3	3	3	14
JBA consultants & May, P. 2012. Evaluation of the Defra Property-level Flood Protection Scheme: 25918. Bristol: Environment Agency.	2	3	4	3	3	15
Joseph, R. D., Development of a comprehensive systematic quantification of the costs and benefits (CB) of property level flood risk adaptation measures in England, in Architecture and the Built Environment. 2014, University of the West of England: Bristol.	2	3	4	4	3	16
Joseph, R., *et al.*, An analysis of the costs of resilient reinstatement of flood affected properties: A case study of the 2009 flood event in Cockermouth. Structural Survey, 2011. 29(4): p. 279-293.	2	3	4	1	3	13
Kreibich, H., Thieken, A.H., Petrow, Th., Muller, M. and Merz, B., Flood loss reduction of private households due to building precautionary measures – lessons learned from the Elbe flood in August 2002. Natural Hazards and Earth System Sciences, 2005. 5: p. 117-126 .	2	3	3	3	3	14
Lamond, J., Rose, C. B., Joseph, R. & Proverbs, D. 2016. Supporting the uptake of low cost resilience: summary of technical findings (FD2682). London: Defra.	2	3	4	1	3	13
May P., Emonson, P., Jones B., Davies A., Post-Installation Effectiveness of Property Level Flood Protection 2014, Defra.	2	3	4	2	3	14
National Flood Forum Blue Pages 2016	1	3	4	1	3	12
Office of the Deputy Prime Minister 2003. Preparing for floods - interim guidance for improving the flood resistance of domestic and small business properties. London: ODPM	2	3	4	1	2	12
Wassell, P., *et al.*, Resilient Reinstatement : The costs of flood resilient reinstatement of domestic properties. 2009, Report from Cunningham Lindsey and Crawford & Co: London	2	3	4	2	3	14
FEMA 2015. Reducing Flood Risk to Residential Buildings That Cannot Be Elevated. Washington, DC.: Federal Emergency Management Agency (FEMA)	2	3	2	1	3	11
Hawkesbury-Nepean Floodplain Management Steering Committee 2007. Reducing vulnerability of buildings to flood damage - Guidance on building in flood prone areas. New South Wales, Australia: Hawkesbury-Nepean Floodplain Management Steering Committee.	2	3	2	1	3	11
Committee on Climate Change, Assessing the Economic Case for Property Level Measures in England - Final Report (9X1055). 2012, Royal Haskoning: Peterborough.	2	3	4	1	3	13
Committee on Climate Change, Assessing the Economic Case for Property Level Measures in England - Final Report (9X1055). 2012, Royal Haskoning: Peterborough.	2	3	4	1	3	13

Table A3.3 The value of direct intangible benefits and of indirect benefits (including co-benefits) of installing measures.

REF	Peer Review No-1, Yes-2	Uniqueness of data (no-1, some-2, unique data-3)	Geographical distribution (General-1, rest of the world-2, Europe-3, UK-4)	Sample size (small less than 100-1, medium 100-1000-2, large >1000-3)	Judgemental score/ soundness of methodology (1-not clear, 2-clear with limitations, 3-sound and well applied)	Total Score
Defra, Flood Resilience Community Pathfinder Scheme Evaluation. 2015, Defra: London.	2	3	4	1	2	10
JBA Consulting, May, P. & Chatterton, J. 2012. Establishing the Cost Effectiveness of Property Flood Protection: FD2657 - Final report. London: Defra.	2	3	4	1	3	10
Joseph, R. D., Development of a comprehensive systematic quantification of the costs and benefits (CB) of property level flood risk adaptation measures in England, in Architecture and the Built Environment. 2014, University of the West of England: Bristol.	2	3	4	4	3	13
Joseph, R., D. Proverbs, and J. Lamond, Assessing the value of intangible benefits of property level flood risk adaptation (PLFRA) measures. Natural Hazards, 2015. 79(2): p. 1275-1297.	2	3	4	4	3	13
Multihazard Mitigation Council, NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities 2005, National Institute of Building Sciences Washington D.C.	2	3	2	3	3	10
Office of the Deputy Prime Minister 2003. Preparing for floods - interim guidance for improving the flood resistance of domestic and small business properties. London: ODPM.	2	3	4	1	2	10
Owusu, S., Public attitudes towards flooding and property level flood protection (PLFP) uptake. 2014, Heriot-Watt University: PhD.	2	3	4	2	3	11
Wassell, P., *et al.*, Resilient Reinstatement : The costs of flood resilient reinstatement of domestic properties. 2009, Report from Cunningham Lindsey and Crawford & Co: London	2	3	4	2	3	11
Committee on Climate Change, Assessing the Economic Case for Property Level Measures in England - Final Report (9X1055). 2012, Royal Haskoning: Peterborough.	3	3	4	1	3	11
Lamond, J., Rose, C. B., Joseph, R. & Proverbs, D. 2016. Supporting the uptake of low cost resilience: summary of technical findings (FD2682). London: Defra	2	3	4	1	3	13
May P., Emonson, P., Jones B., Davies A., Post-Installation Effectiveness of Property Level Flood Protection 2014, Defra.	2	3	4	2	3	14
Multihazard Mitigation Council, NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities 2005, National Institute of Building Sciences Washington D.C.	2	3	2	3	3	13
Office of the Deputy Prime Minister 2003. Preparing for floods - interim guidance for improving the flood resistance of domestic and small business properties. London: ODPM.	2	3	4	1	2	12
Poussin, J.K., W.J.W. Botzen, and J. Aerts, Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters. Global Environmental Change-Human and Policy Dimensions, 2015. 31: p. 74-84.	2	3	3	2	3	13
Wassell, P., *et al.*, Resilient Reinstatement : The costs of flood resilient reinstatement of domestic properties. 2009, Report from Cunningham Lindsey and Crawford & Co: London	2	3	4	2	3	14
Hawkesbury-Nepean Floodplain Management Steering Committee 2007. Reducing vulnerability of buildings to flood damage - Guidance on building in flood prone areas. New South Wales, Australia: Hawkesbury-Nepean Floodplain Management Steering Committee.	2	3	2	1	3	11
Committee on Climate Change, Assessing the Economic Case for Property Level Measures in England - Final Report (9X1055). 2012, Royal Haskoning: Peterborough.	2	3	4	1	3	13

APPENDIX 5: Meta-analysis of costs sample

Meta- analysis of UK studies

Extra cost of installation over like for like reinstatement on repair

Resilience						
NPV						
	ABI 2006					**Thurston**
Cost of package without floor	10595	14555	12635	10390	16515	4800
Cost of package with floor	16745	21705	18285	15560	24675	12000
Maintenance cost						
Survey cost	600	600	600	600	600	
Discounted whole life cost						
Replace gypsum plaster with water resistant material, such as lime	2925	3350	2875	2725	3600	1400
Replace doors, windows and frames with water-resistant alternatives.	4670	5630	5650	3710	6635	600
Mount boilers on wall	150	150	150	150	150	
Move washing machine to first floor	200	200		200		
Replace ovens with raised, built-under type	200	200	200	200	200	
Move electrics well above likely flood level	300	375	250	250	500	675
Move service meters well above likely flood level	500	500	500	500	500	
Replace chipboard kitchen/bathroom units with plastic units	1650	4150	3010	2655	4930	2125
All measures above and Replace timber floor with solid concrete	6150	7150	5650	5170	8160	7200
property type	3 bed semi	4 bed detached	2 bed ground floor flat	2 bed terrace	3 bed bungalow	semi detached

JBA used discretionary retrofit										
	JBA		**ASC**				**Owusu**			
Cost of package without floor	24910	19070	14150	10370	10020	11770	14479	10611	10253	12017
Cost of package with floor	33550	£25,320	21500	16700	15340	17580	22000	17088	15697	17962
Maintenance cost		506	0	0	0	0				
Survey cost	450	450	450	450	450	450				
Discounted whole life cost	40747	32517	22654	17723	16336	18622				
Replace gypsum plaster with water resistant material, such as lime	4510	4280	2300	2000	1870	1970	2354	2047	1914	2016
Replace doors, windows and frames with water-resistant alternatives.	12460	9260	6430	5330	4240	5790	6580	5454	4339	5925
Mount boilers on wall	1140	1140	170	170	170	170	174	174	174	174
Move washing machine to first floor	0	0	230	230	230	0	235	235	235	0
Replace ovens with raised, built-under type	740	740	230	230	230	230	235	235	235	208
Move electrics well above likely flood level	800	800	430	340	290	290	440	348	297	297
Move service meters well above likely flood level	0	0	570	570	570	570	583	583	583	583
Replace chipboard kitchen/bathroom units with plastic units	5260	4648	3790	1500	2420	2750	3878	1535	2476	2814
All measures above and Replace timber floor with solid concrete	8640	7812	7350	6330	5320	5810	7521	6477	5444	5945
property type	pre 1919 terrace	all residential	detached	semi	terrace	flat	detached	semi	terrace	flat

based on pricing 2007 cohort data					
	Joseph				**Davis Langdon**
Cost of package without floor	22600	18400	16800	28300	10595
Cost of package with floor	25100	20400	23100	na	16745
Maintenance cost					
Survey cost					
Discounted whole life cost					
Replace gypsum plaster with water resistant material, such as lime					2925
Replace doors, windows and frames with water-resistant alternatives.					4670
Mount boilers on wall					150
Move washing machine to first floor					200
Replace ovens with raised, built-under type					200
Move electrics well above likely flood level					300
Move service meters well above likely flood level					500
Replace chipboard kitchen/ bathroom units with plastic units					1650
All measures above and Replace timber floor with solid concrete					6150
property type	Detached	semi	terrace	bungalow	3 bed semi

APPENDIX 6: Meta-analysis of avoided direct damages

Sample (see spreadsheet)

Avoided damage resilience with concrete floor

						depth 500-1000			
	JBA	ASC				Joseph			
	semi	Detached	semi	terrace	flat	det	semi	terrace	Bungalow
Threshold year	£83189.33	£123,336	£96,230	£89,174	£96,108				
2	£72881.81	£108,185	£84,555	£78,389	£84,409				
5	£39352.66	£59,374	£46,169	£42,672	£45,951	£150,398	£113,394	£99,289	£163,771
10	£20610.03	£30,325	£23,941	£22,353	£23,820	£75,199	£56,697	£49,644	£81,885
20	£12066.97	£18,888	£14,953	£13,944	£14,862	£37,600	£28,349	£24,822	£40,942
25	£7795.442	£13,164	£10,452	£9,733	£10,377	£30,080	£22,679	£19,858	£32,754
40	£5047.944	£8,843	£7,079	£6,608	£7,026	£18,800	£14,174	£12,411	£20,471
50	£3216.279	£5,940	£4,807	£4,501	£4,770	£15,040	£11,339	£9,929	£16,377
75	£2101.389	£3,698	£2,928	£2,737	£2,922				
100	£804.0699	£1,375	£1,092	£1,016	£1,083				
200	£402.0349	£667	£525	£487	£520				

Avoided damage resilience without concrete floor

	JBA	ASC				Joseph			
	semi	Detached	semi	terrace	flat	det	semi	terrace	Bungalow
Threshold year	£53094.98	£66,229	£57,770	£54,207	£57,145				
2	£46853.24	£58,603	£51,093	£47,965	£50,547				
5	£25521.41	£33,170	£28,506	£26,687	£28,199	£136,726	£103,086	£90,262	£148,883
10	£14111.77	£17,671	£15,344	£14,577	£15,225	£68,363	£51,543	£45,131	£74,441
20	£8136.38	£11,108	£9,619	£9,111	£9,537	£34,181	£25,771	£22,566	£37,221
25	£5148.687	£7,821	£6,752	£6,373	£6,688	£27,345	£20,617	£18,052	£29,777
40	£3333.305	£5,309	£4,609	£4,360	£4,566	£17,091	£12,886	£11,283	£18,610
50	£2123.05	£3,616	£3,164	£3,001	£3,135	£13,673	£10,309	£9,026	£14,888
75	£1418.12	£2,293	£1,947	£1,846	£1,947				
100	£530.7625	£821	£708	£667	£700				
200	£265.3812	£394	£338	£317	£334				

	Lamond House Type A(1)	House Type A(2)	House Type B(7)	House Type C(8)	C(8)-No_ membrane	Electric installation (Using House Type C(8)	Cement sand render (Using House Type A1(2)
Threshold year							
2	£60,225	£39,206	£52,556	£49,988	£43,515	£22,359	£5,501
5	£24,090	£15,682	£21,023	£19,995	£17,406	£8,944	£2,201
10	£12,045	£7,841	£10,511	£9,998	£8,703	£4,472	£1,100
20	£6,022	£3,921	£5,256	£4,999	£4,352	£2,236	£550
25	£4,818	£3,136	£4,205	£3,999	£3,481	£1,789	£440
40	£3,011	£1,960	£2,628	£2,499	£2,176	£1,118	£275
50	£2,409	£1,568	£2,102	£2,000	£1,741	£894	£220
75	£1,566	£1,019	£1,366	£1,300	£1,131	£581	£143
100	£1,204	£784	£1,051	£1,000	£870	£447	£110
200	£602	£392	£526	£500	£435	£224	£55

APPENDIX 7: Meta-analysis of Intangibles and Indirects

Meta - Analysis of intangible Benefits of PLFRA measures

Item	Authors	Publication Topics	Value of Intangible benefit	Survey Method	Sample Size	Research observations	List of items included as intangibles	Elicitation Format
1	Wassell, P., Ayton-Robinson, R., Robinson, D., & Salkeld, I. (2009)	Resilient Reinstatement : The costs of flood resilient reinstatement of domestic properties. London: Report from Cunningham Lindsey and Crawford & Co.	N/A	N/A	400 (for cost analysis) and 500 for telephone survey	This study did not investigate the either intangible or indirect benefits of flood protection measures.	N/A	N/A
2	Owusu, S. (2014)	Public attitudes towards flooding and property level flood protection (PLFP) uptake	£795	Mailed questionnaire Survey	256 out of 1647	The researcher combined the mailed questionnaire survey with focus group. The study only assumed that the cost of alternative accommodation is the only indirect benefit	The stress of flood events; the loss of sentimental items; the loss of community spirit; anxiety of future flooding; Getting house back to normal; Having to stay in temporary accommodation; Loss of irreplaceable items (e.g. photos	Stated preference method (Choice modelling)
3	Office of Deputy Prime Minister. (2003)	Preparing for floods - interim guidance for improving the flood resistance of domestic and small business properties:	N/A	N/A	N/A	This publication is not relevant to this section of the research	N/A	N/A
4	Multihazard Mitigation Council. (2005	NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities Washington D.C	N/A			Intangible benefits of shelters were not included in the study	N/A	N/A

Item	Authors	Publication Topics	Value of Intangible benefit	Survey Method	Sample Size	Research observations	List of items included as intangibles	Elicitation Format
5	Joseph, R.D. (2014)	Development of a comprehensive systematic quantification of the costs and benefits (CB) of property level flood risk adaptation measures in England	£653	Mailed questionnaire Survey	280 out of 2309	The research was based on those people who had experienced one or more flood event in the past. The value of the intangible makes no allowance for medical cost, which was stated to be up to £970.00	Stress of flooding; worrying about future flooding; Strains between family; Deterioration in both physical and mental health; Loss of irreplaceable/ sentimental item; worrying about increase in insurance premium; worry about inability to obtain insurance cover; psychological effect such as sleepless night, nightmares, increase anger etc	Contingent Valuation method (CVM)
6	May P., Emonson P., Jones B., Davies A. (2014)	Post-Installation Effectiveness of Property Level Flood Protection	N/A	Online questionnaire; Telephone interviews and meetings; Desk study	Not stated in the publication	The main aim of the research is to carry out systematic evaluation of the effectiveness of Property Level Protection schemes, funded between 2007 and 2012, under flood conditions.	N/A	N/A
7	Joseph, R., Proverbs, D., & Lamond, J. (2015)	Assessing the value of intangible benefits of property level flood risk adaptation (PLFRA) measures.	£653	Mailed questionnaire Survey	280 out of 2309	The research was based on those people who had experienced one or more flood event in the past. The value of the intangible makes no allowance for medical cost, which was stated to be up to £970.00	Stress of flooding; worrying about future flooding; Strains between family; Deterioration in both physical and mental health; Loss of irreplaceable/ sentimental item; worrying about increase in insurance premium; worry about inability to obtain insurance cover; psychological effect such as sleepless night, nightmares, increase anger etc	Contingent Valuation method (CVM)
8	JBA *et al.*. (2012)	Establishing the Cost Effectiveness of Property Flood Protection	£2,513	Stakeholder workshops, case studies, flood group meetings and telephone interviews with residents	80 attendees at stakeholder workshop; 9 case studies; 58 telephone interviews	The figure is based on the census assumption that there are 2.36 person per household. The value also includes £970 for central value of medical and productivity costs for an average four months per person. The intangible benefit stated was arrived at by reviewing other publications. In this research no separate survey was carried out to assess the value of intangible benefits. This value was based on the 2010 report on future climate change metrics.	Ill health; Mental stress of flooding; fear of further flooding; avoidance of stress; loss of items of sentimental values (e.g. family photos, diaries etc.); the general practitioner care cost; lost utility because of restricted activities; pain and suffering, anxiety about the future and concern and inconvenience to family members and others.	N/A

The 2010 report on future climate change metrics.

Item	Authors	Publication Topics	Value of Intangible benefit	Survey Method	Sample Size	Research observations	List of items included as intangibles	Elicitation Format
9	Defra. (2015)	Flood Resilience Community Pathfinder Scheme Evaluation	Not provided	Face to face; mailed survey; online and hand delivered	13 pathfinder project managers; 27 project stakeholders	This is an evaluation of community pathfinder project, based on 13 communities funded projects		N/A
10	Committee on Climate Change. (2012)	Assessing the Economic Case for Property Level Measures in England - Final Report (9X1055)	£2,513	N/A	N/A	This value was based on the 2010 report on future climate change metrics.	Ill health; Mental stress of flooding; fear of further flooding; avoidance of stress; loss of items of sentimental values (e.g. family photos, diaries etc.); the indirect and intangible care costs; lost utility because of restricted activities; pain and suffering, anxiety about the future and concern and inconvenience to family members and others.	N/A
11	Hames, D. & Vardoulakis, S. (2012)	Climate Change Risk Assessment for the Health Sector. (Defra Project Code GA0204)	£1,065	Stakeholder workshops, especially medical practitioners	Not stated in the publication	The unit values for psychological stress are derived, and comprises of the three welfare components: medical costs; the costs of lost productivity, and disutility. This includes mild depression end-point, which is the GP care cost; The study also used the value of £225 which has been used in the industry since 2004	Psychological effects included memory of the stress from flooding and damage, and the stress of recovering after an event, including that arising from settling claims with insurers and dealing with builders and repairers	

Meta - Analysis of indirect Benefits / costs of PLFRA measures

Authors / Indirect cost items	Wassell, P., Ayton-Robinson, R., Robinson, D., & Salkeld, I. (2009)	Owusu, S. (2014)	ODPM. (2003)	Multihazard Mitigation Council. (2005	Joseph, R.D. (2014)	May P., Emonson P., Jones B. Davies A. (2014)	Joseph, R., Proverbs, D., & Lamond, J. (2015)	JBA consultants. (2012)	Defra. (2015)	Committee on Climate Change. (2012)
Telephone expenses					£150.35		£150.35			
Extra expenses on Food					£231.65		£231.65			
Unpaid leave					£302.70		£302.70	???		
Extra travelling expenses					£185.00		£185.00			
Emergency Services cost					N/A		N/A	5.6% of direct costs from 2007 floods in England data		
Cost of absence from work		£2,235			N/A		N/A	£3,149		£3,149
Alternative accommodation cost (AA)		£6,695			£6,545		£6,545	£6,695		£6,695
Sample Size					280					
Survey method					Mailed questionnaire survey					
Comments	Benefits of resilient reinstatement was excluded from the study	AA cost was obtained from Weathernet insurance data based on 2007 flood event		Indirect benefits/ costs were not included in the study	The total sample was 280, however, not all 280 respondents were affected by these indirect costs. AA cost was obtained from insurance loss adjuster database based on 2007 flood event	Indirect benefits/ costs were not included in the study	The total sample was 280, however, not all 280 respondents were affected by these indirect costs. AA cost was obtained from insurance loss adjuster database based on 2007 flood event		Indirect benefits/ costs were not included in the study	

APPENDIX 8: Summary of model features UK cost benefit analysis studies

Economic evaluations for partnership funding such as contained within the 'Multi-coloured manuals' have usually been based on economic replacement value for direct damage of buildings and contents. Economic replacement estimates are lower than the financial cost of replacing, usually new for old, contents and fixtures that are borne by owners, occupiers and their insurers. They also assume no VAT costs.

	Thurston	JBA *et al.*	Royal Haskoning	Owusu	Joseph	Lamond	Davis Langdon
Financial Model	Discount rate re future benefits = 5%	Discount rate 3.5%; VAT inc in both costs and benefits	Discount rate 8%; VAT included = yes (re costs)	Discount rate 3.5%; vat included (re costs)	Discount rate 8%	Discount rate 3.5%	8%
Economic Model	Y – 3.5%; VAT excluded	Y – 3.5%; VAT excluded from Cs and Bs	Y 3.5% No VAT				
Resilience with floor	Y	Y	Y	Med cost only	Y but not contents		
Resilience without floor	Y	Y	Y	Med cost only	Y but not contents		
Manual resistance	Y	Y	Y	Y (all 3 cost bands)	Yes, inc contents		
Automatic resistance	Y	Y	Y	Med cost only	Yes, inc contents		
Manual + resilience without floor	Y	Y	Y				
Automatic + resilience with floor	Y	Y	Y				
other						Defined low cost packages	Individual measures
Spontaneous retrofit	yes		yes				Yes
At reinstatement	yes	yes	yes	yes	Yes	Yes	Yes
New build	n	no	Yes	n	no	No	No
Depths	WAAD	WAAD	WAAD	WAAD	Variable	Assume	
1 m	Shallow <0.05 and deep 0.05m						
Property types	Semi-det	Det; Terr; semi-det; Flat; bungalow	Det; semi; terr; flat.	Averaged across 4 prop types	Bung; Det; semi; terr.	Four defined types	3 types: Flat; terrace/semi; detached
Contents	no	Y	Y	Y	Y	No	Yes
Indirects	yes	Y	Y	Y	Y	No	No
Intangibles	yes	Y	Y	Y	Y	No	No
Reliability model	yes	Y	Y	Y	Y	No	No
Years		20	20	20	20	20	15 yrs; 45 yrs

APPENDIX 9: International publications

The following section provides a summary of the key international publications which provides evidence of benefits associated with installation of property level measures.

S.No	REF	Summary of Evidence
1	Highfield, W.E. and Brody, S.D. Evaluating the effectiveness of local mitigation activities in reducing flood losses. Natural Hazards Review, 2013. 14(4): p. 229-236.	The study was conducted in USA using longitudinal data (11 years study from 1999-2009) of 450 CRS participating communities to encourage Local jurisdictions to enhance NFIP's minimum standard of flood plain Management. This paper addressed the gap in understanding of the degree to which mitigation activities reduced flood loss at a community level. There was evidence of reduction of damage as a result of effective mitigation techniques such as free board requirements, open space protection, and flood protection using combination of both structural and non-structural measures (including community education and public involvement programme). On an average the savings per point using the above mentioned flood protection measures ranged between 3000- 7000 dollars (2009 estimates). The main limitation found around such activities was that they are both expensive and time consuming, many communities wait to enact these structural provisions until after major events.
2	Hudson, P., *et al.*, Evaluating the effectiveness of flood damage mitigation measures by the application of propensity score matching. Natural Hazards and Earth System Sciences, 2014. 14(7): p. 1731-1747.	The study was conducted in Germany using 1697 (in the year 2003) and 461 (in the year 2006) interviews with private households after the floods in 2002, 2005 and 2006 around Danube and Elbe catchments in Germany. The study measures the effectiveness of damage mitigation measures by controlling the bias and overestimation in measurement. The study evidenced that after correcting the bias the measures still proved to be very effective. Flood-adapted use, flood-adapted interior fitting, and water barrier are still potentially very effective DMMs, preventing on an average EUR 14385, 11302 or 8551 of building damages, respectively. Flood-adapted interior fitting is more effective than water barriers at reducing building damage because it has reduced the vulnerability level of the building. Water barriers would reduce the amount of water entering the house, but, dependent on the magnitude of the flood, may be overtopped and then would not work at all. Considering the magnitude of the floods suffered, which was up to a 1 in 500-year return period in some cases (Risk Management Solutions, 2003), it may be that water barriers may be more effective at reducing building damages incurred from smaller magnitude flood events.
4	Kreibich, H., Thieken, A.H., Petrow, Th., Muller, M. and Merz, B., Flood loss reduction of private households due to building precautionary measures – lessons learned from the Elbe flood in August 2002. Natural Hazards and Earth System Sciences, 2005. 5: p. 117-126 .	The study was conducted in Germany. Interviews were undertaken in 2003. In total 1248 interviews were completed in Saxony and Saxony-Anhalt, 639 along the rivers Elbe and Mulde in Saxony-Anhalt and 609 along the Elbe tributaries. A detailed socio-scientific questionnaire, with questions about the total damage, affected area per storey, estimated damage ratio, type and amount of the most expensive damage, kind and costs of all building repairs and all expensive affected domestic appliances etc. were included. The study evidenced the effectiveness of damage mitigation measures from the six different building precautionary measures under consideration, flood adapted use and adapted interior fitting were the most effective ones. They reduced the damage ratio for buildings by 46% and 53%, respectively. The damage ratio for contents was reduced by 48% due to flood adapted use and by 53% due to flood adapted interior fitting. For buildings, the mean damage ratio was reduced by 29% for the cases where water barriers were available. Flood adapted use, adapted interior fitting as well as the installation of heating and electrical utilities in higher storeys reduced the mean damage ratios of buildings by 46%, 53% and 36%, respectively. Expressed in absolute values, a mean damage reduction for contents of 9000 EUR and for buildings of 30 000 EUR was achieved due to adapted use or adapted interior fitting. The installation of heating and other utilities in higher storeys could reduce the mean absolute damage by 24 000 EUR.

S.No	REF	Summary of Evidence
5	Multihazard Mitigation Council, NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities 2005, National Institute of Building Sciences Washington D.C.	The study was conducted in USA with two study components. The first component was cost-benefit analysis of FEMA mitigation grants estimated the future savings from FEMA expenditures on mitigation activities. This component was quantitative and considered a statistical sample of FEMA-funded mitigation activities selected from the National Emergency Management Information System (NEMIS) database. The second component of the study was community studies, assessed the future savings from mitigation activities through empirical research on FEMA-funded mitigation activities carried out in community contexts. The hazard mitigation cost categories addressed in this study are: 1. Cost of project mitigation activities (e.g., building retrofit, bridge improvement, equipment tie-down, buyouts); 2. Cost of process mitigation activities (e.g., education, community organization to deal with hazards, vulnerability analysis); and 1. Nonmarket costs (e.g., effects on wetlands or historic sites). Other primary datasets include interview data from knowledgeable person, and field data, FEMA grant application files. The NEMIS database was used to help select the stratified sample of grants for the benefit-cost analysis of FEMA mitigation grants and the communities for in-depth analysis. Purposive sampling of communities was performed on one hundred thirteen (113) communities met Criteria 1 and 3 through 6, but only 76 communities were at high risk of at least one hazard. The impact of the grant was not only on reduced building damage but also on reductions in power outages and reduced casualties. In addition to the process grant's cost, there were projected costs of $23.1 million for replacing/retrofitting old code buildings and $12.4 million for developing codes for new buildings, or a total implementation cost of $35.5 million. The total net benefits of mitigation, excluding the process activity grant, were estimated at $37.8 million (total benefit of $73.3 million minus $35.5 million). Netting out the $16.76 million in process grant activity costs, it is immediately seen that net benefits are still positive. Put another way, the benefit-cost ratio without the process activity grant cost is 2.06. The ratio, including the grant as part of costs, falls to 1.4, but is still above one. For intangible benefits associated with displacement, cost were calculated for the 100-year flood event. The benefits included rent for an apartment, furniture and other household items. Median rent by county from the U.S. Census determined rental costs. Rent for furniture and household items are a fixed $300 per month. An additional $100 per month covered an average increase in commute time. Sensitivity studies consider an estimation of monthly displacement cost of 25 percent and an underestimation of 50 percent.
6	Poussin, J.K., W.J.W. Botzen, and J. Aerts, Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters. Global Environmental Change-Human and Policy Dimensions, 2015. 31: p. 74-84.	The study estimates the potential damage savings and the cost-effectiveness of specific flood damage mitigation measures that were implemented by households during major flood events in France. The sample total size was 8201 households, which were equally divided over the 3 regions. In total, 885 respondents returned the mail survey, of which 530 have been personally flooded at least once in their home. A variety of variables have been used to assess the effectiveness of the mitigation measures in reducing flood damage. The effects of several variables that potentially influence the level of flood damage are estimated using ordinary least squares (OLS) regression models. Linear regressions are calculated in a stepwise manner, thus excluding explanatory variables. The main outputs from the study indicate with empirical evidence that some mitigation measures can substantially reduce damage during floods. However it is also seen that the effectiveness of the mitigation measures differs geographically based on hazard characteristics (e.g., slow onset river flooding or more rapid flash and coastal flooding). Further, the cost-efficiency of the flood damage mitigation measures depends strongly on the flood probability faced by households.

S.No	REF	Summary of Evidence
7	FEMA 2015. Reducing Flood Risk to Residential Buildings That Cannot Be Elevated. Washington, DC.: Federal Emergency Management Agency (FEMA)	This study was conducted in USA which focussed on alternative mitigations measures other than elevating home which in the longer run may reduce cost of damage in the future and reduce flood insurance premium using two illustrative case studies. Case study 1 included the flood insurance premium before and after the flood mitigation project on a single family one-story home without a basement on a crawlspace foundation located in an AE Zone (1% annual chance of flooding). Estimated cost range: $6,300 to $9,500 including annual maintenance Useful life: 15 to 20 years with limited annual maintenance costs Current annual flood premium: $1,147 for maximum coverage ($250,000 building and $100,000 contents) Estimated annual flood insurance premium post mitigation: $610 for maximum coverage Estimated annual reduction in premium: $537 Estimated time to recover mitigation cost: 12 to 18 years Case study 2 includes the flood insurance premium before and after the flood mitigation project on a concrete/masonry wall single family two-story home with a basement located in an AE Zone where the first floor elevation above the basement is at the BFE. Estimated cost range: $72,000 to $108,000 including annual maintenance Useful life: 30 to 50 years and little or no additional annual maintenance costs beyond maintaining flood openings Current annual flood premium: $6,537 for maximum coverage ($250,000 building and $100,000 contents) Estimated annual flood insurance premium post mitigation: $1,631 for maximum coverage Estimated annual reduction in premium: $4,906 Estimated time to recover mitigation cost: 15 to 22 years
8	Hawkesbury-Nepean Floodplain Management Steering Committee 2007. Reducing vulnerability of buildings to flood damage - Guidance on building in flood prone areas. New South Wales, Australia: Hawkesbury-Nepean Floodplain Management Steering Committee.	The study was conducted in Australia (New South Wales) taking into account the Hawkesbury-Nepean Regional Floodplain Management. The document provides information to facilitate informed decision making about development on flood prone land to assist in reducing the increase in the adverse consequences resulting from flooding. The guidance provided in the document is for the building industry, council health and building surveyors, builders and owner builders. The main components of the guidance are : 1. Managing flood risk through land use planning opportunities 2. Designing safer subdivisions in flood prone areas 3. Reducing vulnerability of buildings to flood damage The evidence for cost of installation and effective damage reduction shows that to adapt a standard two-storey brick veneer house to flood-aware design principles to withstand a flood of record in the Hawkesbury- Nepean valley, would cost an additional $10,000), representing a 5% increase in the total cost of the standard house. The long-term benefits of designing and building a flood-aware two-storey house, which can provide a family greater assurance against loss of the building and dramatically reduce their personal liabilities from flood damage, far outweigh the initial cost of building. Cost data from Reed Construction (December 2004, Cordell Housing Building Cost Guide, Volume 34, Issue 4) has been used for the study.

APPENDIX 10: Evidence gaps and additional targeted search from key publications

REF	Notes
Kreibich, H., S. Christenberger, and R. Schwarze, Economic motivation of households to undertake private precautionary measures against floods. Natural Hazards and Earth System Science, 2011. 11(2): p. 309-321. Peer reviewed Data not unique/ some added Geographical setting Europe Sample size: Large Sound methodology	The study was conducted in Germany. Interviews were undertaken in 2005 and 2006. In total 759 interviews were completed along the rivers Elbe and Danube catchments with detached, solid single-family private home owners to understand the economic motivation of people to invest in precautionary measures . A detailed catalogues and price lists for building materials and household appliances were used as back-up information for the cost assessments. The study concluded by comparison of costs and benefits that large investments, such as building a sealed cellar, are only economically efficient if the building is flooded frequently, and if it is located in a high flood risk area. In such areas it would be preferable in economic terms not to build a new house at all – or else to build a house without a cellar. Small investments, however, such as oil tank protection, can prevent serious damage at low cost. Such investments are still profitable even if the building is flooded every 50 years or less on average. The study also pointed that Financial incentives built into insurance contracts coupled with limits set on governmental relief programmes would provide an economic motivation for people to invest in precautionary measures.
Kreibich, H., Thieken, A.H., 2009. Coping with floods in the city of Dresden, Germany. Nat. Hazards 51, 423–436. Peer reviewed Data not unique Geographical setting Europe Sample size: Large Sound methodology	The study was conducted in Germany. Interviews were undertaken in 2002 and 2005/2006 in Dresden. In total 321 interviews were completed 300 (after 2002 flood and 21 after 2005/2006 flood) The flood discharge in 2006 was the second highest discharge since 1940 at the Dresden gauge although its return period was only about 15 years. This situation enables a comparison of the preparedness of authorities and households in the flood endangered city of Dresden in 2002 after a long period of relatively low flood discharges and in 2005/2006 just a few years after a severe flood event. Before August 2002, the flood risk awareness and flood preparedness of authorities and households in Dresden was low. Damage avoided as a result of private precautionary measures (building loss ratio with and without measures undertaken. 67% of the households had actually undertaken building precautionary measures before the floods in 2005 and 2006.) the percentage of households with flood experience between the two floods differed drastically (3% and 80%) and the percentage of households who were convinced of the effectiveness of private precautionary measures also increased from 65% after 2002 flood to 90% after 2005/06 flood. Flood damage was significantly lower, due to the less severe flood situations and the much better preparedness. Measures with long-lasting effects like private building precautionary measures or structural measures are advantageous, especially if the technique is robust and still able to function in decades (Umweltamt Dresden, 445 personal communications). However, it is an important challenge for the future to keep preparedness at a high level also without recurrent flood experiences.
Kousky, C. and E. Michel-Kerjan, Examining flood insurance claims in the United States: Six key findings. Journal of Risk and Insurance, 2015 Peer reviewed Data unique Geographical setting USA Sample size: Large Sound methodology	The study conducted in USA is the first large-scale analysis of all the residential NFIP claims filed between January 1978 and the end of December 2012: a total of over 1 million claims distributed across the entire United States over this 35-year period. It is the first large-scale analysis of flood insurance claims in the FEMA. The research does not have data on the amount of elevation of all insured single-family residences (buildings are considered elevated if their first floor is above the base-flood elevation, i.e., the 100-year return period flood) but does have a variable that is a simple binary variable on whether any elevation has occurred. Using this variable, the average across all elevated buildings was determined, claims as a percent of building value are roughly 16 to 18 percent less than for non-elevated buildings. The NFIP estimates that the minimum regulations for new construction avoid $1 billion in flood losses each year and that structures built in compliance with NFIP criteria experience 80 percent less flood damage, suggesting post-flood claims should be lower. A study commissioned by FEMA using different methods similarly found that the mitigation provisions of the NFIP save roughly $1.1 billion each year. Structural characteristics of the Insured can also impact flood claims. The study concluded that all things being equal, elevating the house limits the chance of it being flooded and should also lower the magnitude of claims.

REF	Notes
The Flood Working Group., The Insurance of Flood Risks, Institute of Actuaries of Australia Editor. 2008, Institute of Actuaries of Australia: Coolum, Australia. Peer reviewed Data not unique Geographical setting: Australia Sample size: small (illustrative examples) Sound methodology	This study conducted in Australia discusses estimating the cost of riverine Flood; customer prices for flood insurance; and what encourages mitigation or avoidance of flood risk. The methodology of determining risk premium was based on illustrative case studies of properties with high and medium risk levels. Whilst the normal flood models identify this, a number of houses are erroneously identified as being at risk of flood due to the models not being sufficiently refined, and also because no consideration is made of local mitigation efforts. The authors noted that the risk at an individual address can change due to mitigation activities, as well as further development of low-lying land. It may be desirable to have a further (invariably manual) process to deal with corner cases where the underlying flood level that was retrieved is 'too high'. By too high, it is meant that for some reason it has come to light that the customer's risk is much lower. This may be through a separate flood survey that the customer has obtained (e.g. from their local council), mitigation actions that have been implemented (such as building on a high mound, tall 'poles' and so on) or through an obvious data error (such as the risk being on top of a high hill). In these situations, it is still desirable to be able to adjust the level and hence the final premium.
Thieken, A., *et al.*, Data Collection for a Better Understanding of What Causes Flood Damage – Experiences with Telephone Surveys, in Geophysical Monograph. 2017. Peer reviewed Data unique in deductive sense Geographical setting Europe and UK Sample size: small in deductive sense Sound methodology	In comparison to on-site surveys mainly Germany, the data cover a larger number of affected properties in different environmental and socioeconomic settings, as well as a variety of factors that potentially influence the amount of damage. In this study, sampling strategies, questionnaires, and problems encountered when questioning residents and business owners are outlined. Very few studies has looked into the problems of data collection and its effect on damage assessment. This is a key document which bases its conclusions on practical experience and deductive evidences. Has a small section on reflections from the UK The study indicates the importance of computer aided telephone interviews to be a suitable method for collecting valid loss data. The limitation may be that very low or very high loss data might be underrepresented due to the sampling procedure. However, the average losses and damage patterns are well covered in such data sets, making them extremely valuable for detailed damage analyses and loss modeling. They allow insights into damage- causing processes and effective countermeasures, since far more parameters, e.g., about the flood impact or the characteristics of the affected structure, are gathered than during the loss adjustment procedures. The authors also noted that continuous efforts to collect damage data are needed. It has to be doubted whether depth-damage curves that are based on data that were gathered 10 or 20 years ago are still valid today. It has been seen that in countries with well-established loss assessment guidelines and appraisal procedures and a well-developed flood insurance market, new (empirical) approaches are more difficult to establish than where only very little work on loss estimation had been undertaken.
Kreibich, H., *et al.*, A review of damage-reducing measures to manage fluvial flood risks in a changing climate. Mitigation and Adaptation Strategies for Global Change, 2015. 20(6): p. 967-989. Peer reviewed Data unique in deductive sense Geographical setting : Developed world Sample size: small in deductive sense Sound methodology	One of the most extensive reviews based on experiences from the developed world using deductive method. This review analyses potentials of land-use planning and private flood precautionary measures as components of adaptation strategies for global change. Focus is on their implementation, their damage-reducing effects and their potential contribution to address projected changes in flood risk, particularly in developed countries. Empirical data on costing accumulated from different published sources. The study indicates that there are evidences in research that there is a large potential for adaptation strategies of integrated risk management approaches including spatial planning and private precautionary measures. Damage-reducing measures are expected to gain even more importance given the increase in flood risk due to climate change and increasing vulnerability. Zoning policies and flood proofing of buildings is particularly relevant for new developments, where the location can still be adjusted and additional costs for building precautionary measures are relatively small. Optimizing future developments (or re-developments) in a risk neutral way avoids the levee effect. Relying only on structural measures may not be desirable since adaptive management is hardly possible and potential future disasters may become unmanageable. Private flood damage reduction has become an integral component of contemporary flood risk management, but many flood endangered households and companies still do not undertake any precautionary measures, despite the fact that these effectively reduce damage and are efficient in many situations. There might be various reasons for such actions, for instance, it is usually difficult for home or company owners to estimate the efficiency of such up-front investments, due to uncertainties associated with the damage-reducing effects of these measures as well as with the flood probabilities.

REF	Notes
Gersonius B, Z.C., Puyan N, Billah MMM. Efficiency of private flood proofing of new buildings—adapted redevelopment of a floodplain in the Netherlands. in Flood Recovery, Innovation and Response. 2008. London: WIT Transactions on Ecology and the Environment. Peer reviewed Data not unique/some additional economic information Geographical setting : NL Sample size: small in deductive sense Sound methodology	This study was undertaken in the Netherlands. Flood damage databases have been constructed from a synthesis of all data available from both secondary sources, such as the ABI and FEMA database, and from the real experience of floods. The data is built up from knowledge about the effect of flood water on both the fabric of the building and its contents. In order to investigate the efficiency of private flood proofing of buildings, benefit cost analyses for different building types and elevations are conducted for a case study in Dordrecht, the Netherlands. The benefit for each damage reduction strategy is calculated by estimating the difference in expected annual losses compared to the traditional way of building. For example the following five different types of buildings were considered 1. Semi-detached property with a ground floor area of 63m2; 2. Terraced property with a ground floor area of 48m2; 3. Terraced property with a ground floor area of 39 m2; 4. Ground floor flat with a ground floor area of 81m2; 5. Bungalow with a ground floor area of 63 m2. Five types of measures that can be taken were analysed to understand the effectiveness of flood proofing measures to reduce damage. The cost of implementation of mitigation measures such as wet proofing can range from EUR 15400 to EUR 26200 depending on the type of building. Similarly permanent dry proofing installation may range between EUR 6600 to EUR 8200. The developed database is successfully used to inform the choice between reducing the probability of floods by reinforcing protection works (in this case land raising) versus the reduction of potential impact of floods by adapting the built environment. The nonstructural responses were also investigated along with building the structure on columns, building with an elevated entrance, dry proofing by sealing and by shielding, and wet proofing. It was also mentioned that nonstructural measures may sometimes be more economical in managing flood loss than structural measures in terms of cost and benefit.

APPENDIX 11: WAAD method and sensitivity analysis

The Weighted Annual Average Damage Method

This is a method for scaling up estimates of damage prevented by measures on an individual property level to a portfolio of at-risk properties. Flood Re will require a method to achieve the same for their properties to estimate the costs and benefits of any schemes to incentivise measures.

According to Messner *et al.* (2007):

Normalisation of damage/frequency data was utilised in the derivation of House Equivalents, which became the cornerstone of Standard of Service evaluations in the National River Authority's Flood Defence Management Manual.

This approach obviates the need for both property threshold levels and flooding threshold levels in the broad scale evaluation of annual average damages.

Research by J Chatterton Associates in the late 1990s improved and extended the sample base in the derivation of weighted depth/damage data by flood frequency to some 9,000 properties within 14 flood plain locations, covering 11 flood return periods.

Although the data utilised is restricted to the English Midlands, it fairly represents the typical damage that might be expected for selected UK flood events if there is no knowledge of the location of the property in the flood plain nor its threshold in relation to the flood hydraulic surface. Attempts to improve the database of properties in other locations of England and Wales did not noticeably change the weighted distribution function.

So multiple generalisations and approximations were necessary to make this methodology applicable nationally with datasets that were readily available.

Key inputs include the weighted depth/frequency data and the depth damage data. The MCM profile (fig 1) and an alternative site specific profile (fig 2) are shown below. In general this demonstrates that in high frequency events with low flood return periods the majority of property flooded will suffer shallow flooding below 300mm. Low frequency floods with longer return periods generally see flooding at greater depths. Even so the majority of flooded property see floods below 300mm. Critically the return periods shown are not property risk return periods but flood return periods. The proportion of properties flooded in each AEP band changes based on broad assumptions.

For the Scotland broad scale analysis (which is a useful template for application of the broad scale method) a number of PAR's (Project Appraisal Reports) of recent vintage were scrutinised and the following statistics were deduced:

The 5-year flood affects 5% of 200-year flood plain properties

The 10-year affects 10% of 200-year flood plain properties

The 25-year flood affects 25% of 200-year flood plain properties

The 50-year flood affects 80% of 200-year flood plain properties

The 100-year flood affects 93% of 200-year flood plain properties

An individual property is unlikely to conform to this profile, for example a property protected to 75 ARP behind community defences but suffering in the 100yr flood may suffer 3ft of flooding above 75 years or zero below.

The implication of these profiles are quite far reaching both when thinking about individual properties and when thinking about portfolios.

In a portfolio this method weights low depths of flooding heavily. If, as our findings suggest, the depth damage estimates at low depth are the most inaccurate, then this method will severely underestimate the losses to be avoided.

Sensitivity to profile assumptions

Using the table included in Haskoning (2012) the following sensitivity analysis was performed:

1. Changing the return period/depth profiles;
2. Hanging the assumed depth damage curves to reflect higher damage at low depths (2007 claims data).

A11.1: original Annual Average Damage for a property (taken from Haskoning, 2012)

Annual Exceedence Probability	Exceedence probability	Damage (£)	Probability of flood in interval	Mean damage (£)	Annual interval damage (£)
50%	0.5	0			
			0.3	6,312	1,894
20%	0.2	12624			
			0.1	14,371	1,437
10%	0.1	16118			
			0.06	16,718	1,003
4%	0.04	17317			
			0.02	18,436	369
2%	0.02	19555			
			0.01	20,691	207
1%	0.01	21826			
			0.005	21,826	109
0.5%	0.005	21826			
Average annual damage					5,018

Calculation using site specific profile (from Owusu) (table 2) slightly reduces the predicted damage

A11.2: using site specific profile

Annual Exceedence Probability	Exceedence probability	Damage (£)	Probability of flood in interval	Mean damage (£)	Annual interval damage (£)
50%	0.5	0			
			0.3	6,566	1,970
20%	0.2	13133			
			0.1	14,753	1,475
10%	0.1	16374			
			0.06	8,198	492
4%	0.04	22			
			0.02	15,188	304
2%	0.02	30354			
			0.01	32,519	325
1%	0.01	34684			
			0.005	34,684	173
0.5%	0.005	34684			
Average annual damage					4,739

Calculation using 2007 claims data damage profiles (table 3) almost doubles the AAD to £9,552

A11.3: changing the depth damage profile

Annual Exceedence Probability	Exceedence probability	Damage (£)	Probability of flood in interval	Mean damage (£)	Annual interval damage (£)
50%	0.5	0			
			0.3	13,058	3,917
20%	0.2	26116			
			0.1	27,271	2,727
10%	0.1	28426			
			0.06	29,266	1,756
4%	0.04	30106			
			0.02	31,485	630
2%	0.02	32865			
			0.01	34,297	343
1%	0.01	35730			
			0.005	35,730	179
0.5%	0.005	35730			
Average annual damage					9,552

Sensitivity to time of take up

Further sensitivity analysis was undertaken to indicate the importance of considering the time during the Flood Re 20-year programme at which measures are taken. Two different aspects were considered:

1. How many properties per year could potentially be subject to post flood installation of measures.

2. How the time of uptake would affect the cost benefit profile of a property (from a Flood Re perspective).

Number of properties benefitting from improvements post flood

For example, for a 20-year programme of PFR nationally that was based on 'post flood' upgrading, and taken up fully by every flooded household, then it would depend on the number flooded each year.

From the 2014 Environment Agency Long Term Investment Strategy:

772,000 properties are at greater than 1 in 100 year risk from surface water

748,000 properties are at greater than 1 in 100 year risk from river and coastal flooding.

Table 3: Number of properties at risk from flooding in England

The 4 flood likelihood categories are:

high: greater than or equal to 1 in 30 (3.3%) chance in any given year

medium: less than 1 in 30 (3.3%) but greater than or equal to 1 in 100 (1%) chance in any given year

low: less than 1 in 100 (1%) but greater than or equal to 1 in 1,000 (0.1%) chance in any given year

very low: properties within flood risk areas but at less than 1 in 1,000 (0.1%) chance in any given year

This implies that an annual average of over 22,500 properties will flood and 12,000 would be within the high risk category most suitable for resilient retrofit.

If it assumed that 12,000 high risk households per year are flooded and improved, then potential improvements to 240,0000 households could be achieved. This is fewer UK households than are deemed to be at high risk of flood.

A11.4: Properties at risk from flooding

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

Impact on cost benefit of delay

Looking at shorter time windows for the cost benefit analysis was the method chosen to test this assumption. Looking at low cost resilience for the high risk properties most suitable for retrofit (ie with positive cost benefit over 20 years. Table 1 shows the initial cut off periods for the four house types included in Lamond *et al.,* (2016). It can be seen that properties up to a 20 year return period display positive cost benefit ratios on the whole with the exception of house type C with a membrane.

Sensitivity analysis using shorter discounting period (table A11.2) based on flood likelihood has an effect on cost benefit ratios which increases for larger return periods. However there is a minimal effect on the cut-off point for positive cost benefits for properties up to 20 year return period.

A11.5: Discounted benefit cost Ratio (BCR) of low cost resilience measures 20 year payback period

Discounted benefit cost Ratio (BCR) of low cost resilience measures							
Flood Threshold year	House Type A(1)	House Type A(2)	House Type B(7)	House Type C(8)	C(8)-No_ membrane	Electric installation (Using House Type C(8)	Cement sand render (Using House Type A1(2)
2 years (0.50)	24.4	20.8	14.9	10.5	13.5	59.6	62.5
5 years (0.20)	9.8	8.3	6.0	4.2	5.4	23.8	25.0
10 years (0.10)	4.9	4.2	3.0	2.1	2.7	11.9	12.5
20 years (0.05)	2.4	2.1	1.5	1.0	1.3	6.0	6.3

A11.6: Discounted benefit cost Ratio (BCR) of low cost resilience measures shorter payback periods

		Discounted benefit cost Ratio (BCR) of low cost resilience measures							
		Flood Threshold year	House Type A(1)	House Type A(2)	House Type B(7)	House Type C(8)	C(8)-No membrane	Electric installation (Using House Type C(8)	Cement sand render (Using House Type A1(2)
Assuming flooding every year	Discounting over 19 year	2 years (0.50)	23.6	20.1	14.4	10.1	13.0	57.5	60.3
Assuming flooding every 2 and half years	Discounted over 17.5yrs	5 years (0.20)	8.7	7.4	5.3	3.7	4.8	21.2	22.2
Assuming flooding every 5 years	Discounting over 15 years	10 years (0.10)	4.0	3.4	2.4	1.7	2.2	9.7	10.1
Assuming flooding every 10 years	Discounting over 10 years	20 years (0.05)	1.4	1.2	0.9	0.6	0.8	3.5	3.7

APPENDIX 12: Analysis of 2007 claims data

Analysis of alternative accommodation costs for 2007 claims data (AA costs) (Sample 2,309)

Statistics

A12.1a: Actual alternative accommodation cost

N	Valid	2309
	Missing	0
Mean		£6,999.69
Median		£6,747.72
Mode		£0.00
Std. Deviation		£3,324.21
Minimum		£0.00
Maximum		£29,625.19

The above statistical results shown on tables 1a were generated from the 2309 data set. In table 1a, zero data entry was taken to be a value, hence the minimum is shown to be £0.00, and this has effect on the mean, median and mode results. Table 1b excluded zero values. Alternative accommodation cost for those returning a non-zero value is the more valid figure to use for costs saved.

Table 2 is the correlations analysis result for the 2309 dataset.

Statistics

A12.1b: Actual alternative accommodation cost

N	Valid	2246
	Missing	63
Mean		£7,196.03
Median		£6,810.48
Mode		£7,412.96
Std. Deviation		£3,153.88
Minimum		£590.26
Maximum		£29,625.19

Pearson correlation of alternative accommodation cost with reinstatement cost is significant but weak at 0.2 (sample 2,309).

A12.2: Correlations

		Reinstatement costs	AA Cost
Reinstatement costs	Pearson Correlation	1	.244**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	315781807710.705	21865767689.653
	Covariance	136820540.603	9473902.812
	N	2309	2309
AA Cost	Pearson Correlation	.244**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	21865767689.653	25504288183.543
	Covariance	9473902.812	11050384.828
	N	2309	2309

** Correlation is significant at the 0.01 level (2-tailed).

The following analyses were based on a combination of the claims records and survey results for 247 respondents surveyed by Joseph (2014). With regards to the total number of 'Not applicable' entries on question relating to Alternative accommodation, from the 247 responses 56 respondents returned 'Not applicable' (See table 3). This does not mean that AA cost was not recorded against 56 respondents, it could mean that the respondents did not relocate to alternative accommodation, instead they decided to use upstairs or stay in a caravan, and in answering the question, they believe that they are still in their properties, hence the choice of 'Not applicable'. On our claim database, out of the 247 used for AA analysis, only 47 claims have zero AA costs.

A12.3: No of days in alternative accommodation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-3 months	7	2.8	2.8	2.8
	4-6 months	60	24.3	24.3	27.1
	7-9 months	74	30.0	30.0	57.1
	10-12 months	35	14.2	14.2	71.3
	Over 12 months	15	6.1	6.1	77.3
	Not applicable	56	22.7	22.7	100.0
	Total	247	100.0	100.0	

A12.4: Relationship between alternative accommodation cost and size of household

Number of people living in the household	No of days in alternative accommodation	Mean	N	Std Deviation
1	1-3 months	4,614.00	1	
	4-6 months	3,965.23	8	3299.964799
	7-9 months	6316.46	3	3200.160272
	10-12 months	8487.07	11	6337.599849
	Over 12 months	6708.37	5	4127.349791
	Not applicable	1499.13	7	3966.321383
	Total	5505.11	35	5145.010901
2-3	1-3 months	3,791.01	5	789.3828037
	4-6 months	6,511.03	48	4128.621815
	7-9 months	8,465.27	57	5144.685808
	10-12 months	10,356.26	20	6481.192938
	Over 12 months	12,063.95	8	7030.487482
	Not applicable	2176.18	38	3808.482597
	Total	6820.10	176	5586.166328
4-6	1-3 months	1,419.90	1	
	4-6 months	4,044.09	4	1152.513665
	7-9 months	7,353.03	14	5644.238442
	10-12 months	6,769.76	4	3648.165373
	Over 12 months	6,450.00	1	
	Not applicable	0.00	10	0.000000
	Total	4531.40	34	4951.921352
Over 6	Over 12 months	6,000.00	1	
	Not applicable	0.00	1	0.000000
	Total	3000.00	2	4242.640687
Total	1-3 months	3,569.85	7	1186.703994
	4-6 months	6,007.13	60	3996.417198
	7-9 months	8,167.73	74	5157.047601
	10-12 months	9,358.92	35	6170.995751
	Over 12 months	9,500.23	15	6136.794818
	Not applicable	1363.64	56	3286.154132
	Total	**6287.79****	**247**	**5479.438366**

** With Zero treated as a valid entry, hence the difference between the mean values in table 4 and table 5.

Analysis of reinstatement costs vs construction types and age

This data exhibits the expected pattern of increased reinstatement costs across property types from terraces to bungalows. Duration of flooding also displays expected influence with property flooded for longer experiencing higher reinstatement costs. Not many large differences between cavity and solid walls. The floor type shows small differences with timber floors slightly cheaper on average than concrete floors. However the variability within classes exceeds the variability between classes.

A12.5: Mean/median reinstatement cost crosstab by age and wall construc-

Row Labels	Count of Reinstatement cost	Mean Cost	Median Cost	Min	Max
1921-1955	490				
Cavity	324	£42,958.50	£42,200.44	£13,403.27	£184,134.00
Cavity with insulation	19	£40,232.34	£40,134.70	£15,370.00	£50,060.17
Solid	147	£43,555.08	£41,332.22	£19,982.00	£166,104.00
1956-1979	753				
Cavity	596	£40,767.77	£38,967.70	9,800.00	90,708.00
Cavity with insulation	66	£42,797.79	£41,586.43	19,645.00	65,342.89
Solid	91	£43,007.04	£41,511.78	21,272.00	106,616.00
1980-1995	356				
Cavity	269	£46,528.24	£47,562.58	17,381.00	90,172.00
Cavity with insulation	62	£42,843.04	£42,188.26	21,113.25	59,649.63
Solid	25	£41,569.39	£40,718.98	23,237.00	56,790.41
Post 1995	171				
Cavity	129	£43,693.27	£42,476.02	19,727.00	142,146.00
Cavity with insulation	31	£44,277.68	£45,621.74	15,771.00	59,890.23
Solid	11	£65,957.38	£52,815.06	39,097.22	166,136.00
Pre 1920	539				
Cavity	52	£39,359.60	£37,731.33	23,504.00	67,109.00
Cavity with insulation	2	£30,343.63	£30,343.63	25,593.59	35,093.66
Solid	485	£41,149.14	£40,089.06	13,727.00	88,246.00
Grand Total	2309				

A12.6: Mean/median reinstatement cost crosstab by age and floor

Row Labels	Count of Reinstatement cost	Mean Cost	Median Cost	Min	Max
1921-1955	490				
Solid concrete	318	£44,332.60	£43,699.39	16,449.00	184,134.00
Suspended timber	172	£40,626.72	£39,092.96	13,403.27	166,104.00
1956-1979	753				
Solid concrete	555	£41,296.69	£39,571.18	15,000.00	106,616.00
Suspended concrete	5	£50,347.14	£51,134.34	40,458.94	58,844.23
Suspended timber	193	£40,748.64	£39,768.70	9,800.00	79,108.00
1980-1995	356				
Solid concrete	255	£46,540.15	£46,815.74	17,381.00	90,172.00
Suspended concrete	3	£49,216.67	£49,364.85	42,340.74	55,944.41
Suspended timber	98	£42,818.49	£42,128.12	18,788.22	87,644.00
Post 1995	171				
Solid concrete	127	£46,537.87	£44,682.17	19,727.00	166,136.00
Suspended concrete	2	£29,478.87	£29,478.87	15,771.00	43,186.74
Suspended timber	42	£42,031.06	£40,959.88	20,420.00	90,214.00
Pre 1920	539				
Solid concrete	239	£40,571.87	£39,164.46	20,255.98	88,246.00
Suspended timber	300	£41,226.82	£40,798.57	13,727.00	68,956.97
Grand Total	2309				

A12.7: Mean/median reinstatement cost crosstab by property type and wall construc-

Row Labels	Count of Reinstatement cost	Mean Cost	Median Cost	Min	Max
Bungalow	217				
Cavity	147	£44,706.62	£43,686.85	£9,800.00	£184,134.00
Cavity with installation	4	£43,652.12	£46,146.52	£33,348.87	£48,966.58
Solid	66	£48,481.43	£43,117.38	£25,538.00	£166,136.00
Detached	228				
Cavity	170	£45,418.36	£43,750.34	£19,759.00	£142,146.00
Cavity with installation	32	£41,944.18	£42,097.25	£21,113.25	£65,342.89
Solid	26	£43,043.20	£42,409.30	£23,237.00	£56,790.41
Semi-Detached	1082				
Cavity	821	£42,951.24	£43,180.22	£13,403.27	£76,584.00
Cavity with installation	99	£41,972.06	£41,092.38	£15,771.00	£60,860.47
Solid	162	£43,073.02	£42,614.34	£16,542.00	£113,084.00
Terraced	782				
Cavity	232	£38,187.10	£37,169.42	£15,666.46	£67,109.00
Cavity with installation	45	£44,590.58	£44,891.50	£15,370.00	£64,835.21
Solid	505	£41,072.50	£40,052.70	£13,727.00	£88,246.00
Grand Total	2309				

A12.8: Mean/median reinstatement cost crosstab by property type and floor

Row Labels	Count of Reinstatement cost	Mean Cost	Median Cost	Min	Max
Bungalow	217				
Solid concrete	147	£47,576.14	£45,801.30	£20,953.00	£184,134.00
Suspended timber	70	£42,179.49	£39,556.81	£9,800.00	£166,104.00
Detached	228				
Solid concrete	141	£46,255.69	£45,321.67	£19,759.00	£142,146.00
Suspended concrete	4	£47,709.19	£46,275.80	£42,340.74	£55,944.41
Suspended timber	83	£41,802.03	£39,872.98	£20,420.00	£90,214.00
Semi-Detached	1082				
Solid concrete	778	£43,589.97	£43,542.47	£15,000.00	£113,084.00
Suspended concrete	6	£44,584.45	£47,878.04	£15,771.00	£58,844.23
Suspended timber	298	£40,991.72	£39,682.59	£13,403.27	£67,683.21
Terraced	782				
Solid concrete	428	£39,867.79	£38,548.45	£15,666.46	£88,246.00
Suspended timber	354	£41,085.26	£40,276.34	£13,727.00	£68,956.97
Grand Total	2309				

A12.9: Mean/ median reinstatement cost by property type and flood

Row Labels	Count of Reinstatement cost	Mean Cost	Median Cost	Min	Max
Bungalow	217				
<24	113	£41,319.86	£39,768.70	£9,800.00	£79,108.00
25-48	68	£49,886.92	£45,488.59	£20,953.00	£166,136.00
49-72	2	£57,137.53	£57,137.53	£50,503.66	£63,771.39
73>	34	£52,074.30	£48,054.04	£32,110.02	£184,134.00
Detached	228				
<24	150	£40,769.06	£39,768.70	£19,759.00	£142,146.00
25-48	62	£52,479.96	£52,678.61	£31,881.11	£87,644.00
49-72	2	£63,421.73	£63,421.73	£36,629.46	£90,214.00
73>	14	£49,035.57	£45,939.58	£32,675.90	£90,172.00
Semi-Detached	1082				
<24	455	£39,573.01	£38,668.12	£15,771.00	£113,084.00
25-48	534	£45,527.91	£46,389.62	£13,403.27	£86,360.00
49-72	70	£46,048.61	£46,022.20	£23,256.00	£73,664.00
73>	23	£37,174.16	£38,449.42	£15,000.00	£48,760.10
Terraced	782				
<24	507	£39,861.55	£38,642.04	£13,727.00	£68,956.97
25-48	174	£40,655.77	£39,141.46	£19,521.00	£67,109.00
49-72	62	£41,976.57	£39,469.06	£15,370.00	£88,246.00
73>	39	£44,131.75	£45,214.14	£24,052.00	£55,579.42
Grand Total	2309				

FLOOD RE