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Supporting the uptake of low cost resilience: summary of technical findings (FD2682)

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This is a report of research carried out by carried out by a research consortium comprising The University of the West of England, Bristol; Mary Dhonau Associates; Cunningham Lindsay; and Birmingham City University, on behalf of the Department for Environment, Food and Rural Affairs.

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Interviews carried out by Mary Dhonau (MDA) and Rotimi Joseph (Cunningham Lindsey)

We hope that communities requiring support to enhance their resilience to flooding will benefit from the results of this research.

1. Executive Summary

This report summarises evidence collected by the Defra research project FD2682 regarding technical aspects of low cost flood repairable approaches designed to limit damage to buildings. It is derived from a Rapid Evidence Assessment (REA) that is reported in greater detail in the accompanying REA report. Flood repairable measures applied to buildings are designed to limit damage or speed recovery once water has entered a property. They include strategies to keep water away from building elements (such as raising power sockets) and the use of waterproof or water resistant materials, including those capable of retaining their integrity and recovering quickly after inundation. The measures are useful when water exclusion approaches are not practical or cost effective, and also as an addition to water exclusion approaches as a failsafe.

The REA comprised a systematic scoping of relevant academic and grey literature; consultation with a panel of experts; interviews with professionals from the sphere of flood reinstatement and property protection; and interviews with occupants of properties where flood repairable approaches have already been adopted. This was followed by an assessment of the costs and benefits of selected low cost flood repairable measures and of illustrative packages of low cost repairable measures.

The review found 139 suggested measures that could be regarded as flood repairable, over half of these being 'low cost' or 'low additional cost' (for example, when adopted during reinstatement or other building work) and which will prove to be cost beneficial for properties in the UK. Four packages of measures were costed. Three of the four packages evaluated could result in a pay back after just one subsequent flood (assuming they were successful in preventing damage). The most appropriate measures for any individual property depends upon a combination of factors, however, including the structure and condition of the building itself; the nature of the flood risk; and the preferences and lifestyle of the occupants.

Scientific evidence on the performance of measures was found to be scanty, but the experts in the industry were seen to be successfully applying experiential knowledge along with current guidance on an *ad hoc* basis. The wider industry was seen as less well informed, with some flood repairable features being removed at reinstatement, as their purpose and value is not yet understood.

The report concludes that further research is needed to provide evidence of the potential effectiveness of flood repairable approaches. Attention should also be directed towards understanding the performance of flood repairable measures during and after floods to ensure that the potential effectiveness is realised in practice. Improved technical guidance and training is recommended to further develop the understanding and awareness within the flood damage industry.

2. Background

The Technical Report forms part of the outputs from FD2682, a research project that aims to identify barriers and propose solutions to promote low cost approaches that would make properties at flood risk more resilient to damage from flood waters. The project's aim supports the long-term goal of enabling individuals and communities to take more ownership for the management of their flood risk and to recover more quickly as a result. The project seeks to identify barriers to resilient reinstatement and ways to overcome them, both within the affected communities and within the professional networks engaged in the process.

The project fits within the context of extensive past research (much of it initiated by Government) on 'flood resistance' and 'flood resilience' that has led to structural interventions, community capacity building and planning policies. This new research will build on the earlier research, avoiding replication of previous findings focusing on low cost approaches and innovative strategies.

The scope of interventions for the research has been clearly specified as excluding measures to keep water out of a building so that the focus becomes internal adaptation or what is often known as 'wet-proofing' or 'water entry strategy', also sometimes known as flood resilience and here termed flood repairable. This is adapting a building so that when floodwater enters a building, damage to materials is minimised and building elements that are damaged can be easily repaired or replaced. Measures include use of waterproof or fast drying finishes and relocation of sensitive services above expected water levels. A flood repairable strategy is often recommended to deal with residual risk in protected properties, and in properties where protection is not practical, e.g. due to high depth of expected flooding. Some of the measures can be termed 'no regrets' or 'low regrets' options as they are cheap to install, particularly during reinstatement, other refurbishment or alteration to properties. In some cases, the measures may offer other benefits, such as improved air tightness leading to lower heating costs. Low cost, 'low regret' adaptations are more widely applicable than more costly resilient approaches, extending the potential uptake to any home likely to be flooded (even those with other forms of protection) as a failsafe. The report will therefore focus on measures that fall within the low cost category or low additional cost category when implemented at the intervention opportunities throughout the building lifecycle.

It is well recognised that, despite efforts by multiple agencies, the tendency of communities at risk to adopt measures to protect their property from flooding is generally low. A lack of guidance on the range and suitability of low cost flood repairable measures, and deeper understanding of their economic costs and benefits in relation to other mitigation options, is known to be an existing and critical barrier.

Although other more comprehensive and costly schemes may prevent a higher percent of damage in an individual building, the rationale for focussing on low cost approaches in this project is that this poses the lowest financial barrier to implementation, in some cases being near to zero cost. Low cost resilience could be adopted more widely, preventing just as much damage on a community level; the project is, therefore, designed to address some of the informational barriers to uptake, while also engaging with the professional networks that would support property owners and occupiers to implement the measures. This report summarises the evidence regarding the range of low cost approaches available, their efficacy and their costs and benefits.

The purpose of the Technical Report is to summarise the findings from the Rapid Evidence Assessment (REA) regarding appropriate flood repairable adaptations (ie - low cost materials and approaches) to make properties less susceptible to damage and more repairable after flooding. It is also designed to provide costing information comparable to other property level flood risk management (FRM) approaches.

Objectives:

The objectives set for the Technical Report were to:

- Collate the evidence regarding low cost materials and approaches for existing buildings that limit future flood damage
- Gather performance data for improved cost benefit assessment of low cost materials and approaches
- Prepare costs for individual measures and ‘packages’ of measures
- Prepare cost benefit analyses for selected individual measures and ‘packages’ of measures

3. Description of approach

Two methods were applied to achieve the report objectives: a Rapid Evidence Assessment comprising a scoping review, followed by a consultation process with the Project Board and further evidence gathering; this information then fed into design of illustrative low cost resilience packages and a cost benefit analysis of selected interventions.

3.1 Rapid Evidence Assessment

The Rapid Evidence Assessment (hereafter REA) synthesised the available research and practice based information regarding low cost resilience approaches. The REA included a review of academic and policy literature; technical material; information from consultation with the Project Board experts; and interviews with professionals and homeowners.

3.1.1 Primary question, secondary and supplementary questions

The primary question concerned the technical aspects of identifying low cost approaches that limit future internal flood damage and loss.

> ***How can low cost adaptation approaches be used in existing residential and small business properties to limit the damage from flood water?***

Further secondary research questions to be addressed by the Technical Report are:

a. What low cost adaptation approaches are there?
b. What evidence exists on the impact of adaptation approaches on future flood damage?
c. What are the costs and benefits of implementing the low cost approaches?

In addition, there were several themes that Defra wished to explore (alongside the main research question relating to barriers to uptake and means of overcoming these). Those pertaining to the Technical Report were:

- Does the approach require ‘bespoke’ or innovative materials, or is it about using existing knowledge and materials in a different way?
- Is it possible to develop ‘packages’ of low-cost materials that can be used to make properties flood repairable?
- For potentially useful products, are there criteria for their existing accreditation that would also serve to indicate to users that the products are suitable for use in resilient repair following a flood?

3.1.2 Summary of methods used

Scoping review

To ensure that the conclusions are based on the best available evidence no matter what subject area the research derives from, a systematic search protocol for evidence was employed. In a multidisciplinary field such as flood risk management, a challenge for this scoping review is to ensure adequate coverage of all the potential sources of evidence. The study search strategy was chosen to maximise coverage of all relevant disciplines, via a structured key word search. The agreed search pattern was used to interrogate academic search databases, search engines and websites of relevant organisations in addition to resources already known to the review team. (Full details regarding the procedures employed can be found in the accompanying Rapid Evidence Assessment Final Scoping Report).

All sources retrieved were then assessed for relevance at title and then abstract level, using the following criteria:

- **Relevant subject(s):** Studies which concentrate on approaches at a building, building component or building material level that can be applied as retrofit.
- **Types of intervention**: Studies relating to adaptations that can be applied as retrofit at a low cost or at a low additional cost during reinstatement.
- **Types of outcome**: prefer studies that contain evidence of performance.
- **Types of study**: Empirical studies, technical studies and statistical analyses. Guidelines and policy documents.
- **Geographical scope of studies**: worldwide.
- **Language scope**: English language only.

A rapid full text screening identified and rejected those lacking relevance, or which were obviously derived from other studies, thus containing no unique information.

An interim report for consultation was prepared where the titles were subject to the following analyses:

1. The publications were categorised on the basis of relevance to the three sub questions.
2. A table of interventions identified by the literature was derived.
3. The level of cost information and preliminary categorisation of cost category was identified.
4. The presence or absence of evidence supporting the effectiveness of the measure was noted.
5. Studies containing evidence of effectiveness of measures were summarised.
6. Presence or absence of advice on how and when to carry out interventions was noted.

Consultation with the Project Board

The interim report provided a vehicle for feedback from experts outside the review team, via a process of consultation with the Project Board (PB) through a PB workshop and through written responses from PB members and selected experts. Feedback was sought on specific aspects of the REA as follows:

What is missing from the draft report?

- *Methods/materials/ Intervention opportunities*
- *Documents/ reports/ guidance*
- *Evidence sources/case studies*

How does this report relate to Building Standards and British Standards?

- *Building Standards that relate to the measure*
- *British Standards that relate to the measure*
- *Material properties that could indicate resilience to floodwater*
- *Any conflicts that arise between standards and resilience*

Which elements of the new materials are worth investigating and why?

- *Is it likely to be low cost at reinstatement*
- *Is it likely to be low cost at other times*
- *For less well evidenced measures if worth pursuing more evidence about the performance of the measure*
- *For newly suggested measures – Is this worth investigating?*

What are the unanswered questions?

- *Technical questions*
- *Resource questions, what is low cost?*
- *What is the role for proprietary products/kits?*
- *Ideas for increasing uptake*

The replies from all the consultees were reviewed and formed the basis of the specific targeted searches and follow up described below.

Specific targeted searches and follow up

All the comments received were reviewed, and highlighted issues were investigated by the appropriate members of the project team (where these were judged to be within the project's scope) or noted for future reference. Where further resources, documents or other information had been signposted, these were first cross-checked against the listings amassed during the REA compilation. This revealed some reports suggested by the Project Board members had been reviewed at an earlier stage, but had been found to contain no new or unique information; others were of tangential interest.

Particular issues arising from this process included:

The need for precision regarding the uses of different types of plasterboard (also known as dry-lining): a leading UK manufacturer lists 7 different categories, each with subdivisions, whilst the US/Canadian trade body lists 15.

The appropriate usage of different types of plaster, and the issue of ‘breathability’ relating to specific construction techniques, particular in historic properties, was also investigated in detail (as discussed in section 4.3.5).

An array of problems arise from insulation materials in a post-flood situation (including disintegration, or difficulty/failure to dry out) and this issue again highlighted the importance of precision of terminology.

A final recurrent theme was how best to capture the potential cost-effectiveness of some measures over the longer-term, and this is discussed further in section 3.2.

As a result of this process, several additional academic sources were successfully identified, including Bradley *et al.*, (2014) regarding drying conditions; Straube (2003) and Lstiburek (2002) both concerning moisture in buildings.

Fact finding interviews with professionals

A series of fourteen fact finding telephone interviews, one face to face and three written responses to the interview questions with individuals from the professional and practitioner community were undertaken to capture additional evidence, as well as examples of current practice in relation to measures and materials. These interviews were used to collect qualitative data and testimonial evidence on current practice as well as identify extra materials for the review.

Fact finding Interviews with homeowners

Thirteen semi-structured face-to-face interviews with homeowners in their adapted property were conducted. These included discussion around the nature of the adaptations specifically undertaken, together with the drivers for this approach to flood adaptation, as well as any barriers these individuals had encountered in pursuing these methods and experience of performance of resilient features during flooding.

3.2 Analysis of costs and benefits

The following steps were undertaken to analyse the costs and benefits for the identified adaptations:

1. Adaptations that may be potentially considered as low cost either during reinstatement or at other opportunities were tentatively identified. Measures were categorised accordingly.

2. For a selection of those measures related to the building fabric the costs of individual resilient measures was investigated using a standard desktop cost analysis approach undertaken by a qualified quantity surveyor employed within a loss adjusting firm. These costs were compared with a like for like alternative treatment of the same element as previously employed in Joseph (2014). The additional cost of resilient reinstatement was calculated.

3. Illustrative packages of measures were defined, validated through consultation with the project board and costed for typical house types and commonly recommended resilient treatments.

4. The savings at next reinstatement for individual measures and packages of measures were calculated using a standard quantity surveying desktop approach as previously employed in Joseph (2014) and compared to additional costs of measures.

4. Results

4.1 Overview of findings from REA

Flood repairable approaches come within the water entry strategy, sometimes also known as resilient reinstatement, resilient repair or wetproofing. Water entry strategy is defined in the 2007 CLG guidance as: '*Allow water through property to avoid risk of structural damage*' noting, however, that for low depths this strategy can always include an '*Attempt to keep water out for low depths of flooding'.* This may include:

- flood-resilient material and designs; access to all spaces to allow drying and decontamination; and design to drain water away after flooding (Escarameia *et al.*, 2012)
- sacrificial approaches; consideration of hydrostatic pressures/impact loads on structures (Kelly *et al.*, 2011)

Although beyond the scope of the present investigation, there are important structural considerations (particularly regarding the effects of depth/velocity of flood flows on the integrity of the building) which can, in some situations, render it inadvisable for non-specialists to apply resilience measures unless an expert assessment of risk has been obtained in advance of any work commencing. It is also important to consider the points at which water will be allowed to enter a property and what means of escape will remain available to the building's occupants as a result of these choices. The impacts upon the security of building contents during and after a flood must be assessed (for example, leaving doors open to permit through-flow during the flood event could permit unauthorised persons to access the contents; likewise, leaving windows ajar to aid the drying-out process). The assessment of the potential for secondary damage, together with security and safety concerns, are considered to be part of the normal professional reinstatement process as outlined in the relevant standard PAS64 (BSi, 2013).

The interface between water exclusion and water entry is also a crucial matter for debate:

First there is the physical interface, particularly the internal surfaces and cavities of external walls and the treatment of floors. The limitations on the height of internal finishes and the presence or absence of cavity insulation are highly relevant. Therefore, knowledge of the structural and drying properties of such materials and the impact they have on wall assemblages has been considered within the scope of this report.

Second there is the question of suitable circumstances for implementation of the water entry strategy. In the literature, water entry strategy is usually associated with recommendations about structural stability but it can also be recommended: as a failsafe – recognising that in long duration flooding many resistant methods may fail; for flash floods where there may be inadequate warnings to implement resistance; in historic properties where resistance is unsuitable. The reason for adopting the strategy and the associated depth of flooding and duration that is expected will impact on the suitability of some of the recommended measures.

Flood repairability of a building can be achieved in different ways. Vulnerable elements (such as electrics) can be raised above the expected flood level or removed (avoidance). Exposed elements can be made of and/or wrapped/coated in flood resistant materials (for example use of plastics) or exposed elements can be made of resilient materials that can accept water without deformation or disintegration and dry quickly afterwards with potential for decontamination (for example cementitious materials). In all cases the need to evacuate the water quickly and safely after a flood is important. For resistant and resilient materials the adequate circulation of air around the exposed elements for reasonably rapid drying must be assured. It follows that there are likely to be multiple possible water entry strategies for any given building and this was reflected in the results found by the structured search.

4.2 Low cost measures

The list of repairable measures was derived from the academic literature, grey literature, information gained from professional interviews, homeowner interviews and project board feedback. The measures include treatments for walls, floors, kitchens, bathrooms, building services, doors, windows, staircases, contents and faster drying. The existing guidance on property protection was seen to be weighted more towards water exclusion strategy with some studies on resilient reinstatement or recovery. There were seen to be a core of commonly recommended measures such as raising of services and replacing mineral wool insulation with closed cell insulation (see figure 1 for an example of guidance highlighting many of these core measures). However there are also some new ideas emerging and measures suggested by professionals and householders in the interviews that are not in existing guidance or detailed in academic literature. Examples of new or emerging measures include the use of cavity membranes and sacrificial plasterboard, water resistant wallboards, creative design of kitchens and bathrooms and nano technology.

Four householder case study summaries are shown in figures 2-5 showing measures adopted for avoidance, water resistance and resilient materials. Two of these homes have been subjected to flooding after the adaptation and suffered far less damage and disruption as a result. Further analysis of the thirteen case studies can be found within the accompanying REA report.

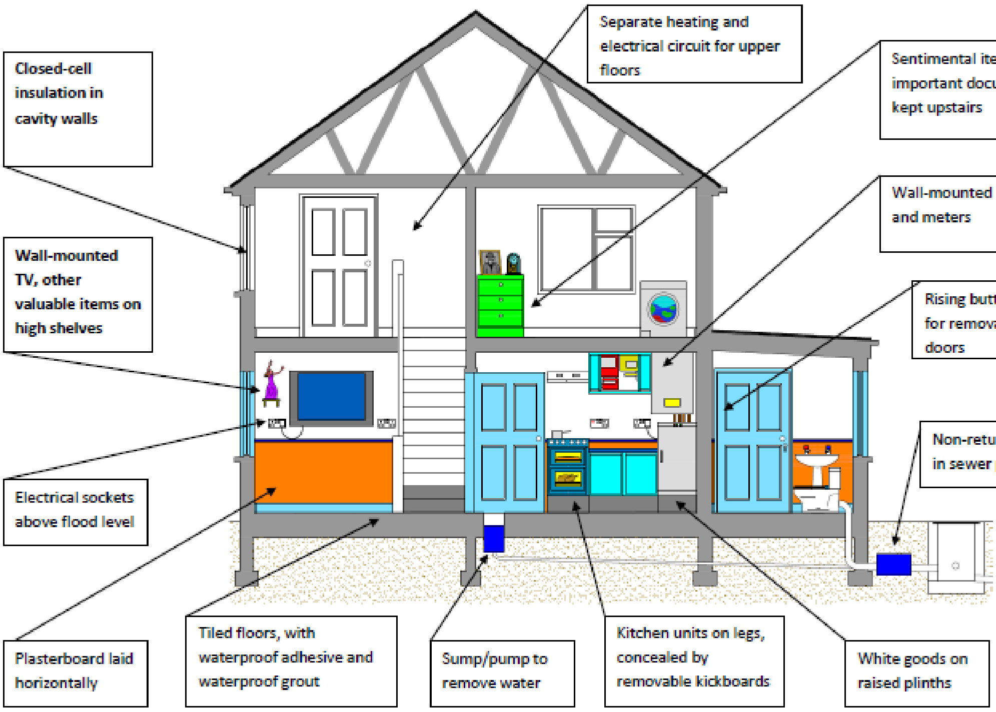

Figure 1: Example of resilience advice (Adapted from original image courtesy of the Eastern Solent Coastal Partnership (www.escp.org.uk)

A preliminary assessment was made as to whether the measures identified could potentially be regarded as low cost, either as a stand-alone adaptation or as part of reinstatement or other renewal, based on the existing literature. Interviewees (for example P#6) pointed out that it is not realistic to expect to deal with deep flooding using solely low cost resilience measures. Equally others (for example P#5) highlighted that for some properties the cheapest and most *ad hoc* measures (typically those focussed on fittings and contents) are most effective, as these approaches can facilitate rapid and efficient cleansing and re-occupation of many buildings suffering minor flooding.

It became apparent that meanings for some recommended measures such as 'tanking' vary depending on the individual's preferred approach; similarly, the diversity of building material alternatives covered by blanket terms such as 'spray foam insulation' can lead to differing opinions on their effectiveness and certainly would be confusing for lay individuals attempting to follow guidance. Some of the measures proposed in the literature were no longer considered to be common or best practice by the Project Board and interviewees: reinstatement practice has changed over the last two decades, with new materials and methods having become more commonly available. Equally there are differences of opinions as to which methods are most suitable. The list of measures (see Appendix 1) is necessarily broad (to incorporate the widest possible range of suggestions, circumstances of flood hazard and other relevant characteristics) and has not been filtered to represent best practice. Only a small fraction of the alternatives can be explored in terms of effectiveness and cost in depth within the scope of this report, and the choice was determined via Project Board feedback and perceived cost. Overall, it should be borne in mind that the measures listed represent examples of the type of approaches currently being employed; it is advisable for property owners to consult a surveyor, in order to select the most appropriate approaches for any given building. Evidence for effectiveness and suitability is discussed below.

4.3 What evidence of reduced damage is there?

Academic studies documenting actual or expected performance of resilience measures in floods are rare and are focussed on the building fabric. The studies including performance data were mainly experimental studies that reported the results of experiments on building assemblies or building components subject to simulated flooding for assessment of dry proofing. The findings suggest that considerations of material properties alone are not sufficient to predict resilience within a building setting. Quality of construction, the interfaces between materials and the drying spaces around materials are equally important to consider.

Anecdotal and testimonial evidence from other studies suggest that a number of interventions will be successful in limiting damage. However, in assessing anecdotal and testimonial evidence within the literature it is likely that a bias towards the reporting of positive results will be present and failures are less likely to be reported. The performance findings reported below are a combination of experimental evidence, testimonial evidence and anecdotal reports.

It is apparent that there are usually many options that can be considered to make building elements more resilient and that the suitability of measures within a building depends on multiple considerations including: type of building and construction; age of building (and any constraints such as listed status); condition of building including pre-existing dampness; preferences, resources and capacities of the building occupants; support available to implement measures (such as warning time); and the characteristics of flood itself (including expected flood type(s), annual probability, flow velocity, duration, speed of onset and depth). The actual measures installed may also depend on the skills and capacities of the contractors employed and the timing considerations regarding disruption to building function while work is carried out.

4.3.1 Performance of different kinds of plaster

Plaster finishes direct to masonry or stone walls have the potential to deteriorate during and after flooding to different degrees. Lath and plaster internal wall finishes, if in good condition, can dry out within a few weeks in a heated building but repeated flood exposure can cause lasting damage (Bowker, 2002). Practitioners suggested that innovations in practice using chemical and biological decontaminants or heat treatment may deal with surface contamination allowing plaster to remain in situ and be redecorated in some cases. There is an additional factor that may need to be considered, however, as some homeowners expressed concerns over the hygiene implications of using flood-resilient wall-finishes, as the following quote illustrates:

"The plaster was unsanitary and covered in sewage and no amount of wiping down would have made it clean. It had to go!" (Association of British Insurers *et al.*, 2011)

The hotel/catering industries make use of biological/enzyme-containing/biocidal cleaning fluids to clean toilet and washroom areas; these products are also in regular use, and were consequently recommended, by several restoration professionals for decontaminating wall and floor surfaces where floodwater has been contaminated with sewage. Installation of appropriate non-return valves can also be a useful adjunct measure to prevent sewage ingress via ground-floor toilets and other drain connections.

Unless a flood is only a few minutes in duration, gypsum-based plasters will absorb large quantities of water (Environment Agency and CIRIA, 2001); Literature contains testimonial reports of damage to gypsum plaster after flooding (Drdácký, 2010). Salt transport during and following a flood is also a consideration, but pre-existing salt issues and damp conditions for walls complicate the assessment of flood damage (P#8, H#5, (Historic England (formerly Eng Heritage)/Pickles *et al.*, 2015). Existing conditions may restrict the options for replacement (for example the presence or absence of a damp proof course and render (PCA guidance). Replacement plasterwork will be prone to initial crack movement and salt deposition, so finishing work should not be commenced until these have ceased. If walls cannot be dried adequately, or are badly contaminated with salts, tanking may be the only practical option (H#8).

If plaster needs replacement, then a lime or cementitious alternative to gypsum will be more resilient (P#4, H#5, (Historic England (formerly Eng Heritage)/Pickles *et al.*, 2015) although additives may need to be added to inhibit the impact of salt transport (H#5) (either as salt neutraliser, applied to bare plaster, or via the use of pre-mixed 'renovating plaster')(P#16). Lime is naturally biocidal, thus inhibiting mould and bacterial growth; however, lime plaster is slow to dry (Office of the Deputy Prime Minister, 2003) and cementitious plaster has better drying speeds. Inconclusive experimental tests on lime based plaster warrant future testing of alternative plaster mixes and finishes.

The case study shown in Figure 2 illustrates the successful use of hydraulic lime plaster, together with other resilient materials.

Case Study – Shropshire

Kitchen – sturdy marine ply shelving system to support white goods and free-standing furniture.

Older property (c 1750) very close to major river; also has groundwater ingress accompanying river flooding. Flooded twice

Other low-cost measures include:

- All sockets raised;
- Wooden skirtings retained, but using 'double vac-treated' wood finished with multiple layers of coats of paint on all surfaces;
- Solid oak stairs have survived numerous floods for past 60 years;
- Original solid wood doors retained, these have also survived multiple floods;
- A stock of plastic trestles (kept in garden shed) used to support items of furniture.

Original solid wood doors retained,

Walls - hydraulic lime plaster (with salt resistant additive) on steel mesh supported by wooden battens (to create air gap).

Concrete floors (put in during post-flood renovations) finished with natural limestone tiles.

Why did the owners choose this approach?
"... a way of taking control ... sandbags are worse than useless!"

Case study created as part of Defra Project *FD2682 Supporting the uptake of low cost resilience* By UWE, Bristol.

With grateful thanks to the Homeowner.

Figure 2: Homeowner case study highlighting the use of resilient materials

Even if solid plaster does not have to be removed due to deterioration, the presence of plaster slows the drying of the underlying masonry (Office of the Deputy Prime Minister, 2003): therefore, the option of removing the plaster and using sacrificial dry lining boards, or applying an air gap method such as plastering over a metal mesh, can be considered (Sheaffer, 1960). This has been applied successfully by homeowners in the UK (for example, H#5 using a lime plaster finish).

An alternative approach for external walls is to line the internal surface with waterproof or self-draining membranes and use sacrificial plasterboard (P#2) as a finishing layer. With this method the drying process for the treated wall will be much faster as the masonry can dry out behind the membrane via the external surface after the building is reoccupied (providing this is not also waterproofed, or lined with waterproof insulating materials), this has been carried out for commercial and residential restorations (P#14, H#9). These methods are unlikely to be regarded as low cost to implement; however, if undertaken as part of post-flood reinstatement, the increased speed of reoccupation may mean a substantial reduction in temporary accommodation costs and/or business losses. Reduced alternative accommodation can help to offset the extra installation costs incurred (H#1, 5; P#14).

4.3.2 Performance of different kinds of wallboard/plasterboard

There are many alternative boards that can be applied to internal walls and on internal surfaces of external walls. These range from standard gypsum, through moisture resistant and water resistant to waterproof boards. Tests in the US on timber framed walls sheathed with plasterboard by Aglan *et al*. (2004) and in more recent work by the same authors (Aglan *et al.*, 2014) were on *Fiberock* which is described as water resistant and not suitable for areas subject to prolonged exposure to standing water (United States Gypsum Company (USG), 2012). In the 2004 study, short term exposure (up to 3 days) was found not to damage the plasterboard, only redecoration was required, whereas in the 2014 study prolonged exposure resulted in warping and debonding necessitating replacement. The failure of standard gypsum plasterboard was also recorded by Lambert (2006) and Escarameia *et. al*. (2006).

Non-paper faced Gypsum board was used by Perkes (2011) and this required painting when subjected to short term flooding on internal walls of test pods – but the external plasterboard disintegrated as it reached a moisture level of 80%. The difference between internal and external plasterboard exposure was due to the fact that water ingress was delayed by the waterproofing therefore the external boards are potentially more representative of performance in a prolonged flood. This suggests that gypsum board (even if strengthened) is only likely to survive short term inundation. Reinstatement professionals expressed the view that plasterboard (and other non waterproof boards) often need to be removed, even if it dried intact, due to contamination (for example P#4). Laying it horizontally is therefore recommended so that the least possible amount of plasterboard needs to be replaced if replacement is needed. In the UK a stronger material *Fermacell* (10mm) splash proof board was used for internal facing of timber walls as well as standard gypsum plasterboard (9mm) on masonry (Escarameia *et al.*, 2006). The splash proof board distorted due to water pressure but was resistant to water penetration. (Although there are some fully waterproof products on the market, the high unit cost would preclude their use in the context of the present investigation).

Cement based boards are recommended as alternatives by practitioners (P#6). Practitioners have also recommended the use of Magnesium Oxide based, which are sold as fire resistant and also as tile backing materials. They are significantly more expensive than gypsum plasterboard but may be used in limited quantities at the bottom of walls (P#6). Practitioners and manufacturers recommend these boards as highly robust to water exposure but the REA scoping found no literature regarding the testing of Magnesium Oxide or, indeed, any of the waterproof alternatives and concerns about breathability of fully waterproof boards have been expressed. Further investigation of their performance was seen as out of the scope of this report due to cost considerations, but highly relevant to resilience thinking in general and an area warranting future research.

4.3.3 Performance of insulation materials

Insulation may be added inside cavity walls, to external wall faces and in various positions related to flooring. There are two main considerations, in improving repairability, that relate to insulation: first, there is the potential for insulation materials to degrade during a flood and need replacing; second there is the potential for insulation to slow or impede drying out.

Degradation of insulation is particularly important when the insulation is placed inside cavities or beneath floor surfaces as the removal may require some destruction of wall and floor finishes even if they are not themselves affected (P#2). Insulation materials that have been shown to slump or degrade are mainly loose fill such as fibreglass (P#5) and mineral fibre (aka mineral wool/rockwool/stonewool) (P#1 after prolonged flooding, P#9); and blown-in mica (Escarameia *et al.*, 2006). Although mineral insulation has been shown to dry out under laboratory conditions when sufficiently supported and drained without degradation (Sanders, 2014) and also has been observed to dry out when removed from flooded buildings (P#11), other professionals cited multiple cases where loose fill insulation slumped (P#1) and in lab tests and simulations the bottom of insulation remained wet for many days (Sanders, 2014) and could take months to dry out in a flooded property.

Closed cell insulation is seen as an alternative material in terms of resilience to direct damage in most guidance and by professionals. However, there are multiple closed cell types, including rigid expanded polystyrene and fibreglass board, blown-in polyurethane foam and polystyrene beads. There is a lack of detailed evidence about either the performance of different closed cell options during flooding or their thermal integrity post flood. Some specialised waterproof insulation materials have been tested in laboratory assemblages and found not to absorb water: for example, one type of blown-in closed cell insulation (*Technitherm*) (Gabalda *et al.*, 2012, CORDIS, 2015). Similarly, caution needs to be exercised as regards 'closed cell' floor insulation materials, as not all of these are suitable for use in a permanently wet environment (such as below the membrane layer in a groundwater flood-risk location); manufacturers' specifications must be examined carefully to ascertain the suitability of the material under consideration (p#16). There was a suggestion that materials *'with certification from the British Board of Agrément (BBA)'* were suitable: however, their suitability is not certain as the BBA tests only for water resistance in normal usage, not in flood situations (British Board of Agrément, 2013). Some professionals recommended materials proven through use in basement waterproofing (P#2, 14); another cited tests that have been conducted on one material (polyurethane closed-cell insulation) for use in flood-specific situations (P#16).

However, the presence of insulation can slow drying speed of walls and floors (Perkes, 2011, Escarameia *et al.*, 2006). This may lead to longer repair times and secondary damage including mould growth (Escarameia *et al.*, 2006). In this respect, insulation that absorbs water will remain wet inside or alongside the wall and delay drying, while water resistant insulation may form a barrier to drying on the insulated face. Hence fibre insulation will often need to be removed for the purpose of drying whereas for more water resistant types, consideration can be given to provision of appropriate air gaps and air flow (for blown-in closed cell insulation) or ease of removal (P#9) for example external fitting. Practitioners suggested that for the purposes of flood repairability it might be preferable to remove and not replace insulation but they are prevented by current building regulations (for example P#2, P#14).

In replacing insulation or when large sections of uninsulated wall need to be disturbed an upgrade to comply with current building regulations is needed (P#1, P#8). Occupiers may prefer to have improved insulation (and even to self-fund or seek grants for a further upgrade) in order to enjoy the enhanced thermal and sound insulation benefits. This was exemplified in the Rochdale Community Pathfinder, where water resistant insulation upgrade was installed as part of the green deal programme (Rochdale Borough Council/Comyn, 2015).

4.3.4 Resilience of timber to flooding

Solid timber can be highly resilient to flooding with testimonial evidence of oak and pine doors (H#5, P#1, 7) dressers (H#1), staircases (P#2,7,14, H#5) and floors (P#1,14, H#7) surviving even quite prolonged flooding with quick and careful drying and slight restoration (P#16). Professionals questioned the need to replace suspended solid timber floors with concrete in the majority of cases (P#1, 2, 8, 14,16) (see also O'Leary, 2014) unless there are additional damage/deterioration issues. This finding is, however, highly dependent on the type, quality and treatment of timber components. The nature of the (historic) timber components in older properties also differs from that used in modern construction (P#16): slow-grown timber with greater structural density was used in the past, in contrast to modern lumber products and may, therefore, have already survived a considerable number of floods.

Testing suggests that hardwood is resilient (Lambert, 2006), however low cost modern oak doors have required replacement, due to distortion. Non-engineered oak floor covering has low tolerance to swelling during floods (P#14). Solid wood kitchens may require replacement as the joints open up and due to contamination concerns (P#7). Varnishing (marine varnish) and new breathable varnishes (P#6), painting and other treatments of timber can be used to improve resilience, however they may need to be renewed regularly to remain effective and re-treated after flooding.

Where new timber components are used as part of repair, these should be primed on all surfaces prior to installation (not merely on the faces to be painted) in order to inhibit mould /rot during the drying phase after subsequent flooding (P#16). Window joints are usually glued, but if fixings are required these should be stainless steel (rather than ferric) as most timbers are acidic (oak in particular) and corrosion will result (P#16) and (O'Leary, 2014). Timber staircases can best be dried out and retained, unless in the context of a frequently flooded basement, where concrete replacement steps may be justified (P#16).

Timber based products, panelling and veneers and MDF/particleboard by contrast do not respond well to flooding (Lambert, 2006). These may be regarded as sacrificial materials with the exception of marine ply compliant with BS1088 (at about 3 times the cost of standard ply) that has been seen to survive flooding (H#8). Modern timber framing in buildings requires specialist treatment (P#10) and panels will usually need to be removed for restoration.

4.3.5 Unexpected consequences / breathability of the building fabric

Multiple authors, the Project Board and interviewees highlighted the fact that the properties of building materials, and even testing of assemblages, is useful information, but that it needs to be considered in the context of a whole building; the strategy for resilience that is selected must be based on an assessment of the building and occupant capacity and preference.

Key decisions include the balance between water entry and water exclusion approaches and the avoidance of trapped water, slow drying material or water vapour between building layers and behind finishes. The potential for secondary damage is high if drying is delayed and, therefore, the choice of resilient materials should be contextualised within a recovery/reinstatement plan. The latter will need to recognise (as far as possible) the likely drying approach and which materials will be sacrificed and which preserved if possible. This can be difficult for property occupiers to determine in isolation, as reinstatement processes may not be carried out in full knowledge or recognition of the resilient features (P#5).

Some observed/unexpected consequences and trade-offs were mentioned by professionals and homeowners:

- Replacement of suspended timber floors with a concrete alternative was seen as appropriate in some circumstances (for example, in areas prone to a high water table) (P#8, 9, 12); in other cases it would introduce a high cost (and potentially slow drying) material and decrease breathability (P#1, 4, 1, 8, 11, 14). This, in turn, can cause difficulties for the property (as well as neighbouring properties) due to reduced airflow and interfaces. If replaced, the slab should be thicker than normal (P#6); if floor insulation is damaged, the whole floor would need replacement (P#10).
- Application of closed cell spray insulation within a timber frame structure is not appropriate, an open-cell type is required (to avoid timber decay) (P#9);(Historic England (formerly Eng Heritage)/Pickles *et al.*, 2015). Alternatively suitable air gaps, external fixing of insulation or integrated insulating panels may be considered.
- Contamination issues mean that resilient components often have to be removed for cleaning of voids or materials behind them, causing secondary damage (P#1). Post flood cleaning may damage materials that are resilient to flooding therefore understanding the likely contamination level and cleaning method can inform the choice of strategy.
- Poorly applied measures that fail (for example cementitious tanking) can add to the reinstatement costs for insurers who are then required to reinstate to a higher standard (P#3). High quality installation with well specified materials is therefore recommended.
- Application of plastics or plastic/waterproof coatings on wall surfaces can create drying problems for underlying masonry or timber (Project Board).

4.3.6 Recommendations for services

Avoidance of inundation of water sensitive services by raising them above the likely flood level is a commonly recommended approach. The efficacy of passive avoidance is self-evident and testified to by homeowners (H#1, H#2, H#3, H#4, H#5) and professionals (P#4). Professionals reported that most occupiers readily accept the raising of meters, control panels and boilers (P#1), although other services (for example, fires and radiators) may be more difficult or costly to reposition. Larger boilers can be raised on plinths, whilst smaller units may be wall-mounted (P#16) or relocated to an upper floor, if available. Central heating radiators should only be replaced if prolonged flood exposure has affected their structural integrity (by exacerbating pre-existing corrosion); superficial rust patches can be rubbed down, treated and repainted, provided the unit is otherwise sound (P#16). If replacement of services that cannot be raised is required after flooding then resilient alternatives may be sought – for example, radiators that are corrosion resistant. Dropping electrical services from above is also frequently recommended and isolating circuits below the flood-line from those above, this is in line with much current practice. Modern cabling and piping within walls and floors is usually well protected and, by following current regulations during reinstatement, old properties may become more resilient (P#1).

The raising of electrical sockets is a low cost measure highly suitable for implementation during reinstatement and has been widely advocated. Siting of sockets at a minimum of 450mm above floor level is part of Building Regulations (Part M) which applies to new dwellings and work on non-dwellings only (H M Government, 2013a, H M Government, 2013b). This height may be sufficient to protect many systems subject to shallow flooding (P#1); However, while some professionals followed the height recommendation for all reinstatement properties and found most homeowners accepted raised sockets (P#1) others found reluctance for raised sockets when not presented as part of regulations and compliance is apparently not required for repairs/renewals to dwellings, as stated in Part M section 0.3, p11).

One alternative (potentially lower cost) approach was suggested, this being to remove switch-plates/covers from affected sections, allowing them to dry, and to drain any remaining water from conduits, followed by inspection by an independent electrical inspector; if corrosion of steel back-boxes has occurred, these can be replaced with plastic equivalents (P#16).

The case study shown in Figure 3 illustrates the use of measures appropriate in a groundwater flooding situation, where water exclusion had been found to be inadequate.

Case Study – Oxfordshire

Kitchen has free standing furniture, including a solid wood dresser (same age as house) that has survived countless floods.

Listed building (c1800); affected by various combinations of groundwater/surface water flooding 4 times in 14 years.

Other low-cost resilient measures include:

- Plinths for white goods and range;
- Retained original solid pine internal doors on rising butt hinges (so can be removed);
- All sockets raised;
- Lounge furniture raised on bricks for minor floods;
- Bookcase made of deal with 6 coats of paint, and half-inch above ground (to prevent water getting trapped behind it);
- Non return valve in sewer chamber.

Water comes up through the floor but tiled floors are easy to mop up after a flood.

Why did the owners choose this approach?

"Previous owners had attempted 'tanking', but it was pointless ... you can't keep water out of here! "

Walls finished with lime plaster and 'old-fashioned' paint; dado to mark where post-flood decoration needs to go up to.

Case study created as part of Defra Project *FD2682 Supporting the uptake of low cost resilience*
UWE, Bristol and Mary Dhonau Associates.

With grateful thanks to the Homeowner.

Figure 3: Homeowner case study highlighting avoidance and resilient materials

The case study shown in Figure 4 illustrates easily removable furniture and fittings.

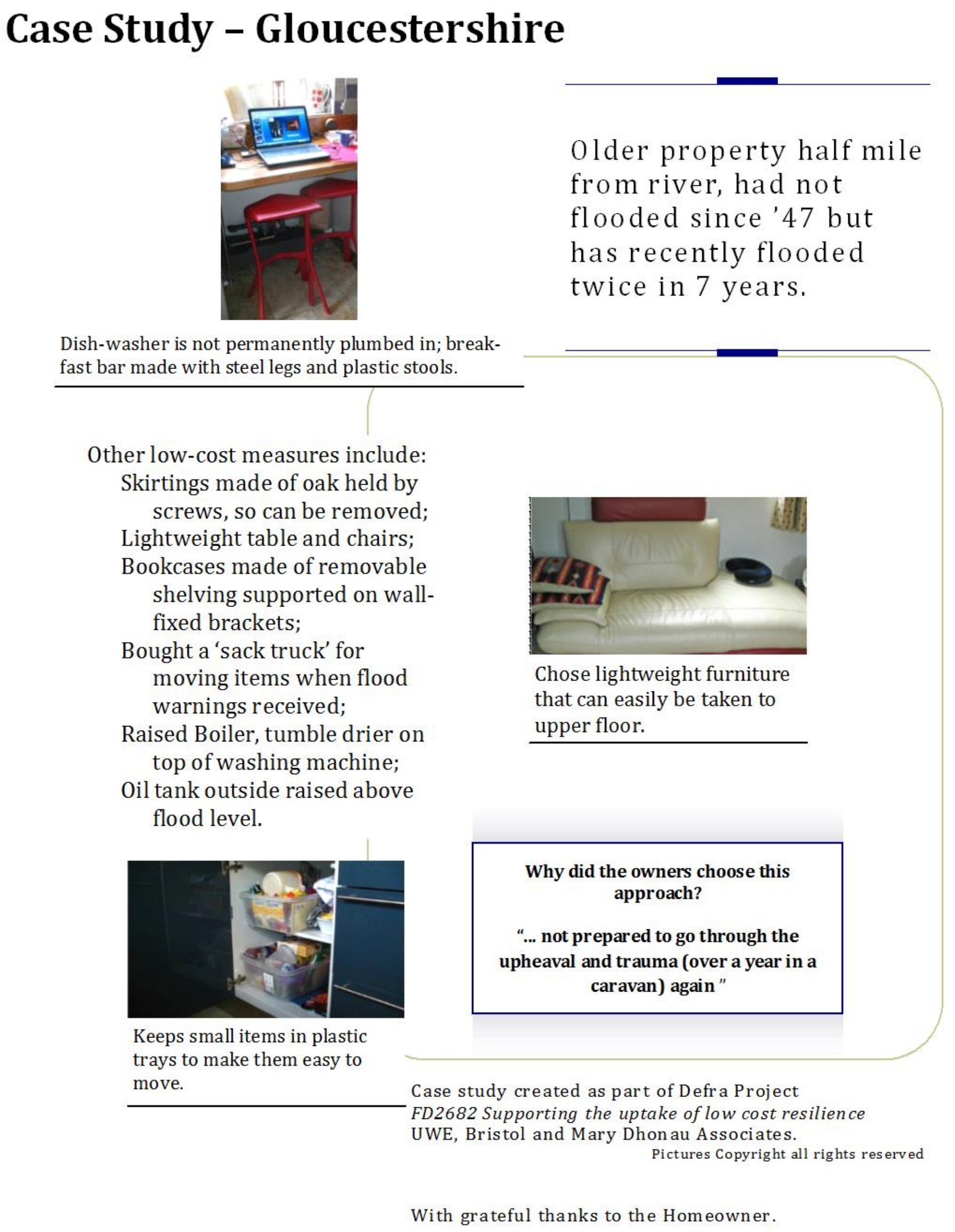

Figure 4: Homeowner case study highlighting the use of lightweight and movable contents

4.3.7 Recommendations for contents/fittings

Avoidance of flooding via removal of contents, or raising belongings above expected flood level temporarily, before a flood is a commonly recommended measure. This includes the replacement of fitted units with free standing ones – particularly in living rooms and bedrooms (P#1) but not for kitchens. Small and lightweight furniture is recommended for ease of handling and occupiers have implemented these changes with success (H#1, H#9), likewise wall-mounted cupboards for home/office use (H#9). Hinges that allow for removal of doors and creative designs that allow for detachment of panelling or other normally fixed items have been used by homeowners (H#3). Raising furniture, ovens and appliances above the flood line is an alternative (P#5). Temporarily raising items, such as furniture, using bricks/blocks, can be of benefit particularly for low-level surface water flood events (H#7, H#8). Furthermore, things that can't be raised or removed in a hurry can be wrapped in plastic (H#3).

In choosing contents and fittings that are not removable, material properties are most relevant. Use of plastics for furniture and fittings has been seen to improve resilience. Modern PVC doors have been seen to stand up well to flooding (for example P#1), plastic chair legs and plastic or steel kitchens or kitchen carcases with sacrificial or removable doors (for example P#5, P#6) although plastic kitchens are potentially expensive and homeowners are often reluctant to install them. Metals can also be used and these are seen as easy to decontaminate as they are robust to powerful cleaning methods. Choice will depend on cost and aesthetics. The possibility of secondary damage for contents needs to be considered, particularly in prolonged flooding. For example, fabrics and electrics may need to be thrown away because of moisture in the atmosphere during flooding (P#4) and they may need to be removed during drying to prevent moisture damage (BSi, 2013).

Floor coverings that are resilient include tiling and resins with waterproof adhesive and grout. However, the performance of even waterproof adhesive may be variable in prolonged floods (P#4). Hardwood flooring can be resilient but may need refixing (Soetanto *et al.*, 2008). Vinyl flooring may also survive inundation, if suitable adhesives have been used (P#16). The performance of carpets and (lower quality) laminates is poor and this is borne out by observation and testing. Any recommendation to adopt removable carpets/rugs will, however, only be appropriate where both sufficient warning time is likely to be available, and occupants have the physical capability of carrying out the procedure (P#16). Non-engineered floor covering (such as laminate styles) are prone to swelling during floods and should be avoided (P#14, P#16). Sealed Bamboo flooring, although currently in fashion for use in bathrooms, is 'splash-proof' but it is not suitable for use in flood situations (P#16). There can be difficulties regarding the floors in listed buildings, but there are cases where Conservation Officers have accepted the use of resilient tiles (resembling quarry tiles) as a replacement for stone-flag floors (p#16). A low-cost free-standing pump can be used in conjunction with a sump to drain below-floor voids, rather than a permanently fixed pump (p#16; H#6).

The case study shown in Figure 5 includes the use of resilient floor finishes, as well as other resilient materials.

Case Study – Worcestershire

Plastic kitchen units with removable wooden doors.

Older property close to major river. 3 floods and 2 near-misses in 14 years.

Other low-cost measures include:

- **All sockets raised;**
- **Wooden skirting replaced by tiled border;**
- **Sump and pump to control water accumulating in sunken patio area;**
- **Cement render used on internal walls;**
- **Items also raised on breeze blocks during floods.**

Entire ground floor is tiled, with removable rugs/non-fitted carpets.

Floodproof giant plastic bags to protect furniture

Why did the owners choose this approach?

"Floods becoming more prevalent ... displaced for 8 months following last flood."

Case study created as part of Defra Project *FD2682 Supporting the uptake of low cost resilience*
By UWE, Bristol and Mary Dhonau Associates.

With grateful thanks to the Homeowner.

Figure 5: homeowner case study illustrating us of water resistant materials

4.4 When and how to make adaptations.

Two elements underlie the question of when and how to make adaptations. There are more studies that explore the barriers to adaptation than there are studies that look for positive opportunities and behaviours. However, the supplementary question around adaptations in other aspects of climate behaviour is also relevant if lessons can be learned across sectors.

Successful adaption of buildings is most likely when stakeholders have the desire and ability (financial, practical) to make changes. The most commonly reported factor that contributes to the desire to adapt property to flooding is flood experience, usually direct experience of flood damage to the home or business. It is also commonly recognised that this desire is strongest in the period immediately following a flood (Steinführer *et al.*, 2009). These are also potentially occasions where cost of installing resilience measures may be at its lowest. Within the property lifecycle it has been suggested that adaptation can take place naturally and most cost effectively at reinstatement (Joseph *et al.*, 2011) or at pre-planned maintenance or renewal of fixtures and fittings (Soetanto *et al.*, 2008) The disruption associated with installing resilience will also be lower at this point.

However, this is not the only point at which measures can be taken. Some evidence exists that during insurance renewal, businesses in particular may be driven to install measures (Lamond and Proverbs, 2009a), and this may well increase in importance with the launch of Flood Re. (The latter scheme, launched in 2016, aims to enable home insurance to be widely available and affordable in areas at risk of flooding; business premises, however, are not included in the Flood Re scheme as it currently operates, which may render smaller businesses more open to resilience approaches).

At property transfer there is the potential for the vendor to take measures in order to present a lower risk to the buyer, during negotiations. However the greater opportunity may be the tendency for new owners to invest in their new property if they are properly advised.

Finally, there is the chance that property owners will install measures as a result of some other external influence, such as an awareness campaign. It is well recognised that despite efforts by multiple agencies, tendency of communities at risk to adopt measures to protect their property from flooding is generally low. Studies in the UK have been carried out to explore the barriers to climate adaptation generally (Bichard and Kazmierczak, 2009) and to flood adaption (Thurston *et al.*, 2008) The recent work of Joseph *et al*., (2011) Lamond and Proverbs (2009a) and Wassell *et al.,* (2009) have related specifically to 'resilient' or 'flood repairable' adaptation. All these studies have identified a complex set of constraints that need to be addressed in order for change to occur within a variety of 'theory of change' models. For example, Lamond and Proverbs (Lamond and Proverbs, 2009b), adapting Grothmann and Reusswig (2006) specifically for resilience, considered that there were information, financial, emotional and timing barriers that impacted variously on the necessary awareness and perception of risk, ownership of the risk, knowledge of solutions, resources to implement solutions and belief that the measures would work. Other models include Spence *et al.,* (2011), Bubeck *et al.,* (2012) and work summarised by Fell *et al*., (2014).

At the intervention points, guidance and advice is delivered to property owners and occupiers by the wider 'property support network', and these include: Damage management professionals such as loss adjusters, building surveyors and reinstatement contractors, local authority; General builders and building/DIY suppliers, property care advisers; Surveyors, valuers, estate agents, estate managers; Insurance brokers, property care advisers, product providers, underwriters.

Relevant information from the professional interviews, regarding the role of the property support network echoes themes in the literature regarding the lack of awareness among many of those professionals who could potentially support low cost resilience. A general lack of guidance on water entry (as opposed to water exclusion) was revealed and even those active in promoting resilience have had to rely on general surveying expertise and the generic guidance available.

During the reinstatement process, there is little opportunity for loss adjusters and contractors to specify resilience due to restrictions on betterment. An exception to this arose from the impetus generated by the recent repair and renew grants (hereafter RRG) which applied to homes and businesses flooded between 1 December 2013 - 31 March 2014 and during December 2015).Those measures seen as neutral in terms of cost are sometimes specified; however, residents often decline measures such as raised sockets due to aesthetic considerations. Measures such as plastic kitchens are similarly unpopular.

Professionals felt that lack of education and awareness were a huge barrier to uptake, but that the RRG had made some difference both to awareness in the profession and to willingness of homeowners to install measures. As measures are beginning to become more common, more evidence of effectiveness will be recorded and a debate about the suitability of different measures is emerging. The attitude of insurers in cost cutting and not promoting resilience is widely expressed as a barrier, although some insurers are more forward thinking than others. Awareness raising and education is required at all levels including the general building trade and loss adjusters.

Professionals reported a reduced tendency to strip out during reinstatement and increased attempts to retain and dry where possible due to cost and environmental considerations. This may reduce the opportunity for higher cost resilience measures such as replacement lime on mesh or membrane treatment to those properties unless major flooding has occurred. Low cost resilience may be more widely applicable and more relevant under these changed circumstances.

With scant official guidance, individuals are also increasingly seeking out information from less formal networks such as flood action groups, the National Flood Forum (NFF) (National Flood Forum, 2008) and web based sources of guidance and advice such as the ‘Blue pages’ (Blue Pages (NFF), 2014). Further, it is clear that people also rely on informal networks of friends and family for guidance and support. Homeowners interviewed for this study had all undertaken significant research and, in some cases, a degree of trial and error in arriving at suitable measures for their property.

4.5 Costs and benefits of low cost measures and packages of measures

Cost information is rarely presented in studies, nor are there existing catalogues of solely low cost measures; in addition, costs differ depending on whether an intervention is applied at reinstatement or planned building work, or as a stand-alone intervention specifically to reduce risk. It is apparent that some contradictory views of cost categories exist in the literature. This may be in part to do with underlying assumptions about the timing of interventions (whether during or after reinstatement) or about the labour requirements. Despite these uncertainties in precise estimates of costs, the weight of evidence and expert opinion suggests that low cost approaches can be used to prevent some of the damage from floodwaters entering the home. Increasing their uptake could, therefore, save money for households, small businesses and their insurers.

Low cost approaches can be taken individually or as part of a package of measures; however, particularly for low-level surface water flood situations, individual measures may suffice of themselves and so present very low financial barriers to implementation. Different measures are most appropriate at different stages of the property lifecycle: for example, at reinstatement or during planned building work or replacement (such as kitchen refurbishment). Further refinement is needed in the assessment of ‘low cost’ but it is tentatively taken within this report to mean low cost (under £750 for an individual measure or under £5,000 for a package of measures) to install either at replacement or at reinstatement or at any time. This figure was in line with the approach adopted in the first edition (2011) of the ‘Homeowner’s Guide to Flood Resilience (Dhonau and Rose, 2014) in which items assessed as costing less than £700 were described as ‘inexpensive’ or ‘low cost’ but with a slight uplift to allow for inflation; it is also consistent with the guideline price categories for fitted kitchen components employed by a leading consumer group magazine (Which?, 2015).

Evidence also suggests that, although low cost resilient approaches may not be the most cost beneficial way to limit damage, within the constraints of insurance contracts and available funding for homeowners and small businesses, they are cost beneficial in general and can be the most practical approach in overcoming financial barriers to implementation.

4.5.1 Definition of costed packages

For this study, four low cost repairable packages were specified, as an illustration of some potential approaches that might be taken at reinstatement of flooded buildings. The range of buildings was selected to include commonly encountered house types in England (see table 1). The house types included terraced, semi-detached and detached properties. In addition there were a range of assumptions for the existing internal treatments, consistent with properties of various ages, including: lime plaster, gypsum plaster and plasterboard walls; concrete and timber floors; and floor coverings from vinyl, carpet, laminate and tiles.

Repairable packages were specified to cover a range of commonly suggested low cost measures that were previously identified by the review and during interviews. They are not intended to be the best recommended approach for the specified property types, but they are selected to demonstrate a range of appropriate treatments that were judged to have the potential to be implemented at low cost. The packages were finally specified after consultation with the experts on the Project Board and costed using a desktop approach. The detailed packages include assumptions for existing treatments and the diagrams of house type layouts are shown in Appendix 2.

4.5.3 Cost benefit summary

If the resilience measures were successful in preventing damage in a subsequent flood, three out of the four packages would result in a pay back after one flood (without consideration of discounting). The fourth package, including a membrane (cost £1,500), would not quite pay back after one flood if reinstatement costs are considered. If the membrane is not included in this package it would also pay back after one flood.

Individual measures from these packages representing a single event payback (if they prevented all damage) include: the raising of sockets; rising hinges on doors and kitchen cabinets; tiling replacement of floor coverings; cement sand render; adding salt additives to lime plaster; adding waterproof grout, and replacing softwood doors with UPVC. (Full details of each package are presented in Appendix 2).

Table 1: Summary of flood repairable packages

Package Number: A1 House Type 1: Semi-detached Net Internal floor area: $49m^2$ **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: $37m^2$ **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: $48m^2$ **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: $72m^2$ **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

4.5.2 Costed Package summary

The total additional cost of the repairable packages ranged from the cheapest at £1,890 to the most expensive at £4,770. This extra cost was based on like for like reinstatement costs of £5,530 - £8,950. The like for like cost is based on the reinstatement cost of the resilient elements only. For example, there were no low cost measures applied for kitchen unit carcases, therefore they were not included in the like for like costs. Floor construction was not changed as, based on previous studies, this was not seen as a low cost measure. The results support the opinion expressed in section 4.2 that low cost resilience measures are not able to prevent all damage but can be useful in limiting damage. Higher cost approaches may be able to prevent more damage but they will be appropriate for fewer flood risk scenarios. A cavity membrane was included in package C8, behind sacrificial plasterboard in order to give an indication of whether this commonly suggested approach could be seen as low cost. Although it did not fall within the limit of £750 for a single measure it can be seen as low cost if applied as part of a package of measures.

To fully understand the costs and benefits of repairable packages it will also be necessary to factor in:

1. Reductions in alternative accommodation costs
2. Expected return period and discounted cash flows
3. Expected failure rate (or planned sacrifice) for resilience measures
4. Co-benefits of measures

Each package offers the potential to reduce reinstatement time following a flood. This could result in reduced alternative accommodation costs adding to the financial benefit of using repairable measures. However the reduction is highly dependent on the speed of drying and replacement time for items not covered within the repairable package and the need to relocate while repairs are carried out.

Most of the measures within the costed packages are designed to completely prevent damage and obviate the need to replace the element after another flood. However failure rates for the measures are not available from the literature and have not been established by this review.

Measures offering potential additional benefits that could offset the cost of installation include: changing to closed cell insulation offering potential thermal benefits, and changing to UPVC door potentially offering improved security, thermal benefits and aesthetic improvement.

5. Conclusions

The results of the REA and accompanying consideration of costed packages of low cost repairable measures have revealed a vast range of different measures that can be used to limit damage from water that enters a property during a flood event. It is concluded that it is not possible to specify an ideal set of repairable measures that will be universally appropriate for properties at risk. There are a number of factors that can affect the technical specifications appropriate for a building and flood risk scenario; it is also important to take into account the preferences and lifestyles of the occupants of the buildings.

A total of 139 repairable measures have been identified, comprising approaches applied to the fabric of the building as well as recommendations for fixtures, fittings and contents. The repairable measures can be categorised in a variety of ways: for example, based on the building element they are designed to protect, or by the kind of water entry strategy adopted. The review highlighted the critical importance of understanding the detail of proposed measures given the different interpretations attached to common descriptions of measures such as ‘tanking’. It is also important, when choosing adaptations, to recognise the type of strategy they are designed to fit within, and to avoid combining incompatible measures.

Evidence of performance of a minority of the measures in a flood (or simulated flood) is available from a small number of laboratory experiments, as well as testimonial and anecdotal evidence from professionals, property owners and occupiers. The efficacy of avoidance measures is seen as self-evident when applied as a passive measure. However, some avoidance measures depend on pre-flood actions by property occupiers and, therefore, in a similar way to flood gates, are subject to failure due to non-deployment. The efficacy of other low cost measures varies, and some of the evidence is contradictory (perhaps due to testing under a variety of flood conditions). Very few measures were seen as universally effective and many will eventually fail under particularly long or deep flooding. However, given the prevailing flood condition in England is shallow and short lived, the effectiveness of proposed low cost measures is seen as potentially high.

Low cost approaches can be taken individually or as part of a package of measures; however, individual measures may suffice of themselves and so present very low financial barriers to implementation. Study of the costs of selected resilience measures and packages has revealed that a variety of low cost packages can be specified that would be expected to limit damage during future flooding. Assuming the measures were effective in preventing damage, three of the four suggested packages would expected to pay back after a single flood event on the basis of physical reinstatement costs, and would be expected to be more cost beneficial if reduced alternative accommodation costs and co-benefits were also accounted for.

(The fourth package fails to do so only due to the inclusion of a single higher-cost component, this being a cavity membrane). Despite some uncertainty around precise costing (particularly in relation to the timing of works) adoption of these measures will prove to be cost beneficial for many properties in the UK.

Resilient features may, however, be removed either to reduce drying times, or due to ignorance on the part of households and professionals. For example, inundation of materials by contaminated water is an issue which poses particular challenges for householders; professionals are also fairly divided in their approach to the need to replace contaminated materials. This is also an area with a paucity of scientific evidence, as most testing is carried out with clean water. Even if materials survive a flood with their structural integrity intact, the desire to remove contaminated materials means that resilient features may still be removed at the insistence of the occupant (H#10) or the insurer (H#12). The use of biocidal detergents (as used in the hotel industry) has been suggested as a reactive means of addressing some of these concerns; a preventative approach would be the wider adoption of non-return valves (to prevent sewage ingress via toilets/internal drains).

Further research and guidance in this area is critical to increasing the popular acceptance of repairable approaches and ensuring that resilient materials are not stripped out unnecessarily. Lack of knowledge of flood repairable approaches and lack of detailed guidance is also seen as a barrier to installation of measures. Measures are often most cost effective during reinstatement or planned building work, however these opportunities may be overlooked due to the desire to reinstate quickly and not delay other works. In the opinion of the professionals, the recent Repair and Renew Grant opportunity was helpful in raising the profile of flood repairable approaches, but also highlighted the general lack of experience in and guidance available to the industry.

Further research is also needed to provide evidence of the potential effectiveness of flood repairable approaches. Attention should also be directed towards understanding the performance of flood repairable measures during and after floods to ensure that the potential effectiveness is realised in practice. Improved technical guidance and training is recommended to encourage the level of awareness and understanding of the professionals within the flood damage industry.

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Appendix 1: List of suggested low cost measures for water entry strategy

MEASURE TYPE	Depth	Low-cost items	SPECIFIC interventions
Key:	*Low up to 100mm, Medium = up to 300mm, High = up to 900mm, Any = up to one storey* ****** potential to be installed at low cost*		
Water compatible walls	Any		Silicon-mineral/Magnesium Oxide board, instead of plasterboard (concerns with breathability)
	Any	*****	Use cement based moisture-resistant plasterboard or waterproof board
	Any	*****	Use cellulose-fibre reinforced gypsum for areas with short duration floods
	High	*****	Fix plasterboards horizontally on timber framed walls rather than vertically (aka sacrificial plaster board/dry-lining)
	High		Plastic lining of walls/membrane /tanking
	High	*****	Plastic cladding materials (such as simulated wood panelling, per 2009 paper from a case study) (caution - concerns over dampness hence against Bldg Regs)
	Any	*****	Removable timber (or other) cladding material
	Any		Cement Render/cement sand render/water-resistant cement-based plaster coated on to internal walls then skimmed
	Any		Lime based plaster/ hydraulic lime coating with Porous paint on top of plaster, (and salt resistant additive) to allow water vapour to pass out as drying proceeds.
	Any		Hydraulic lime on stainless mesh, mounted on tanalised battens, with membrane to sep this from wall. (Hyd lime also contains an additive making it impermeable to water but permeable to water vapour; finish with compatible permeable paint.)
	High		Ceramic/porcelain tiles (with water-resistant grout and adhesives, as used in swimming pools)
	Any	*****	Closed-cell type insulation (to replace mineral insulation in cavity walls) (eg sprayed polyurethane foam or SPF)
	Any	*****	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		Replace timber wall plates and joists on sleeper walls with corrosion resistant steel alternative
	Any		Install a damp proof material around the ends of floor joists where built into walls

	Any		Internal lining of timber-framed walls - use marine ply/WBP-bonded ply, BS1088. demountable fixings, sacrificial joints and lime-based finishing layer
	Any		Replace corroded timber frames with treated timber
	Any		Replace corroded steel frames with galvanised steel equivalents
	High	*****	Seal between wall, floor and partitions (continue concrete seal 0.5m up walls)
	Any	*****	Avoid (non-breathable) vinyl wall-coverings, use microporous paint temp finish, then paper (breathable wallpapers must be affixed with breathable adhesives)
Water compatible floors	Any	*****	Avoid fitted carpets, parquet and laminate flooring: use ceramic tiles, loose fitting rugs; removable carpets (eg fixed with hook-and-loop -tape or hooks-&-eyes set into floors)
	Any	*****	Vinyl/thermoplastic tiles replaced by ceramic tiles (vinyl sheet flooring can be retained)
	Any	*****	Quarry tiles, coated to prevent staining
	Any	*****	Cement-rich floor screed
	Any		Foam glass and mastic asphalt screed
	Any	*****	3mm epoxy resin waterproof floor treatment added to concrete floor screed
	Any	*****	Suspended floors - preservative-treated joists/ floorboards
	Any		Marine ply (instead of chipboard/ other timber)
	Any	*****	Suspended floors (brick and block) - need to create low point/well in soil or sub-floor, to collect water then pump out
	Any		Solid floor/Replace timber floor with solid concrete (and tile finish with falls for drainage to sump/pump) concerns with breathability
	Any	*****	Ensure effective connection between the damp-proof membrane for the floor and the damp proof course in the wall
	Any		If oak blocks on concrete need replacing, use tiles. If oak blocks set in bitumen need replacing, then use screed and new finish on top.
	Any	*****	For suspended floors, if oak floorboards need replacement, then use (cheaper) treated timber.
	Any		Treated floorboards, WBP plywood, screed or tiles to replace chipboard
	Any	*****	Remove ash-bedding from underneath quarry tiles in Victorian houses (retains moisture and impedes drying out)
	Any	*****	Clear and repair air bricks/vents to suspended timber ground floors (aids drying out process via airflow imps)
	Low		Move airbricks to above expected flood level and duct down to floor void (periscope principle)
	Any	*****	Closed cell insulation in boards for floors
	Any		Silicon-mineral board instead of chipboard (concerns with breathability)

	Any		Design floor levels and exit routes to shed water once flood has receded to minimise standing water.
	Any		Replace the kitchen units with proprietary plastic or water-resistant alternatives (PVC or steel) and build off floor; use acrylic or removable wooden doors; steel kick-boards.
Water compatible kitchen fittings	Low	*****	Fit kitchen units with extendable plastic or stainless steel feet or support on raised brick/stonework (for floods <50mm deep only)
	High	*****	Replace ovens with raised, built under type
	High	*****	Oven/microwave mounted part way up wall (shoulder height/eye-level)
	Med		Tanking around cooker, with its own flood barrier.
	Any	*****	Specify the least expensive kitchen possible and to expect to replace it (aka Sacrificial approach)
	Any	*****	Free standing removable units (eg pitch pine), then carry upstairs when flood warning rec'd.
	Any		Use Belfast sink on brick base, not a 'sink unit'
	Any		If space permits, brick-built carcasses concealed by 'normal' looking but removable doors
	High	*****	Limit number of base units and have removable doors so only bottom carcases need replacing
	High	*****	Avoid built in appliances and have strong work surfaces that can support appliances during a flood
	Low	*****	Removable kick boards - wrapped around units avoiding end sections that extend to the floor
	High	*****	Better to have a table and/or high-level 'breakfast bar' than a (fixed) island.
	Any		Avoid kick heaters and use radiators instead.
Water compatible bathroom fittings (ground flr/ basements)	High	*****	Waterproof tile adhesive and water-resistant grout for tiled walls
	Any		Replace baths having chipboard stiffening panels with cast iron or pressed steel models
	Any	*****	Some acrylic baths have integral encapsulated (ie waterproofed) base-boards (cost same as normal acrylic baths).
	Any	*****	Have a wet room rather than shower tray.
	Any	*****	Use of an anti-siphon toilet
	High	*****	No vanity unit around wash-hand basin use wall mounted cupboards/shelves
	Any	*****	Gravity drained toilets (grnd floor) replaced with pumped system
	Med		Sump and pump system (with alarm in case pump fails)
Building Services	High		Raised electrics = dual purpose, as more accessible for older/less mobile people when raised.
	High	*****	Electric cables drop from first-floor level down to sockets at high level on walls;

	Any	*****	Central heating pumps and controls raised above max expected flood level; and any pipe insulation below exp'd flood level replaced by closed-cell type
	Any		CH control unit moved upstairs, so radiators serving upper floor(s) can still be used (ground floor underfloor heating only).
	Med	*****	Wall-hung fires >1m above flood level (depending on expected flood depth)
	Any	*****	Raised meters 1m above expected flood level, and use plastic housing.
	Any	*****	Boiler mounted above max expected flood level
	Any	*****	Seal radiators with polyethylene sheeting
	Any		Use enamelled radiators, which wipe clean after flood.
	Any	*****	Use demountable radiators.
	Any		Use an enamelled finish woodburning stove (cast iron rusts after a couple of floods)
	Any		Ensure woodburners allowed to go completely cold before water enters (cast iron will crack if still hot)
	Med		Raise woodburner up on robust metal support.
	Any	*****	Where possible, incoming telephone lines/cable services/ and internal control boxes should be raised above the expected flood levels.
	High		Through-wall service connections raised >900mm above the ground floor level
	Any	*****	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	*****	Place services including electrics in easy to access conduits to allow draining and drying
	Any		Anti backflow devices on foul drainage
	Any		Anti-backflow valves (NRVs) to sewer pipework AND dishwasher/washing machine pipes.
	Any	*****	Toilet 'bungs' ; sink and shower 'bungs' (to prevent sewage ingress)
	Any	*****	Water supply pipework insulation can be replaced with flood resistant closed cell material below the expected flooding level.
	High		Outside fuel tanks raised on concrete plinth (standard plastic bunds float, pipes then fracture)
Doors/windows/staircases	Any	*****	Water compatible steps/stairs (partly or fully eg resilient staircase of solid timber/steel
	Med	*****	Sep piece of carpeting for bottom-most stairs, removable when flood warning received - then nail back down (but looks like normal fitted stair carpet).
	Any	*****	If normal staircase has to be replaced, use open-tread type made of oak. (Half the wood, so cost-neutral at rebuild stage).

	Any		Replace internal doors with solid hardwood doors (caution - avoid cheap 'oak-style' doors)
	Any	*****	Consider installing cheapest possible doors to be sacrificial.
	Any	*****	Removable /light weight internal doors/replace door hinges with rising butt hinges. These allow doors to be lifted off.
	Any		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	*****	Retain traditional solid wood doors, on rising butt hinges, and use on trestles to support furniture etc
	Any	*****	For wooden windows and external doors - use oil-based or waterproof stains, paint or varnish timber
	Any	*****	Replace doors, windows, skirting boards, architraves, doorframes and window frames with fibreglass (GRP), PVC-U or similar
	High	*****	Hopper style windows with fixed lower panels below the likely flood depth. (caution ensuring adequate low level escape routes)
	Any		Replace skirting boards with ceramic tiles
	Any	*****	Treat wood skirting, painted on ALL sides
	Any	*****	Oak skirting held with screws, removable.
	Any	*****	Use of toughened glass in doors/windows /cabinets (reduce damage from floating debris)
	Any	*****	Use non-corrosive door/window hardware fittings (eg stainless)
	Med	*****	Wall cupboards/built-in-wardrobes - rebuild off floor with plastic legs, concealed by removable plinth
	Any	*****	Use PVC wall cupboards instead of timber
	Any		Bookcases formed of fixed brackets but with easily removed shelving.
	Any	*****	Oak exterior doors oiled repeatedly with linseed oil
Speed of reoccupation/drying	Any		Speed reoccupation and drying through optimum height of the floor air gap (to aid speed of drying of gypsum boards) needs heating cable in vertical air gap.
	Any	*****	Rapid drying techniques (rather than trad slow drying/dehumidifiers etc) - depends on building suitability
	Any	*****	Steam cleaning of plastics/hardwoods
	Any	*****	Buy wet/dry vacuum cleaner to remove pockets of water
	Any	*****	Maintain stock of water absorbing bags to absorb seepage/clean up water
Contents Protection	Med	*****	Plinths (or equivalent methods) for white goods
	Any	*****	Waterproof bags for furniture
	Ay	*****	Water-tight covers for appliances
	Any	*****	Use polytunnel-grade thick plastic, plus recycled carpet underlay to prevent corner puncturing it, and duct tape to hold it all in a parcel
	High	*****	Raise furniture on bricks/breeze blocks/plastic trestles (or similar) before water enters.

	High	*****	Robust shelving system (marine ply) to support white goods
	Any	*****	Relocate valuables/docs etc
	Any	*****	Move furniture to pre-arranged storage / used pre-arranged removal firm; Hire/borrow etc van/flat-bed to move your furniture etc to a location out of floodplain.
	Any		Cast iron woodburning stove enamelled (or they rust)
	Low		Woodburner raised up 6"
	Any	*****	Plastic kitchen stools
	Any	*****	Lightweight settees etc, easily lifted upstairs
	High	*****	Wall mounted TV
	Any	*****	Buy a sack truck for moving things
Miscellaneous	Any	*****	Businesses should include flooding in continuity plans
	Any	*****	Locate computers above flood level (businesses and domestic users)
	Any	*****	Flood warning devices/alarms property-specific Community-based (eg for small watercourses/surface water flooding) - high overall cost but shared among multiple beneficiaries.
	Any	*****	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)
	Any	*****	Protect the upstairs carpets (plastic sheeting/dust sheets) before carrying loads up from ground floor
	Any		Flood flaps/vents/ports - allow water to enter and exit sealed 'crawlspaces' or unoccupied basements, thus equalising hydrostatic pressure (FEMA requirement in USA)
	Any	*****	Sealed buckets and lids, to allow small items to float
	Med	*****	When raising wooden furniture on bricks, wrap bricks in plastic to prevent water wicking up into legs
	Any	*****	Switch off all electrical appliances before floodwater enters, to avoid damage from short-circuiting
	Low	*****	Plastic furniture raisers, as sold for use by older people to raise seat heights
	Low	*****	Choose furniture with legs, not castors (eg sofas), easier to raise further with bricks
	High	*****	Use carpenters’ telescopic metal trestles to raise heavy furniture (more robust than plastic trestles)
	Low	*****	Choose TV stand made of glass and metal, not wood
	Any	*****	Generator back up for pumps, in case electrics fail
	Any	*****	Biocidal detergent for post-sewage flood clean up (as used in hotel/catering trades)

Appendix 2: Costed repairable packages

Packages Descriptions

Package Number: A1

House Type: Semi-detached

Net Internal floor area: 49m²

Building Elements / Parameters	Existing construction (like for like reinstatement)	Resilient option	Like for like reinstatement cost (£)	Additional Resilient cost (£)
External wall construction:	Solid brick wall internally rendered with lime plaster – (the existing lime plaster required to be hacked off up to 1.2m)	Add salt resistance additive to lime plaster. This is additional cost.		
Internal wall construction	Rendered block wall with lime plaster.	**As existing but with the addition of salt resistance additive**		
Floor construction	Suspended timber floor	**As existing**		
Floor finishes	Carpeted floor throughout with the exception of bathroom which has vinyl sheet.	Lay removable carpets. Vinyl sheet in the bathroom		
Type of external door	Hardwood panel door	As existing		
Type of internal door	Softwood flush doors with butt hinges	Use rising butt hinges for easy removal of doors		
Services	Electric socket located below the flood level	Rewire ground floor; including extra over cost	**£8,950.00**	**£2,470.00**

		of raising socket above flood level and installation of non return valve		
Kitchen	MDF kitchen units with non removable doors	Sacrificial carcasses with removable doors		
Bathroom	Wooden bath panel and vanity unit mounted on the floor	Install acrylic bath panel and mount vanity unit on wall		

Packages Descriptions

Package Number: A1 (2)

House Type: Mid-Terraced

Net Internal floor area: 37m^2

Building Elements / Parameters	Existing construction (like for like reinstatement)	Resilient option	Like for like reinstatement cost (£)	Additional Resilient cost (£)
External wall construction:	Mixture of solid brick and cavity wall construction. The cavity wall was filled with Rockwool insulation. Internally rendered with gypsum plaster - (the existing gypsum plaster was hacked off up to 1.2m)	Cement sand render with 3mm thick finishing coat. Install close cell insulation full height		
Internal wall construction	Rendered block wall with gypsum plaster.	**Cement sand render**		
Floor construction	Solid concrete floor	**As existing**		
Floor finishes	Laminate floor finishing throughout.	Quarry floor tiles (kitchen and bathroom). Ceramic floor tiles in other rooms with water resistant grout		
Type of external door	Hardwood panel door	As existing		
Type of internal	Softwood flush	Use rising butt		

door	doors with butt hinges	hinges for easy removal of doors	**£5,530.00**	**£1,890.00**
Services	Electric socket located below the flood level	Rewire ground floor; including extra over cost of raising socket above flood level and installation of non return valve		
Kitchen	MDF kitchen units with non removable doors	Sacrificial carcasses with removable doors		

Packages Descriptions

Package Number: B (7)

House Type: Semi-detached

Net Internal floor area: 48m^2

Building Elements / Parameters	Existing construction (like for like reinstatement)	Resilient option	Like for like reinstatement cost (£)	Additional Resilient cost (£)
External wall construction:	Brick cavity walls with fairfaced blockwork; inner leaf of cavity wall was finished with gypsum plasterboard. The cavity wall was filled with Rockwool insulation.	Water resistant board panel and apply 3mm skim coat. Closed-cell insulation		
Internal wall construction	Internal wall is of stud partitions, with gypsum plasterboard	Fix water resistance board panel and apply 3mm skim coat		
Floor construction	Suspended timber floor	**As existing**		
Floor finishes	Laminate floor (dining and hallway); carpet (lounge) and ceramic tiles (kitchen and cloakroom).	Ceramic floor tiles in the lounge, dining and hallway; ceramic floor tiles in the kitchen and cloakroom as existing with water resistant grout		
Type of external door	Six panel door	Install UPVC door		
Type of internal door	Softwood flush doors with butt hinges	Use rising butt hinges for easy		

		removal of doors	**£7,410.00**	**£3,520.00**
Services	Electric socket located below the flood level	Rewire ground floor; including extra over cost of raising socket above flood level and installation of non return valve		
Kitchen	MDF kitchen units with non removable doors	Sacrificial carcasses with removable doors		

Packages Descriptions

Package Number: C (8)

House Type: Mid-Terraced

Net Internal floor area: 72m^2

Building Elements / Parameters	Existing construction (like for like reinstatement)	Resilient option	Like for like reinstatement cost (£)	Additional Resilient cost (£)
External wall construction:	Brick cavity wall internally finished with gypsum plasterboard.	Apply ventilated cavity membrane to the inner leave of the external wall (assuming up to 1.20m high) Fix gypsum plasterboard as existing but horizontally (sacrificial), Closed-cell insulation		
Internal wall construction	Internal wall is of stud partitions, with gypsum plasterboard	As existing but fix horizontally (sacrificial)		
Floor construction	Concrete floor	**As existing**		
Floor finishes	Carpets in the dining, lounge, hallway and study; ceramic floor tiles in the kitchen, conservatory and cloakroom.	Lay removable carpets. Ceramic tiles in the Kitchen, conservatory and cloakroom as existing		
Type of external door	Six panel door	Install UPVC door		
Type of internal	Softwood flush	Use rising butt		

door	doors with butt hinges	hinges for easy removal of doors	**£7,770.00**	**£4,770.00**
Services	Electric socket located below the flood level	Rewire ground floor; including extra over cost of raising socket above flood level and installation of non return valve		
Kitchen	MDF kitchen units with non removable doors	Sacrificial carcasses with removable doors		