APPENDIX E: **ADAPTATION LEVERS: EVIDENCE BASE**

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E.1 Managing the probability of flooding

The Foresight Future Flooding studies concluded that physical engineered defences are likely to continue to play a significant (but not sufficient) role in managing future flood risks (Evans et al, 2004b). At the coast this finding is supported by a more recent review of Shoreline Management Plans (England and Wales only) which confirms a policy of 'hold the line' in the majority of coastal areas (ASC, 2013). The ASC analysis (for England only) found that 54% of the coastline is currently covered by Hold-the-Line, with 43% under No Active Intervention and 2% Managed Realignment. However, the proportion of coastline under Hold the Line declines to 39% by the 3rd epoch (50-100 years) with Managed Retreat increasing to 16%. The Environment Agency's Long Term Investment Scenarios (Environment Agency, 2014) are also primarily based on the on-going provision of defence infrastructure.

In Scotland, the Flood Risk Management (Scotland) Act 2009[1] (FRM Act) focuses on a risk based approach to managing flooding. The FRM Act encourages responsible authorities to consider a wide range of options, including *'natural flood management'*, whilst continuing to recognize the important role of traditional defences in protecting people and property.

Northern Ireland has a similar focus under the umbrella of *'living with rivers and the sea'* that recognises the continuing need to provide new flood alleviation infrastructure within the context of a portfolio of flood management measures[2].

The Flood and Coastal Risk Management Appraisal Guidance (Environment Agency, 2010) includes a basic incremental benefit cost test that encourages the provision of a standard of protection that is higher than would be provided according to a standard benefit to cost test which might show the highest benefit to cost ratio from minimal and relatively ineffective interventions because the costs would be so low (e.g. just sandbagging selected key properties). The implementation of the Flood and Coastal Resilience Partnership Funding policy statement (Defra, 2011) also can encourage the provision of higher standards when local contributions are used justify more costly defence scheme than would be justified through a standard benefit cost approach.

Examples of the real options and adaptive flood risk management also tend to focus on managing the probability of flooding (for example the Treasury Green Book – Supplementary Guidance on dealing with Climate Change) and the political response to the 2013/14 Winter floods reinforced a defence led approach as expressed through the allocation of new funds for flood alleviation schemes announced by the Government in the aftermath of the floods. Nevertheless the Foresight conclusion of the insufficiency of an engineering-only approach remains generally valid.

[1]http://www.legislation.gov.uk/asp/2009/6/pdfs/asp_20090006_en.pdf Accessed 10 May 2015

[2]http://www.dardni.gov.uk/living-with-rivers-and-the-sea.pdf Accessed 10 May 2015

E.1.1 Construction/maintenance of coastal and river flood defence infrastructure

A wide range of flood defence infrastructure (for example linear defences, pumps, barriers, beaches etc.) is used to reduce the chance of flooding. The protection they provide is not absolute (providing protection up to a notional design storm) and, as occasionally witnessed, they may be overtopped or even breached.

The UK has a long history of providing river and coastal defences with modern approaches stretching back to 1930 when the Land Drainage Act was passed following the serious flooding in 1927 and the publication of the Royal Commission report on this event. As a result, many towns and cities (both at the coat and on rivers) across the UK now rely upon built defences. Table E1 presents the number of properties within defended areas today and the standard of protection they receive.

Table E1 Present day: Number of properties in coastal and fluvial defended areas

Representative Standard of Protection (years)	No. of properties notionally protected		
	England and Wales	Scotland	Northern Ireland
<1:10	58,000	0	0
>1:10 <1:75	220,000	1,600	31,000
> 1:75 <1:500	570,000	89,000	13,000
>1:500	250,000	0	0

Note: The numbers in the above table have been derived from the data used in the FFE

In England and Wales investment in flood defences since 2011 has helped to reduce flood risk to around 180,000 homes in the last three years and improve the condition of many defences. The planned yearly spend on flood defences is however lower for the current period (2011/12 – 2014/15) - after taking into account the effect of inflation – than in previous years. This remains the case even allowing for efficiency savings and additional funding contributions secured to date from local authorities and businesses (see Defra (2011) for the 'Partnership funding" initiative). The ASC highlight that if the current investment plans for flood defence in England continue into the future, the country will face an increasing risk of flooding due in part to climate change, as well as asset deterioration and population growth (ASC, 2012). Less information is available on the long term investment plans in Scotland, Northern Ireland and Wales.

In general, however, it is accepted that continued investment in flood defences, either from public or private sources, has a role to play in managing future flood risk and that such investments are likely to continue to be prioritised based on an assessment of risk and an associated consideration of benefits and costs. It is however likely that the case for investment will be increasingly influenced by:

- **New arrangement for subsidizing flood insurance (Flood Re) has a finite life of some 25 years (Defra, 2014).** After this those exposed to high levels of flood risk will be asked to contribute the full costs of insurance cover, and this is likely to lead to increasing demands from this population for higher levels of flood protection to minimize their personal insurance costs. Indeed, it may be in the interests of those involved to contribute more towards the protection schemes that they require, given that this will both complement national funding to support a given local scheme (through the Partnership Funding arrangements in England for example) and will (presumably) reduce these insurance premiums back to something like current or anticipated Flood Re levels.
- **Innovation in delivering adaptive and multifunctional defences.** The concept of adaptation is increasingly promoted in appraisal guidance (for example in the Treasury Green Book Annex 1, HM Treasury, 2009, Defra Policy Statements, Defra, 2009 and Environment Agency guidance, Brisley et al, 2015). Developing adaptive solutions requires innovation and a willingness to think more strategically and collaboratively about the design and delivery of flood and coastal

defences. As a result, the delivery of adaptive strategic is not yet mainstream (despite some high profile successes, such as Thames 2100).

In the high(er) adaptation scenario these two drivers may, in some areas, enable future defence standards to be maintained or even enhanced, despite climate change. In the low(er) adaptation scenario limited innovation is assumed and because of this it is difficult (and hence costly) to adapt future defences. As a result standards of protection reduce in all but the highest potential consequence areas.

Characterization within the Future Flood Explorer (FFE)

The Future Flood Explorer (FFE), described in Appendix F, incorporates the performance of defences through two variables:

- the representative **Standard of Protection** (rSOP) provided to a Calculation Area: The rSoP is expressed in terms of the return period, in years, of a storm event that would overtop those defences assuming they remain structurally intact. Point defences such as barriers and pumps influence this standard. Under this Adaptation Measure the rSOP is therefore influenced by either the construction of new or improved linear defences (for example by raising crest levels) for improving point assets such as pumps, barriers.

  Future changes in the rSOP are determined through a two-step process (Figure E1):

  - First the change in rSOP under a particular climate future assuming no adaptation is calculated; for example if the crest of a defence remains at the same level the rSOP would fall from say 1:100 to 1:10 year return period.

  - The influence of adaptation is then accounted for by reducing this <u>decrease</u> in the rSOP by a given proportion. For example say the crest level of a defence is raised, mitigating 50% of the reduction in standard driven by climate change, the future SoP of the defence in the example above would be 1:55 years (i.e. 50% of the reduction in standard (100-10 = 45 years) is avoided, leading to a future standard of 100-45 = 1:55 year return period).

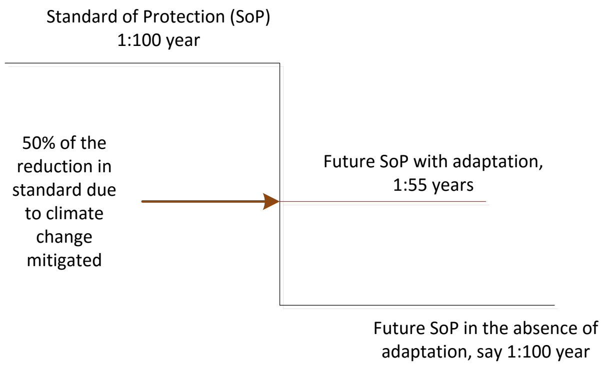


Figure E1 Actions taken to manage the standard of protection of defences are characterized as a reduced impact of the climate change

- the representative **Condition Grade** (rCg) of those defences: The rCg reflects the average Cg of the defences associated with a given Calculation Area. Within the FFE the rCg is used to modify the potential for defence failure. Changes in the rCg are implemented based on an assumed change in rCg from present day to the future.

Note:

The rSOP is used as a reasonable indicator of the potential consequences of flooding (i.e. it is assumed that the highest standards are provided in areas where the consequences of a flood would be highest). As a result continued investment is more likely in high rSoP than in areas protected to a lower standard (because, it is assumed, that the risk-based case for investment is likely to be more easily made in high consequence systems). We recognize that this implies that current standards of protection are in some way optimal with regard to the risk posed in any particular location. There will be exceptions to this of course, but given the significant history of investment (e.g. since the Land Drainage Act 1930) and a formal risk based approach across much of the UK since the early 1990s (e.g. MAFF PAGN, 1993), this is considered a credible assumption.

It is also assumed that a risk-based approach continues to be used to target investments in maintenance in all futures and the majority of defence assets are maintained at a Condition Grade 3 (i.e. Fair condition) or better. This is supported by an analysis of existing assets for England that reveals relatively few properties protected by Condition Grade 4 or 5 assets (Table E2, around 4% of properties are protected by CG 4 or 5 assets). While Table E2 does not show that the proportion of higher Condition Grade assets increases with the Standard of Protection provided, this may be a result of shortcomings in the underlying data used (rather than a property of the real world defences). Nevertheless, the assumption made above that rSOP and rCg are proxies for high potential consequences areas and a positive investment case is considered reasonable.

Table E2 Number of properties in defended areas for the UK

Representative Condition Grade	Percentage of properties within the coastal and fluvial floodplain with defences at a given standard of protection (years) and condition			
	<1:10	>1:10 <1:75	> 1:75 <1:500	>1:500
1	200	1,100	11,000	0
2	17,000	110,000	270,000	210,000
3	37,000	130,000	310,000	280,000
4	3,500	7,600	26,000	14,000
5	190	36	300	0
Undefended	560,000			

This assumption is also supported by an analysis of the LTIS (2014) optimized policy choices (an ambition investment scenario similar to the high(er) adaptation presented here). LTIS Policies 5 and 6 (which both improve flood defences and reduce risk) area applied preferentially to locations with a high current SoP (better than 1:75); Policy 3 (maintain crest level) is applied roughly equally to defences with SoPs above and below 1:75.

Table E3 Number of residential properties in defended areas of England and the optimised LTIS policies applied.

Current SoP	**LTIS Policy Choice**					
	1 Do nothing	2 Do minimum	3 Maintain crest level	4 Maintain current flood risk	5 Improve	6 Improve +
<1:10	12,000	0	3,000	2,300	7,900	21,000
1:10-1:75	38,000	0	68,000	14,000	16,000	72,000
1:75-1:500	84,000	0	86,000	23,000	130,000	180,000
>1:500	72,000	0	980	2,100	110,00	69,000
Undefended	120,000	0	81,000	6,000	36,000	80,000

The evidence above has been used in establishing the changes to rSOP and rCg under the three adaptation scenarios:

Changes in rSOP:

- ***CLA scenario****:* In some areas where the benefit cost case is weakest the standard of protection provided reduces as investment fails to keep pace with climate change. Areas with the highest standards today (such as the Thames estuary) continue to be well protected and standards are maintained into the future.
- ***High(er) adaptation scenario:*** An increased willingness to pay (for example through partnership funding systems in England) and design innovations enable the rSOP to be improved in some of the highest consequence areas (i.e. those with a present day standard of 1:500 years or greater), and the scale of reduction in rSOP in other areas to be reduced.
- ***Low(er) adaptation scenario:*** Standards in all but the highest consequence areas (i.e. those areas with a present day standard of 1:500 or greater) reduce significantly.

Changes in rCg:

- ***CLA scenarios:*** The majority of defences systems (i.e. those with an actual or target condition of rCg = 4 or higher) continue to be maintained at rCg = 4 or better. In areas protected by defences with rCg of 5, the case for continued maintenance or improvement is assumed weak and with time they deteriorate further.
- ***High(er) adaptation scenario:*** The condition of the most important defences are improved. This means assets with a Cg of 2 or 3 are improved to a Cg of 1 or 2 respectively. Assets with current Cg below 3 remain unchanged.
- ***Low(er) adaptation scenario:*** The majority of areas (i.e. those with rCg of 3 or better) continue to be maintained at rCg = 3 or better. In areas protected by defences with rCg of 4 or less it is assumed that the assets are no longer maintained due to a reduction in available funds

Note:

1. The present day values of rSOP and rCg are derived directly from the available data as a defence length weighted average (see Appendix F). This ensures that the rSOP and rCg are locally representative and hence any change reflects that local context.
2. Population growth and development in areas of flood risk is likely to modify the investment case for raising standards in particular areas. This feedback is not considered here.

Table E4 Construction/maintenance of coastal and river defences

Adaptation potential (narrative)

CLA: In some areas where the benefit cost case is weakest the standard of protection provided reduces as investment fails to keep pace with climate change. Areas with the highest standards today (such as the Thames estuary) continue to be well protected and standards are maintained into the future. The majority of defences systems (i.e. those with an actual or target condition of rCg = 4 or higher) continue to be maintained at rCg = 4 or better. In areas protected by defences with rCg of 5, the case for continued maintenance or improvement is assumed weak and with time they deteriorate further.

High(er): Willingness to pay through initiatives such as partnership funding (in England) and innovative designs enable standards to be improved in highest consequence areas (i.e. those with a current rSOP> 1:500) and standards to be maintained for many others (i.e. those with a current rSOP>-1:75 and < 1:500). The condition of the most important assets is also improved (i.e. those with a current rCg> 3). Although less effort is devoted to lower standard systems (current SOP< 1:75), the reduction in standard is less than under the CLA.

Low(er): Effort is mainly directed towards the higher consequence areas and standards are maintained in these areas (i.e. rSOP>1:500). In lower risk areas, standards reduce in response to climate change. Defence condition continues to be appropriately managed (e.g. in England, as set by the EAs target condition grade).

Adaptation potential (quantified)

Changes in the representative Standard of Protection

The proportion of the climate change driven reduction in standard that is prevented

- 0 - no adaptation of defences (standards reduce with climate change)
- 1 - the standard of protection is a maintained to keep pace with climate change
- >1 - standards are raised in despite climate change (2 implies standards have doubled in real terms)

rSOP today (years)	The reduction in standard due to climate change that is avoided								
	CLA			High(er)			Low(er)		
	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
<10	0.25	0.25	0.25	0.75	0.75	0.75	0	0	0
>=10 and <75	0.75	0.75	0.75	1.0	1.0	1.0	0.25	0.25	0.25
>=75 and <500	1.0	1.0	1.0	1.5	1.5	1.5	0.25	0.5	0.5
>=500	1	1	1	1.5	1.5	1.5	1	1	1

Changes in the representative Condition Grade

The change in the present day condition grade and target condition grade.

- NC – no change, 6 – loss of all effective strength (equivalent to undefended)

rCg today	*Future Representative Condition Grade (rCg)*								
	CLA			*High(er)*			*Low(er)*		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
1 or 2	*NC*	*NC*	*NC*	*1*	*1*	*1*	*NC*	*NC*	*NC*
3	*NC*	*NC*	*NC*	*2*	*2*	*2*	*NC*	*NC*	*NC*
4	*NC*	*4*	*4*	*NC*	*NC*	*NC*	*4*	*6*	*6*
5	*NC*	*6*	*6*	*NC*	*NC*	*NC*	*5*	*6*	*6*

E.1.2 Working with natural processes at the coast and in estuaries: Managed realignment

Experience in England and Wales

The 130,000 hectares of coastal habitat[3] along England's coastline play a critical role in reducing flood and erosion risks to people, properties and land. Around half of all fixed sea defences in England are protected and buffered against waves and storm surges by coastal habitats (ASC, 2013). As sea levels rise beaches and coastal habitats reduce in width as they are squeezed between the fixed backshore structures and the high water mark (so-called 'coastal squeeze'). An estimated 70% of inter-tidal habitats (72,000 hectares) may not be able to adapt naturally to sea level rise over the rest of the century because they are squeezed in this way (ASC, 2013). This in turn reduces the protection they provide to backshore defences.

In response, managed realignment has been recognized as an option that can allow coastal habitats to migrate inland in response to sea level rise and reduce the cost of maintaining defences (by dissipating wave energy before it reaches the retreated defence line). Managed realignment can also help restore sediment movement to the downdrift coast. Dawson et al, 2009 showed that artificial defences on eroding cliffs can starve and interrupt sediment supply and increase flood risk downdrift. Removing these defences may lead to economic losses on the cliffed coastline, but also has the potential to reduce flood risk downdrift. Although not a significant feature of present day practice this could be more significant in the future (in some areas, subject to the exact local circumstances).

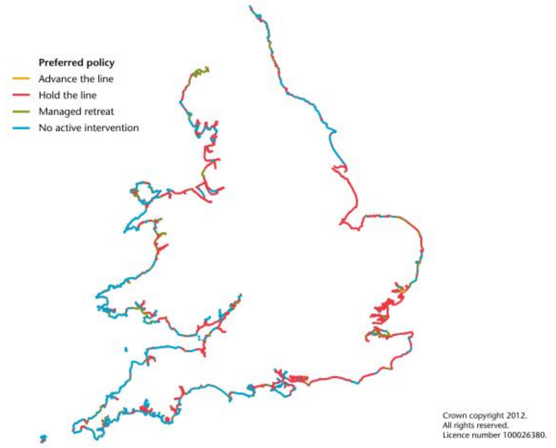
Shoreline Management Plans (SMPs) in England have a combined goal to realign some 9% of the coastline by 2030, rising to 14% by 2060 (Table E5, Figure E2). The implementation of these plans, developed by local authorities in partnership with the Environment Agency and community groups, would involve breaching, removing or setting-back some existing sea defences. Delivering realignment of 9-10% of the coastline in England would lead to the creation of 11,000 hectares of coastal habitat by 2030, rising up to 17,000 hectares by 2060 (ASC, 2013).

The current rate of managed realignment since 2000 (in England) would need to increase five-fold, to around 30km a year, to meet the 2030 aspiration. Around 1% of the coastline has been set back since the 1990s, with some 1,300 hectares of coastal habitat created by 39 separate realignment schemes. Seven major projects currently being planned should set back an additional 0.8% of the coastline by 2016 creating 2,200 hectares of new coastal habitat (ASC, 2013).The implies around 2% of the coastline in England has been (or will have been by the end of 2016) realigned.

[3]Comprising both supra-tidal habitats (i.e. located above the mean high water mark including habitats such as sand dunes, shingle beaches, maritime cliffs) and inter-tidal habitats (i.e. located between the mean low and mean high water mark, including habitats such as saltmarsh and mudflats).

Table E5 Summary of Shoreline Management Plans goals (ASC, 2013)

Policy options	Current state of the coastline	SMPs preferred policy		
		0-20 years	20-50 years	50-100 years
	% of the English coastline			
Hold the Line (HtL)	54%	47%	41%	39%
No Active Intervention (NAI)*	43%	43%	44%	44%
Managed Realignment (MR)	2%	9%	14%	16%



Source: Environment Agency National Coastal Erosion Risk Mapping (2011)

Notes: This map covers preferred managed options indicated in the 22 Shoreline Management Plans covering England and Wales.

Figure E2 Summary of SMP Policy choices (ASC, 2013)

Note:

1. The ASC study reviewed all 22 SMPs in England. Similar analysis has not been carried out for Scotland, Wales and Northern Ireland.
2. A separate analysis has been carried out as part of the current study to investigate the potential vulnerability of the coastline to increasing sea levels. This analysis is reported in Chapter 8 of the main report.

Experience in Northern Ireland

Coastal squeeze is not perceived as a significant issue in Northern Ireland with only one realignment project undertaken to date. In 2009 Rivers Agency breached the Kilnatierney sea defence, a relatively small structure near Grey Abbey on the north-eastern shoreline of Strangford Lough. The landowner (The National Trust), NI Environment Agency and Rivers Agency) cooperated in the removal of the defence and restoration of the land behind as wetland. The maintain objectives of the project centred on environmental benefits and cost savings rather than enhancing the flood defence standard.

Experience in Scotland

The EU Eurosion study (EU, 2004) estimated that 12% of the Scottish coastline is eroding, and that 7% of the coastline is defended; much less than in England. Significant differences therefore exist between the English and Scottish coastlines and consequently the opportunities / need for managed realignment (Werritty et al., 2012). There are for example (i) relatively few opportunities for re-alignment (reflecting the dominance of rocky coastlines – especially in the north and west); (ii) the minimal number of local authority-funded coastal defences and partial information on their SOPs and their current state, (iii) the lack of statutory SMPs in Scotland (although some local authorities have developed them on a non-statutory basis) and, (iv) the lower threat posed by relative sea level rise for much of Scotland. Managed realignment (MR) has not been (and is not anticipated) to be a significant adaptation response in Scotland.

Characterization within the Future Flood Explorer (FFE):

Within the FFE the influence of managed realignment is characterised through the rSOP. It is assumed that realignment is only effective in raising the standard during more frequently occurring storms (below 1:75). For higher return period storms MR is assume to have no impact.

Under the three adaptation scenarios the following assumptions are made:

- ***CLA*****:** The targets set out within the SMPs for England are met across the UK with 9% of the coastline realigned by the 2030s, 14% by 2060s and 16% by 2080s. This acts to reduce the impact of climate change on all coastal defences with an rSOP of less than 1:75 years. The rSOP of high standard defences is unaffected.
- ***High(er) adaption scenario:*** There is a greater emphasis on management realignment to reduce maintenance costs and provide compensatory habitat and the length of coast/estuary realigned increases to 15% by 2030, 25% by 2050 and 30% by 2080. This enables a great proportion of the climate change reduction reduce in standard to be mitigated for coastal defences with an rSOP of less than 1:75 years.
- ***Low(er) adaption scenario:*** Managed realignment schemes reduce as targets fail to be met. This reflects increasing difficulty in implementing realignment schemes due to objections at a community level as a transition from a hold the line to a managed realignment policy is sought. A few schemes continue to go ahead where the environmental or cost case is greatest. This results in only 5% of the coast line being realigned by 2030 and 9% by 2050 (with no further change to 2080).

The quantified implementation of these changes is summarized in Table E6.

Note:

1. It is recognized that a target of 16% target for managed realignment is unrealistic for Scotland and Northern Ireland given their limited length of defence coastline. In the context of this study however the targets set out for England are nonetheless adopted.
2. Management Realignment is usually associated with mitigating the impacts of coastal squeeze on coastal habitats, which in turn reduces the costs of maintaining defences and improves the standard of protection of the new defense line. Only the impact on standard is considered here. Although no specific modelling has been undertaken, this impact is assumed to be relatively small.
3. No attempt is made to consider the environmental gains here (habitat maintained/created or other wider benefits) or the local benefit cost case (that would vary on a case by case basis). The nature of the analysis approach used here precludes this type of local assessment. In reality local considerations, and the detailed design of the managed realignment, will be fundamental considerations when deciding if, or not, managed realignment goes ahead.
4. Given the limited impact on the standard of protection, no attempt is made to target the specific length of coast that is realigned. Instead it is assumed that all defences within a given coastal region are afforded a limited but improved Standard of Protection.
5. It is recognized that the targets for realignment of 9% by 2030s, 14% by 2060s and 16% by 2080s as set out across the SMPs within England are not realistic for Scotland. Given a coastline with limited exposures of soft sediments and/or salt-marshes, they are too optimistic for Scotland and exceed the length of defended coastline. Despite this the targets as set out in England are used, although not ideal this is considered reasonable although will lead to an inevitable overstatement of the potential impact of this measure in Scotland. Similarly the potential for realignment is likely to be overstated in Northern Ireland.

Table E6 Managed realignment

Adaptation potential (narrative)

CLA: The targets set out within the SMPs for England are met across the UK with 9% of the coastline realigned by the 2030s, 14% by 2060s and 16% by 2080s. This acts to reduce the impact of climate change on all coastal defences with an rSOP of less than 1:75 years. The rSOP of high standard defences is unaffected.

High(er): There is a greater emphasis on management realignment to reduce maintenance costs and provide compensatory habitat and the length of coast/estuary realigned increases to 15% by 2030, 25% by 2050 and 30% by 2080. This enables a great proportion of the climate change induced reduced in standard to be mitigated for coastal defences with an rSOP of less than 1:75 years.

Low(er): Managed realignment schemes reduce as targets fail to be met. This reflects increasing difficulty in implementing realignment schemes due to objections at a community level as a transition from a hold the line to a managed realignment policy is sought. A few schemes continue to go ahead where the environmental or cost case is greatest. This results in only 5% of the coast line being realigned by 2030 and 9% by 2050 (with no further change to 2080).

Adaptation potential (quantified)

% of coastline realigned

% coastline realigned in recent years (based on England 1990-2016)	*% of the coastline realigned*								
	CLA			*High(er)*			*Low(er)*		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
2%	*9%*	*14%*	*16%*	*15%*	*25%*	*30%*	*5%*	*9%*	*9%*

Changes in the representative Standard of Protection

Management Realignment is typically not about improving the standard of protection but is more usually associated with reducing costs or gaining habitats (or other benefits). Only the impact on standard is considered here and expressed as the proportion of the climate change driven reduction in standard that is avoided.

- 0 - no mitigation of the reduction in standard of protection
- 1 – full mitigation of the reduction in standard of protection

The degree to which the climate induced reduction in standard is mitigated is assumed to be a function of the % of coastline realigned and the return period of the storm as follows:

rSOP = % of coastline realigned in the future / 2% (the realignment achieved in recent years) * x% (where x is given in the table below and represented the ability of managed realignment to mitigate the impact of climate change on the standard of protection).

rSOP today in coastal areas only (years)	*% of the climate change induced reduction in the standard of protection avoided for each?? additional 2% of the coast realignment*								
	CLA			*High(er)*			*Low(er)*		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
<10	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*
10-75	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
75-500	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
>500	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

E.1.3 Natural flood management practices in rural catchments

Working with natural processes by protecting, restoring and emulating the natural function of catchments, rivers, floodplains and coasts can help to manage flood flows. In some cases, working with natural processes can complement or even replace more traditional artificial flood defence infrastructure.

Natural flood management (NFM) practices (including upland storage, the management of run-off from agriculture, floodplain/river restoration, riparian tree planning, etc) are now widely promoted within various policy and guidance documents (for example within *Flood Risk Management Act*, Scotland, *Working with Natural Processes*, Environment Agency (2010, 2014), *Sustainable Flood Management* (WWF), *Natural Flood Risk Management* (NRW and SE), *Natural Flood Management* (OST, 2011)). The desire to promote such solutions (and the multiple benefits they provide) however has not yet been matched by 'on the ground' take up. This is despite most Catchment Flood Management Plans across England and Wales including policy options for managing runoff and storage.

In part this is due to the lack of scientific evidence regarding the performance of nature based solutions, particularly during more extreme flood events and over large areas. Perhaps the more important constraint however is the lack of demonstration pilots. This is starting to change and is likely to gather pace in the future as experience is gained on the effectiveness of such measures. Examples include:

- **Pontbren, Parrett and Hooder:** The Flood Risk Management Research Consortium (FRMRC) included research into three experimental catchments at Pontbren in Powys, the Parrett in Somerset and the Hodder in Lancashire. Alongside model based analysis these studies concluded that:
    - Land management practices could reduce flows from small, improved grassland catchments by 30% for the median annual flood and by 5% for the 100 year flood.
    - Restoration of upland peat workings can reduce peak flows by 2% across a larger catchment.
- **Pickering, Yorkshire**: In response repeat flooding (in 1999, 2000, 2002 and 2007) Forest Research (supported by the Forestry Commission, the Environment Agency and others) have been exploring the ability of better land use management to help reduce flood risk in Pickering. The project, called *Slowing the Flow*, involves, for example, implementing increased floodplain storage, floodplain planting and woody debris dams. An assessment of the impact of upstream land management measures on flood flows in Pickering Beck (Odoni and Lane, 2010) suggested that given the nature of the interventions and the Beck, as the size of the event increases, so the contribution that the interventions make to reducing flood risk increases, but no guidance is given as to the return periods events and the degree of change in the frequency of a given flood flows. This general finding is however in contrast to findings within FRMRC for example (where the effectiveness of such measures reduces with the severity of the event) and highlights the context specific nature of the reduction in flood flows.
- **Elwy catchment, Wales:** Following severe flooding in St Asaph within the downstream reaches of the Elwy in November 2012, Natural Resources Wales (NRW) initiated a study to investigate how traditional hard-engineered approaches, such as the proposed St Asaph flood alleviation scheme, could be complemented with NFM (NRW, 2015). The analysis undertaken suggests that implementation of NRM measures within the Elwy catchments reduces both flood peaks at local and catchment scales (for example locally on the AfonGell, the modelled reduction in flow was between 28% at the 2-year event and 5% at the 200-year event; at the catchment scale the magnitude of the November 2012 peak flow was reduced by 4% with an average reduction of approximately 10% during the design events).

- **Clwyd catchment, Wales:** In 2014 Natural Resources Wales (WHS, 2014) investigated the potential benefits of the nature based interventions that could be implemented in the Clwyd catchment. Changes in agricultural land use within the Clwyd catchment and recent changes in agricultural practice were both investigated. The study found that the creation of significant areas of improved grassland for grazing and the installation of agricultural drains had led to the removal of vegetation and compaction of soils that had resulted in a reduced capacity of the soil to absorb rainfall, increasing the rate of run-off. Through modelling based analysis the study indicates that if implemented across the catchment, improved land management could reduce peak flows during the summer by up to 25% (equating to a maximum reduction in flood level at Ruthin of 250mm) and reduce peak flows during winter events by up to 8%.

Despite recent studies, overall it remains difficult to determine the significance of measures to store flood waters and manage runoff at a large catchment scale, or how they will influence the magnitude and severity of more extreme floods (say the 50 or 100 year return period event). The relationship between reduction in flow and return period has been investigated further for this project through application of the Soil Conservation Service Curve Number (SCS CN) runoff model to various land cover types and rainfall depths, which also shows how the sensitivity of runoff to land use management options is reduced for longer return period events.

Therefore we must proceed with caution, basing our modelling variables on as much known science as possible. On the other hand, we recognize that creative land management practices (which are much more than simply agricultural practices) can have multiple benefits, by increasing biodiversity in those locations where such practices are implemented, and providing wetland areas where storage is envisaged, if such areas remain wet for the whole year. The reduction in flood risk may be small in these areas, but the environmental gains may be substantial.

Characterization within the Future Flood Explorer (FFE):

The impact of NFM is characterized within the FFE through the percentage change in peak flow. Reductions in peak flow are assumed to be greater for more frequent events (an assumption generally confirmed by the studies above). Implementation within the FFE is via a modification to percentage change in peak flow.

Three adaptation scenarios are defined as follows:

- ***CLA:*** Given the majority of management policies across the UK promote the role of Natural Flood Management (NFM) in some form the CLA scenario also has an element of such measures. The impact of NFM is however restricted reflected the limited level of take-up seen to date; achieving (up to) a 5% reduction on peak flows during more frequent events reducing to 2% during the more severe events (i.e. 1:100 year event) by the 2080s.
- ***High(er) adaption scenario*:** The multiple benefits of NFM is increasingly recognized resulting in wider up take. By 2080s NFM measures deliver (up to) a 20% reduction in peak flows during more frequent events and an 8% reduction during more extreme events (i.e. the 1:100 year return period event).
- ***Low(er) adaption scenario:*** The lack of scientific evidence and demonstration projects continue to restrict take up and limited effort is devoted to NFM measures. As a result NFM measures have no significant impact on peak flows during more frequent or more extreme flood events.

The reductions in flows under the three adaptation scenarios are summarized below in Table E7.

Note:

It is recognized that NFM approaches are unlikely to be viable everywhere. For the purposes of this study, it is assumed that NFM approaches will be more viable in catchments dominated by low-grade agricultural land (i.e. referred to here as Non-Best and Most Versatile – non-BMV - as defined in Appendix A). In catchments dominated by high-grade agricultural land (i.e. BMV land classes as defined in Appendix A) the opportunity for implementing NFM measures reduces and so too does the potential for reducing fluvial flows (i.e. the equivalent value reduces to 2%). It is understood the SEPA's natural flood management maps identify areas which may be suitable for runoff reduction, but a more simplified approach based on mapping areas of BMV and non-BMV land (or equivalent in Scotland and Northern Ireland) is applied here.

Table E7 Impact of Natural Flood Management practices in rural catchments

Adaptation potential (narrative)	**CLA:** Given the majority of management policies across the UK promote the role of Natural Flood Management (NFM) in some form the CLA scenario also has an element of such measures. The impact of NFM is however restricted reflected the limited level of take-up seen to date; achieving (up to) a 5% reduction on peak flows during more frequent events reducing to 2% during the more severe events (i.e. 1:100 year event) by the 2080s. **High(er):** The multiple benefits of NFM is increasingly recognized resulting in wider up take. By 2080s NFM measures deliver (up to) a 20% reduction in peak flows during more frequent events and an 8% reduction during more extreme events (i.e. the 1:100 year return period event). **Low(er):** The lack of scientific evidence and demonstrate continues to restrict take up and limited effort is devoted to NFM measures. As a result NFM measures have no significant impact peak flows during more frequent or more extreme flood events.
Adaptation potential (quantified)	***Changes in fluvial flows*** The climate driven percentage increase in fluvial flow (in the absence any other change) is reduced through the NFM measures. The degree of reduction reflects the relative proportion of BMV and non-BMV land (taken as an indicator of the general viability for NFM measures). The reduction in the increase in fluvial flow during the 100 year event is calculated based on the relative proportion of BMV and Non-BMV land within the catchment (with catchments defined using the European Environment Agency river catchment data set) as set out in the first table below. The potential for managing less extreme floods is then calculated based on a multiplier of the 100 year return period value (using the multipliers in the second table below). *The potential reduction in the 100 year fluvial flow* (table below) *For other return periods, the 100 year reductions are modified according to the table below.* (table below)

The potential reduction in the 100 year fluvial flow

Land type	***Percentage reduction in flood flows***								
	CLA			***High(er)***			***Low(er)***		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
Best and Most Versatile	*0*	*-0.5%*	*-1%*	*0*	*-1%*	*-2%*	*0*	*0*	*0*
Not Best and Most Versatile	*0*	*-1%*	*-2%*	*0*	*-5%*	*-8%*	*0*	*0*	*0*

For other return periods, the 100 year reductions are modified according to the table below.

Return period (years)	**Enhanced % reduction in flow during other return period events (multiplier)**
2	2.5
10	2
100	1
1000	0.5

E.1.4 Urban flood management practices

Widespread flooding in England in 2007 damaged 55,000 properties, with the majority of damage resulting from drains and sewers being overwhelmed by heavy rain (Environment Agency, 2007). The floods highlighted that traditional piped sewer systems cannot readily be adapted to deal with increased rainfall, particularly in densely urban areas. Half of the national sewer network in England is reported to be currently at or beyond capacity.

The probability of surface water flooding can be influenced by the adoption of a number of stormwater and local flood risk management options. These options have been grouped under two broad headings:

- **Sustainable drainage systems (SUDS):** Sustainable drainage systems (such as soakaways, permeable paving, ponds and swales) slow down and store flood water. This helps avoid sewer networks being overwhelmed during periods of heavy rainfall by reducing the peak of hydrograph. SUDS also deliver a range of other benefits, such as improved water quality, amenity, and biodiversity, and can help to counteract the urban heat island effect. SUDS are a low-regret adaptation measure. They have a construction and maintenance costs similar to conventional drainage but deliver a wider range of benefits.

  The Pitt Review into the 2007 floods in England (Pitt, 2008) recommended introducing a consenting scheme for SUDS in new development and the removal of the automatic right for new development to be connected to public sewers for surface water run-off. The Government introduced such a consenting scheme in the Flood and Water Management Act 2010 for England, but announced in December 2014 that the SUDS provisions would not be enacted. Instead, planning policy was strengthened to create an 'expectation' that major planning applications (i.e. those of ten dwellings or more) include SUDS except where physically inappropriate or disproportionately uneconomic. SUDS are also expected for all new development (i.e. of any size) in any area where surface water flood risk is a consideration. Similar expectations are in place in national planning policy in Scotland, Wales and Northern Ireland. Fitting of SUDS to new developments and retrofitting of SUDS to existing developments are the two variants considered by the FFE.

  Although there is no national monitoring in place to assess average uptake, a one-off survey of 111 planning applications in England within areas of flood risk by the ASC in 2014 found that 15% explicitly included SUDS measures. In the absence of other information this is assumed representative of new development across the rest of the UK. Estimating the extent to which SUDS are retrofitted is more difficult. Evidence from the sale of permeable paving, accounting for only 10% of all block paving sales in 2013 (ASC, 2014), suggests uptake is minimal within existing developments.

- **Surface water management:** In England, the Pitt Review recommended that unitary and county councils should take a leadership role in bringing together national and local partners involved in managing local sources of flood risk in the area, and together develop local flood risk management plans (e.g. in England: Local Flood Risk Management Strategies). In Scotland a similar planning process exists (e.g. Surface Water Management Plans). These plans should include wider measures that simply SUDS (as outlined above) and could include measures such as the separation of foul and surface water sewers, temporary or demountable flood defences, the creation of preferential flood pathways to direct flows away from high consequence areas, etc. In response, the Flood and Water Management Act 2010 established 152 lead local flood authorities (LLFAs) in England with statutory responsibilities to identify key flood management assets and investigate flood incidents. As of 2014, however, less than one-sixth of LLFAs in

England had published local flood risk management strategies. This is likely to increase to around half by the end of 2015/16.

Characterization within the Future Flood Explorer (FFE):

Within the FFE the influence of managing urban flooding is implemented as follows:

- **Broader surface water management measures: A reduction in return period event damages (within Weighted Annual Average Damages; WAAD):** Implementation of surface water management plans is modelled as a reduction in impact for at-risk areas where flooding occurs frequently; in practice this is represented by reducing the 30 year return period impact, and longer return period impacts are unaffected, representing SWMPs' focus on the highest risk areas.

- **Sustainable Urban Drainage Systems (SUDS): A modification of the percentage run-off and hence flood return period**: SUDS are represented by modelling the runoff in each Calculation Area (i.e. Flood Area or 1km grid as defined in Appendix F), using the simplified rainfall-runoff relationships (as described in Appendix F).

  The runoff for a Calculation Area is the weighted sum of the runoff calculated for urban and rural areas, with the weighting taken as the proportion of the area which is urbanized, namely:

$$Runoff = \frac{Runoff_{Urban}A_{Urban} + Runoff_{Rural}A_{Rural}}{A_{Total}}$$

  The effects of SUDS, which aim to reproduce rural runoff characteristics (i.e. to mimic the equivalent greenfield runoff signature) are represented as a modification to the proportion of the Calculation Area that produces urban runoff (*u*). The urban extent *u* controls to what extent a Calculation Area behaves in an urban or rural way (as shown in the Figure below).

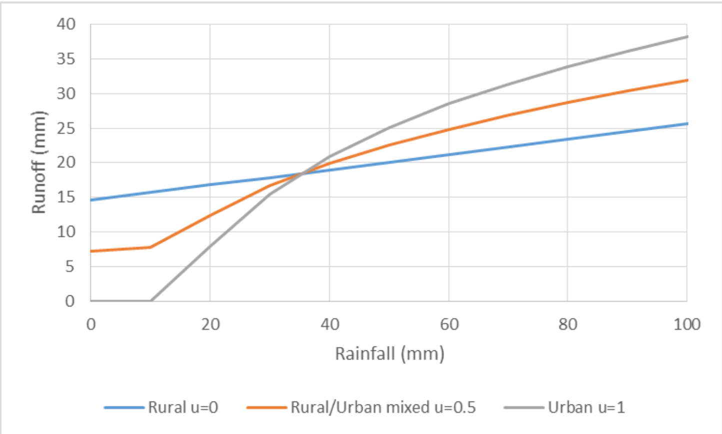


Figure E3 Rainfall – runoff relationship for different levels of urbanisation as parameterised by *u*

New development with SUDS will not change the runoff characteristics of an area since the SUDS will be designed to match greenfield runoff. New development without SUDS will increase the urban area generating runoff in line with the increase in property numbers. Partial uptake of SUDS in new developments is represented by interpolating between these two cases.

For retrofitting SUDS, the effective urban area *u* is reduced as runoff characteristics return more towards greenfield runoff. This is represented as a reduction in the runoff in line with the reduction in effective urban area, which in turn depends on the uptake of SUDS retrofitting.

The resulting change in runoff is then used to move the runoff-return period curve up or down; this is equivalent to a shift in the return period for a given runoff, and hence a shift in the return period of flooding, in the same way that climate change affects fluvial flooding.

Based upon the evidence presented above and the levers available within the FFE the adaptation scenarios have been defined as follows:

- ***CLA* scenario:** Planning policies continue to strengthen and from 2020 onwards 25% of new developments implement Sustainable Urban Drainage (SUDS) - up from 15% today. Retrofitting to existing development continues to be limited (remaining around 10% by area). Broader efforts to manage surface water continue to have a limited impact on flood risk (reducing damages during events occurring more frequently than 1:30 years by 5% by 2020s onwards).
- ***High(er) adaptation scenario:*** Planning policies continue to strengthen and by 2050 onwards 50% of all new developments implement SUDS. Retrofitting also increases, reaching 30% (by area) by the 2050s. A full range of surface water management measures are also increasingly implemented alongside SUDS (reducing damages during events occurring more frequently than 1:30 years by 50% by 2050s onwards).
- ***Low(er) adaptation* scenario:** Continued uncertainty around roles and responsibility for SUDS restrict up take and implementation with new development remains around 15%. Retrofitting to existing developments stops. Wider surface water management measures also reduce and they have no significant impact on reducing flood damages.

The quantified implementation of these changes within the FFE is summarized in Table E8.

Table E8. Impact of urban flood management practices

Adaptation potential (narrative)

CLA: Planning policies continue to strengthen and from 2020 onwards 25% of new developments implement Sustainable Urban Drainage (SUDS) - up from 15% today. Retrofitting to existing development continues to be limited (remaining around 10% by area). Broader efforts to manage surface water continue to have a limited impact on flood risk (reducing damages during events occurring more frequently than 1:30 years by 5% b 2020s onwards).
High(er): Planning policies continue to strengthen and by 2050 onwards 50% of all new developments implement SUDS. Retrofitting also increases, reaching 30% (by area) by the 2050s. A full range of surface water management measures are also increasingly implemented alongside SUDS (reducing damages during events occurring more frequently than 1:30 years by 50% by 2050s onwards).
Low(er): Continued uncertainty around roles and responsibility for SUDS restrict up take and implementation with new development remains around 15%. Retrofitting to existing developments stops. Wider surface water management measures also reduces and they have no significant impact on reducing flood damages.

Adaptation potential (quantified)

Reduction in risk from measures to manage urban surface water run-off

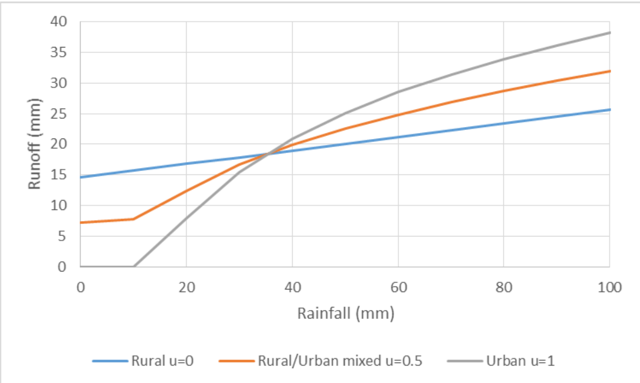
SWMP implementation (such as managing overland flow and storage, improved sewer systems and maintenance, separation of foul and stormwater systems, improvement of culverts, gullies etc) effectively manages flood waters to limit damage to properties exposed to a flood probability >=3.3% (i.e. a return period of 1:30 or more frequent) by the amount shown below. Damages for properties exposed to with probability <3.3% are not affected.

Probability of inundation	*CLA*			*High(er)*			*Low(er)*		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
≥3.3%	*5%*	*5%*	*5%*	*25%*	*50%*	*50%*	*0*	*0*	*0*
<3.3%	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Changes in urban surface water run-off by modifying the effective urban extent due to SUDS uptake

Runoff is modified in line with changes in runoff generating effective urban extent (**u**) and new developments increasing the number of properties by a factor **a**. In the case that SUDS are fitted, the effective urban extent does not change; for retrofitting the effective urban extent is reduced.

Development	*CLA*			*High(er)*			*Low(er)*		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
New									
Take-up	*25%*	*25%*	*25%*	*50%*	*50%*	*50%*	*15%*	*15%*	*15%*
Urban extent	u x (1+3a/4)			u x (1+a/2)			u x (1+0.85a)		
Existing (at significant risk)									
Take-up	*10%*	*10%*	*10%*	*10%*	*30%*	*30%*	*0*	*0*	*0*
Urban extent u	*0.9u*			*0.9u*	*0.7u*	*0.7u*	*u*		



Rainfall – runoff relationship for different levels of urbanisation(as parameterised by variable *u)*

E.2 Managing exposure to flooding

E.2.1 Spatial planning

Current planning policy across the UK (England: National Planning Policy (NPPF), Wales: TAN 15, Scotland: Online Planning Advice[4], Northern Ireland: PPS15) typically seek to ensure inappropriate development in areas prone to flooding is avoided, and where development is necessary, it is safe and does not increase flood risk elsewhere. What is clear, however, is that floodplain development continues, although probably at a far lesser rate than in past decades (Pardoe *et al*, 2011). DCLG's Land Use Change Statistics for England show that 7% of new dwellings were built in 'high flood risk areas' (defined as Flood Zones 2 or 3) in 2011, and 5% of land changing to residential use was in high flood risk areas.

More recent analysis by the ASC found that around 21,000 homes were built in the floodplain (defined as Flood Zones 2 or 3) every year on average between 2001 and 2014 in England (ASC, 2015). This makes up around 12% of all new residential development in England over that time. The annual rate of development in the fluvial floodplain has been higher than the rate outside the floodplain, but since 2008 there has been a marked decrease in the annual rate in the coastal floodplain (ASC, 2012). Recent research for Scottish Government suggests that the percentage of new build in Scotland since 2009 in areas at risk from the 200 year plus climate change event is lower than 12% (Kazmierczak et al, in press). This finding reinforces work by Ball et al. (in press) that reviewed a number of planning applications across Scotland, finding that:

"of 529 planning applications in total on which SEPA gave advice during 2012, 406 responses resulted in an objection by SEPA, with 18 an objection in principle. 354 LPA [Local Planning Authority] decision notices were available for analysis for year 2012 (accessed through the e-planning portals on the LPA websites). When matched to the SEPA advice, these indicated that 21 applications in total were granted contrary to SEPA advice during the year"

The work by Ball suggests that there is only a 5.1 % failure to accede to the planning advice provided by SEPA (i.e. lower than the comparable figure for England). For consistency across the UK (and the greater number of properties within England) value of 12% has been used here. This means the potential to improve the influence of the planning measure in Scotland is likely to be overstated (and it is recommended for future CCRA studies that baseline policies within each country are separately considered).

The ASC's analysis estimates that nearly three-quarters (73%) of residential floodplain development in England has been in areas that are at low risk or well protected by existing river and coastal flood defences (i.e. areas with between a 1-in-100 and 1-in-1000 annual chance of flooding). These tend to be major population centres located on the river floodplain or on the coast that have a reasonably high standard of flood defences in place.

However, 27% of floodplain development since 2001 in England (68,000 new homes) has been in areas with a 1-in-100 or greater annual chance of flooding. Around 23,000 new homes (9% of floodplain development) have been built in areas with a high likelihood of flooding, with a 1-in-30 or greater annual chance of flooding from rivers or the sea, even where flood defences are in place. Development in high risk parts of the floodplain appears to be mostly occurring outside major population centres, in more sparsely populated parts of the country. Community-level flood defences are more difficult to justify on cost-benefit terms in these areas. Elsewhere in the UK this figure is lower, therefore an average for the UK is therefore assumed to be around 20%.

[4]http://www.gov.scot/Topics/Built-Environment/planning/Policy/Subject-Policies/natural-resilient-place/Flood-Drainage/Floodrisk-advice

The influence of spatial planning on flood risk is currently more limited in areas prone to surface water flooding and groundwater flooding than it is for coastal and fluvial sources. Although some planning guidance requires developers to consider the possibility of groundwater and surface flooding, the lack of detailed groundwater flood risk maps, and the limited experience of considering surface and groundwater flooding within the planning process, means that data on development in areas exposed to ground water and surface flooding is limited. For this reason, the influence of spatial planning on surface and groundwater flooding is assumed to be weaker than for fluvial and coastal flooding. In the absence of any quantified information or current policy it is assumed that these are built without regard to the chance of surface water flooding in all but the high(er) adaptation scenarios.

Characterization within the Future Flood Explorer (FFE):

Based on the evidence above the spatial planning lever within each adaptation scenario is used to modify where and how new residential properties are built, as follows:

- ***CLA scenario***: The percentage of new dwellings built within the fluvial and coastal floodplain continues as today (i.e. around 12%). Of these new dwellings, 20% are built in areas with a 1:75 or greater annual chance of flooding with the remaining properties equally split between low and moderate probability areas. The location of development outside of the fluvial and coastal floodplain is unaffected by flood risk considerations.
- ***High(er) adaptation scenario:*** Consideration of flood risk takes a higher priority in the implementation of planning policy by local authorities and fewer new dwellings are built in the floodplain as a whole (reducing to 5% by 2050s), with a negligible number within areas with a 1:75 or greater annual chance of flooding. Surface water hazard mapping is increasingly used to inform development decisions and planning controls are effective at preventing development in areas subject to a high chance of surface water flooding.
- ***Low(er) adaptation scenario:*** Planning controls weaken resulting in a higher proportion of development being built in the fluvial and coastal floodplain (20% of all development) and a higher proportion of that in areas at a high chance of flooding (30% in areas with a 1:75 or greater annual chance of flooding). The location of development outside of the fluvial and coastal floodplain is unaffected by flood risk considerations.

The quantified implementation of these changes within the FFE is summarized in Table E9.

Note:

Residential development projections: Projections for the number of new residential properties are based on the spatially resolved population projections (see Appendix B) and implemented within the FFE as a percentage increase in the residential property numbers within a given Calculation Area.

Non-residential development projections: The projections of future development are based solely on population growth and include only residential development. No attempt is made to estimate the associated development of non-residential properties or infrastructure assets (hospitals, power etc). This is not because of an assumed lack of importance, but due to data limitations and modelling uncertainties.

Table E9 Spatial planning

Adaptation potential (narrative)

CLA: The percentage of new dwellings built within the fluvial and coastal floodplain continues as today (i.e. around 12%). Of these new dwellings, 20% are built in areas with a 1:75 or greater annual chance of flooding with the remaining properties equally split between low and moderate probability areas. It is assumed that this development is in line with planning policy, i.e. that it is has been made safe and resilient and without increasing flood risk elsewhere. The location and design of development outside of the fluvial and coastal floodplain is unaffected by flood risk considerations.

High(er): Consideration of flood risk takes a higher priority in the implementation of planning policy by local authorities and fewer new dwellings are built in the floodplain as a whole (reducing to 5% by 2050s), with a negligible number within areas with a 1: 75 or greater annual chance of flooding. Surface water hazard mapping is increasingly used to inform development decisions and planning controls are effective at preventing development in areas subject to a high chance of surface water flooding.

Low(er): Planning controls weaken resulting in a higher proportion of development being built in the fluvial and coastal floodplain (20% of all development) and a higher proportion of that in areas at a high chance of flooding (30% in areas with a 1:75 or greater annual chance of flooding). The location of development outside of the fluvial and coastal floodplain is unaffected by flood risk considerations.

Adaptation potential (quantified)

Changes in the effectiveness of planning policy

Coastal and fluvial floodplains (fluvial and coastal probability is used to direct new development)

	CLA			***High(er)***			***Low(er)***		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
% of all development that is located in the coastal and fluvial floodplain (residential properties only)	*12%*	*12%*	*12%*	*10%*	*5%*	*5%*	*20%*	*20%*	*20%*
% of above built in									
Less frequent than 1:200	*40%*	*40%*	*40%*	*60%*	*60%*	*60%*	*30%*	*30%*	*30%*
Between 1:75-200	*40%*	*40%*	*40%*	*40%*	*40%*	*40%*	*40%*	*40%*	*40%*
More frequent than 1:75	*20%*	*20%*	*20%*	*0%*	*0%*	*0%*	*30%*	*30%*	*30%*

Off-floodplain areas (Surface water flood is used to direct development)

	CLA			***High(er)***			***Low(er)***		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
% of the remaining new development built in									
Less frequent than 1:200	*33%*	*33%*	*33%*	*60%*	*60%*	*60%*	*33%*	*33%*	*33%*
Between 1:75-200	*33%*	*33%*	*33%*	*40%*	*40%*	*40%*	*33%*	*33%*	*33%*
More frequent than 1:75	*33%*	*33%*	*33%*	*0%*	*0%*	*0%*	*33%*	*33%*	*33%*

Groundwater flood prone-areas

Development control based on groundwater risks alone are not considered here.

E.3 Managing vulnerability of those exposed

E.3.1 Receptor Level Protection Measures: Residential

A number of policy measures encourage individual property owners to protect themselves and their property from flooding. The Environment Agency's Flood & Coastal Erosion Risk Management Strategy (Environment Agency, 2011) and Defra's partnership funding (Defra, 2011) policies encourage local communities to contribute towards their risk reduction, not least by implementing receptor (property) level protection measures (RLP). In addition, moves towards actuarial pricing of flood insurance should provide a signal to those at risk of flooding that they are at risk, and so encourage householders and the owners of non-residential properties to seek and implement risk-reducing measures. In Scotland, the uptake of RLP measures (mainly by residential properties) is much less than in England (see Scottish Government 2015). Little evidence has been identified regarding the take up rates in Northern Ireland or Wales.

At the same time, a number of companies are now providing such measures, including 'kitemarked' devices for preventing the ingress of flood waters into properties, and installations within properties that are less susceptible to flood damage (e.g. plastic kitchen furniture). It appears likely that this will be a continuing trend into the future, particularly in response to surface water flooding given its unpredictable spatial extent but relatively shallow depths.

There are, however, counteracting tendencies to such trends. Property owners are often reluctant to implement risk reducing measures which demonstrate to the wider public that their properties are at risk (see Harries, 2008, 2011) so the implementation of property level measures is not 'plain sailing'. Furthermore, recent research (Defra, 2014) has shown that property level protection measures are only likely to be cost-effective where flood frequencies are high, given the relatively high cost of such measures and their inability to prevent large amounts of damage when a property scale resistance measure is overtopped.

Building Regulations have however been strengthened in recent years to promote property level flood resilience (e.g. Defra, 2007). These provide an opportunity to ensure new properties are flood resilient (through raised thresholds and/or other resilience measures). Retro-fitting RLP to existing properties (using various flood products and property modifications) is also gathering pace. Within the Environment Agency's LTIS studies two scenarios were considered (Environment Agency, 2014). The first was based on evidence of existing take-up, assumed to be between 3% and 5% of properties within the fluvial and coastal floodplain exposed to a high chance of flooding, and the second scenario considered a much higher uptake by 50% of households. In Scotland take up is less, possibly reflecting recent Defra initiatives (see Scottish Government 2015). (This means the potential to improve the influence of the planning measure in Scotland is likely to be understated and it is recommended for future CCRA studies that baseline policies within each country are separately considered.)

In both cases measures are only likely to be effective up to an external flood depth of c. 600mm (Defra, 2007). At flood depths greater than this it is likely that resistance measure (i.e. external flood boards and similar products) will be overtopped, or will be of insufficient strength to withstand the loading of large depths of flood water. Equally, not all of the measures that are implemented will be successful. An evaluation of post-installation effectiveness commissioned by Defra concluded that (Defra, 2014):

'Of the 11 Environment Agency responses received, 6 schemes had been tested and Property Level Protection measures deployed but only 4 provided further detail. The information provided showed that for 79% of properties, Property Level Protection measures either prevented flood water ingress or served to reduce the impact and level of flooding experienced, whilst 21% found that it made no difference at all.'

The limitations of such receptor level protection (RLP) measures are therefore recognised in the analysis presented here, and reflect take-up and effectiveness considerations (assuming RLP measures to be progressively less effective at reducing damage as the severity of the flood event increases). RLP measures are also assumed to be less effective in coastal areas due to the potential for local wave action.

Characterization within the Future Flood Explorer (FFE)

The FFE reflects *take up* (how many assets/properties the method is applied to) and *effectiveness* (how much the measures reduce damage for each property). The FFE therefore uses two levers to represent RLP measures**:**

- Percentage uptake for new and existing properties (separately).
- For those properties that take-up the measures, some are successful and for those properties flood damages are reduced (through a reduction in the Weighted Average Annual Damage, WAAD value used).

The quantified implementation under each future scenario is discussed below (and summarized is Table E10):

- **CLA scenario:** Within the fluvial and coastal floodplain all new residential properties are built with appropriate flood resistance and resilience measures. Outside of the fluvial and coastal floodplain new properties continue to be built without any consideration of RLP measures. There is some limited take up of RLP measures by existing homeowners in areas at a high chance of either coastal or fluvial flooding.
- **High(er) adaptation scenario:** Within the fluvial and coastal floodplain all new residential properties are built with appropriate flood resistance and resilience measures. Grants and incentives support an increase in retrofitting, particularly within areas at the highest chance of flooding. With an increased acceptance of the risk posed by flooding, and confidence in the performance of RLP measures there is some take-up in moderate and low probability areas. With access to improved surface water and groundwater flood maps and associated incentives from insurers there is also some uptake outside of the fluvial and coastal floodplain but is limited.
- **Low(er) adaptation scenario:** As confidence in flood maps reduce, as they are not up-dated, and the enforcement of planning policy weakens only 50% of new developments on the fluvial and coastal floodplain include RLP measures. The level of retrofitting is very limited, with only 3% of properties within areas at a high chance of flooding taking up RLP.

Across all adaptation scenarios it is assumed that:

- Of the properties that take-up property scale measures 80% are successful at reducing damage. This is perhaps an overestimate but there is little evidence to contradict this estimate.
- The reduction in damage is significant for lower depths (below 600mm – assumed to be associated with return periods of 10 years or less in coastal areas, 25 years or less in fluvial areas, 100 years or less in surface water areas; and when groundwater is the only source RLP are assumed to have an effective similar to fluvial settings) with progressively less impact as the severity of the event increase.

Table E10 Receptor level protection measures (residential)

Adaptation potential (narrative)

CLA: Within the fluvial and coastal floodplain all new residential properties are built with appropriate flood resistance and resilience measures. Outside of the fluvial and coastal floodplain new properties continue to be built without any consideration of RLP measures. There is some limited take up of RLP measures by existing homeowners in areas at a high chance of either coastal or fluvial flooding.
High(er): Within the fluvial and coastal floodplain all new residential properties are built with appropriate flood resistance and resilience measures. Grants and incentives support an increase in retrofitting, particularly within areas at the highest chance of flooding. With an increased acceptance of the risk posed by flooding, and confidence in the performance of RLP measures there is some take-up in moderate and low probability areas. With access to improved surface water and groundwater flood maps and associated incentives from insurers there is also some uptake outside of the fluvial and coastal floodplain but is limited.
Low(er): As confidence in flood maps reduce and the enforcement of planning policy weakens only 50% of new developments on the fluvial and coastal floodplain include RLP measures. The level of retrofitting is very limited, with only 3% of properties within areas at a high chance of flooding taking up RLP**.**

Across all adaptation scenarios:

- 80% of the RLP take-up is successful at reducing damage (there is no evidence to suggest this would vary by adaptation scenario).
- The reduction in damage is significant for lower depths (below 600mm – assumed to be associated with return periods of 10 years or less in coastal areas, 25 years or less in fluvial areas, 100 years or less in surface water areas; and when groundwater is the only source RLP are assumed to have an effective similar to fluvial settings) with progressively less impact as the severity of the event increase.

Adaptation potential (quantified)

% uptake of RLP measures

	CLA			*High(er)*			*Low(er)*		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
Off floodplain fluvial / coastal floodplain									
% Take-up for new properties	*0%*	*0%*	*0%*	*10%*	*50%*	*100%*	*0%*	*0%*	*0%*
% uptake for existing properties	*0%*	*0%*	*0%*	*5%*	*10%*	*20%*	*0%*	*0%*	*0%*
On fluvial / coastal floodplain									
% Take-up for new properties (Irrespective of flood prob.)	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*50%*	*50%*	*50%*
*% uptake for existing properties – **High** probability areas*	*5%*	*7%*	*10%*	*20%*	*30%*	*50%*	*3%*	*3%*	*3%*
*% uptake for existing properties – **Moderate** and **Low** probability areas*	*0%*	*0%*	*0%*	*5%*	*7%*	*10%*	*0%*	*0%*	*0%*

Reduction in Residential WAAD value for those properties protected by RLP measures

SOP	**Reduction in WAAD (coastal)**	**Reduction in WAAD (fluvial)**	**Reduction in WAAD (surface water)**	**Reduction in WAAD (groundwater)**
No protection	0%	0%	0%	0%
2	80%	100%	80%	80%
5	80%	100%	80%	80%
10	40%	100%	80%	80%
25	0%	40%	80%	40%
50	0%	25%	40%	25%
100	0%	0%	20%	0%
>200	0%	0%	0%	0%

E.3.2 Receptor Level Protection Measures: Non-Residential

In the case of non-residential buildings and infrastructure take up varies significantly between Category A infrastructure providers (defined here as energy and water infrastructure – see Table 2-1 of the Main Report) and Category B infrastructure providers (defined here as emergency services, businesses, GP surgeries, roads, railway lines – see Table 2-1 of the Main Report).

Increasingly **Category A** infrastructure providers are recognising flooding as a business risk and the importance of providing contingency plans and local protection to high risk sites. After widespread flooding in England in 2007, electricity transmission and distribution companies developed a sector-wide approach to investigating the vulnerability of their substations to river and coastal flood risk, from which a programme of site level protection measures was put in place with funding agreed by the regulator (Ofgen). As a result, take-up of site protection measures has been significant and will continue during the current price control period (i.e. to 2023). Water sectors have been less active in taking action to protect their assets than the electricity sector but are nonetheless assumed (for the purposes of this analysis) to have similar levels of RLP take-up.

There is little evidence to suggest take-up of RLP by the **Category B** infrastructure providers and it is unlikely that more than a few percent of properties outside of areas exposed to a high probability of flooding will be protected.

Characterization within the Future Flood Explorer (FFE)

For Category A infrastructure only, take up is reflected in the FFE. No attempt is made to assess the associated economic damages or the reduction in economic damages. When RLP measures are implemented it is assumed that the level of protection provided is 1:200 year return period.

For Category B infrastructure a combination of take-up and reduction in damage is estimated (using the WAAD non-residential damage values – a similar process to the residential properties).

The quantified implementation of under each future scenario is discussed below (and summarized is Table E11):

- **CLA scenario:** The example of widespread take up of RLP measures in the energy sector is mirrored by other Category A infrastructure providers, with 50% of all assets on the fluvial and coastal floodplain protected by the 2020s raising to 100% by the 2080s. Outside of the fluvial and coastal floodplain take up is negligible. Take up by Category B providers is limited to 10% of assets within the highest risk areas of the fluvial and coastal floodplain by 2080s.
- **High(er) adaptation scenario:** Increasing awareness of flood risk support the wider take-up of by both Category A and B infrastructure providers, particularly within the areas exposed to a high probability of coastal or fluvial flooding (with a 100% of all Cat A and 50% of all Cat B assets protected). Outside of these areas take up increases, particularly amongst Cat A providers (reaching 50%) but remains stubbornly low amongst Cat B providers.
- **Low(er) adaptation scenario** Take up by Category A infrastructure providers slows and fails to raise above 50%.Take up by Category B providers is negligible.

For Category B providers assumptions regarding the successfully implementation of RLP measures and their effectiveness are the same as those made for residential properties (discussed in the previous section).

Note:

The development of new critical infrastructure assets (hospitals, power etc) or other non-residential properties is excluded from the FFE analysis.

Table E11 Receptor level protection measures (non-residential buildings and infrastructure)

Adaptation potential (narrative)

CLA: The example of widespread take up of RLP measures in the energy sector is mirrored by other Category A infrastructure providers, with 50% of all assets on the fluvial and coastal floodplain protected by the 2020s raising to 100% by the 2080s. Outside of the fluvial and coastal floodplain take up is negligible. Take up by Category B providers is limited to 10% of assets within the highest risk areas of the fluvial and coastal floodplain by 2080s.

High(er): Increasing awareness of flood risk support the wider take-up of by both Category A and B infrastructure providers, particularly within the areas exposed to a high probability of coastal or fluvial flooding (with a 100% of all Cat A and 50% of all Cat B assets protected). Outside of these areas take up increases, particularly amongst Cat A providers (reaching 50%) but remains stubbornly low amongst Cat B providers.

Low(er): Take up by Category A infrastructure providers slows and fails to raise above 50%.Take up by Category B providers is negligible.

Adaptation potential (quantified)

% uptake of RLP measures

	CLA			***High(er)***			***Low(er)***		
	2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
Off floodplain fluvial / coastal floodplain (existing non-residential buildings and infrastructure only)									
*% uptake for **Category B** non-residential properties and infrastructure (Irrespective of flood prob.)*	*0%*	*0%*	*0%*	*5%*	*5%*	*5%*	*0%*	*0%*	*0%*
*% take for **Category A** non-residential properties and (Irrespective of flood prob.)*	*0%*	*0%*	*0%*	*20%*	*30%*	*50%*	*0%*	*0%*	*0%*
On floodplain fluvial / coastal floodplain (existing non-residential buildings and infrastructure only)									
*% uptake for **Category B** properties in **High** probability areas*	*5%*	*5%*	*5%*	*15%*	*25%*	*50%*	*3%*	*3%*	*3%*
*% uptake for **Category B** properties in **Moderate and Low** probability areas*	*0%*	*5%*	*5%*	*5%*	*15%*	*25%*	*0%*	*0%*	*0%*
*% take for **Category A** infrastructure providers (irrespective of flood prob.)*	*50%*	*75%*	*100%*	*75%*	*100%*	*100%*	*50%*	*50%*	*50%*

Reduction in non-Residential WAAD value for those properties protected by RLP measures

SOP	Reduction in WAAD (coastal)	Reduction in WAAD (fluvial)	Reduction in WAAD (surface water)	Reduction in WAAD (groundwater)
No protection	0%	0%	0%	0%
2	80%	100%	80%	80%
5	80%	100%	80%	80%
10	40%	100%	80%	80%
25	0%	40%	80%	40%
50	0%	25%	40%	25%
100	0%	0%	20%	0%
>200	0%	0%	0%	0%

Defining Category A and B non-residential properties and infrastructure (see Table 2-1 in the Main Report for details)

Category A - The take up of RLP (either through bunding, raising critical components, ensuring alternative supplies, access and egress improvement etc combine to deliver a minimum standard of 1:200 years return period for Category A infrastructure. These infrastructure include Water infrastructure and Energy infrastructure. These have been selected based on a combination of recent efforts (for example the energy sector has been proactive in protecting their distribution and transmission network in recent years) and the potential for site specific protection. It is recognised that evidence for take up in the water sector is less.

All other non-residential and infrastructure assets are considered Category B.

E.3.3 Forecasting, warning and community response

Management responsibility for of FFWD (Flood Forecasting Warning and Dissemination) in England and Wales is assigned to the Environment Agency (EA) and in Scotland to the Scottish Environment Protection Agency (SEPA). These two agencies are subject to legislation which mandates the consideration of both strategic planning and sustainability, as part of flood risk management decisions by them (see Environment Act, 1995 s 4 (1–3), s 21 and s 31(2), Flood and Water Management Act 2010, s 3(3)(h), Flood Risk Management (Scotland) Act 2009, s 1(c)). There is currently no legislative provision for FFWD in Northern Ireland. However, the Rivers Agency of Northern Ireland (RANI), the statutory flood risk management authority, is implementing the risk assessment requirements of the EU 'Floods Directive' (Directive 2007/60/EC). As part of this process, areas of assessment are emerging for potential targeting of FFWD as part of flood risk management planning.

The Environment Agency allocates spending on flood warning based on a Flood Warning Investment Strategy (Ball et al, 2012). The Environment Agency conducts a 'levels of service assessment' to allocate funding priorities for flood warning according to location, establishing target standards of quality for the service in each flood warning area. The aim is to reduce risk and impact through investment in better forecasting, dissemination and public communication in the areas that most need them. Assessment is according to a risk matrix of risk, reflecting standard of protection and impact (Andryszewski et al., 2005). One prominent recent aspect has been expansion of 'Floodline Warnings Direct' (FWD), a centrally hosted warning and dissemination system that sends messages to the telephones of people in flood warning areas. SEPA provides a similar service in Scotland (although in Scotland current signup rates are significantly lower than those in England at around 16% in coastal area and 32% in fluvial areas (as advised by SEPA during this project).

The lead for the management of groundwater flooding at a local level is taken by the local flood authority. Some communities are covered by groundwater flood warning and alert systems, normally based on identifying trigger levels in boreholes in the vicinity of the community but in general forecasting and warning of groundwater flooding is less consistent in its implementation than other sources of flooding.

The reduction in damage achieved through forecasting and warning services depends on the ability to reach those able to respond and the actions in response to warning. A similar approach to quantifying the benefits is taken across the UK based largely on methods set out in Parker (1991) as revised by Parker *et al.* (2007) and where necessary translated for use (e.g. as set out in the Environment Agency on the benefit of 'non-asset Flood and Coastal Erosion Risk Management (FCERM) measures', Environment Agency, 2015).

Within these methods, a central consideration is lead time. Based on a survey of homeowners in 2006, average direct benefits per household assuming an <8hr lead time was £1337, for lead times in excess of 8h this increased to £1726, based on a total average damage of £30000 per property (Parker et al., 2007) – i.e. between 3% and 5%.

Flood forecasting and warning also reduce indirect damages; perhaps more significantly than direct damages. There is however limited quantitative evidence on the reduction in indirect damages afforded by forecasting and warning systems.

Characterization within the Future Flood Explorer (FFE):

Within the FFE both direct and indirect damages are assumed to reduce as forecasting and warning services improve (and increase as they degrade). Both take-up (the % of residential and non-residential properties signing up to the service) and the effectiveness of that service (expressed through a % reduction in the standard damage values given within the WAAD tables) are considered.

In determining the values used within the FFE the following assumptions are made:

- *The update of warning services is greatest in coastal areas.* This reflects the heightened perception of risk (Parker, 1991 and Parker et al, 2007) and the maturity of the flood warning system since it was implemented after the 1953 event. Numerous events have been tracked down the North Sea during this time, and warnings to the communities affected have become better publicised and more targeted as a result of this experience.
- *The effectiveness, in terms of reduction in damage, increases with return period of the event.* This reflects the longer lead time, and hence greater opportunity to act, that is typically associated with more extreme events (Parker, 1991)). This is recognized as a significant, but necessary, simplification. For example effectiveness of warnings in reducing damage during flash flood events (e.g. at Boscastle in 2004) is typically very low despite the rarity of the event. In the majority of fluvial and coastal storm events however, as the return period of the event increases the opportunity for people to take risk reducing actions, such as in Tewkesbury in 2007, typically increases.

The quantified implementation of under each future scenario is discussed below (and summarized is Table E12):

CLA scenario: Flood forecasting and warning (FF&W) continues to be a significant component of the flood risk management effort and continues to improve (with up to 75% of residential properties in coastal areas acting on warnings and slightly less in fluvial areas and amongst non-residential properties by the 2080s). Effectiveness also improves, reflecting the ability to forecast more frequent events with long lead times and continued increases in awareness amongst those at risk. As a result direct damages associated with storm events occurring more frequently (on average) than 1:75 years are reduced by 5% by the 2080s.

High(er) adaptation scenario: With the recognition that in lower consequences areas and in areas of high natural value traditional defences are unlikely to be affordable/desirable, significantly greater emphasis is placed upon FF&W (with up to 100% of residential properties in coastal areas acting on warnings and slightly less in fluvial areas and amongst non-residential properties). Coupled with science advances in radar and model technologies accuracy improves and lead times extend. Warnings are widely believed and tailored to the specific needs of recipient and communities are better able to respond due to an improved understanding of risk they face. As a result direct damages associated with storm events occurring more frequently (on average) than 1:75 years are reduced by 15% by the 2080s.

Low(er) adaptation scenario: Reduced investment in observational networks and awareness campaigns leads to a reduction in the accuracy of forecasts and an increase in the number of false warnings. This leads to an associated loss in confidence and hence effectiveness. Take-up reduces to 25%. For those signed up lead times and accuracy are poor and hence FF&W has no impact on damages.

Note:

1. Although flood forecasting and warning is primarily targeted towards saving life the impact on people (and the ability for people to successfully evacuate etc) is not included here. Only direct and indirect damages are considered.
2. It is assumed that the impact on indirect damages is in direct proportion to the reduction in direct damages. The FFE applies a multiplier to the direct damages to account for these 'indirect' damages. In the absence of a forecasting or warning response this is set to 1.7 (as discussed in more detail in Appendix F). Where forecasting and warning systems are in place this is reduced by 50% to 1.35. For example, if the direct damage to a property without any warning system were £100, then the direct plus indirect damages would be £170. With warning, the £100 is reduced to £95 (i.e. by 5%), and £70 is reduced to £35. The total damages, direct and indirect, with the warning system becomes £130. This calculation process is used across all adaptation scenario.

3. Effective forecasting and warning of surface water flooding (capable of reducing direct damages) remains out of reach under all scenarios.

Table E12 Flood forecasting, warning and community response

Adaptation potential (narrative)

CLA: Flood forecasting and warning (FF&W) continues to be a significant component of the flood risk management effort and continues to improve (with up to 75% of residential properties in coastal areas acting on warnings and slightly less in fluvial areas and amongst non-residential properties by the 2080s). Effectiveness also improves, reflecting the ability to forecast more frequent events with long lead times and continued increases in awareness amongst those at risk. As a result direct damages associated with storm events occurring more frequently (on average) than 1:75 years are reduced by 5% by the 2080s.

High(er): With the recognition that in lower consequences areas and in areas of high natural value traditional defences are unlikely to be affordable/desirable, significantly greater emphasis is placed upon FF&W (with up to 100% of residential properties in coastal areas acting on warnings and slightly less in fluvial areas and amongst non-residential properties). Coupled with science advances in radar and model technologies accuracy improves and lead times extend. Warnings are widely believed and tailored to the specific needs of recipient and communities are better able to respond due to an improved understanding of risk they face. As a result direct damages associated with storm events occurring more frequently (on average) than 1:75 years are reduced by 15% by the 2080s.

Low(er): Reduced investment in observational networks and awareness campaigns leads to a reduction in the accuracy of forecasts and an increase in the number of false warnings. This leads to an associated loss in confidence and hence effectiveness. Take-up reduces to 25%. For those signed up lead times and accuracy are poor and hence FF&W has no impact on damages.

Adaptation potential (quantified)

% uptake (no. properties and businesses taking up and acting on warning)

Return period of flooding (years)	**CLA**			**High(er)**			**Low(er)**		
	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
Coastal areas									
Residential	75%	75%	75%	100%	100%	100%	50%	50%	50%
Non-residential	50%	50%	50%	75%	75%	75%	25%	25%	25%
Fluvial areas									
Residential	50%	50%	50%	75%	75%	75%	25%	25%	25%
Non-residential	30%	30%	30%	50%	50%	50%	25%	25%	25%

% reduction in DIRECT damages (implemented as a % reduction in the estimated WAAD)

% reduction in Residential WAAD value

Return period of flooding (years)	**CLA**			**High(er)**			**Low(er)**		
	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
<10	2%	3%	3%	3%	5%	5%	0%	0%	0%
10-75	3%	5%	5%	5%	7%	10%	0%	0%	0%
>75	5%	6%	7%	7%	10%	15%	0%	0%	0%

% reduction in Non-Residential WAAD value

Return period of flooding (years)	**CLA**			**High(er)**			**Low(er)**		
	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
<10	2%	3%	3%	3%	5%	5%	0%	0%	0%
10-75	3%	5%	5%	5%	7%	10%	0%	0%	0%
>75	5%	6%	7%	7%	10%	15%	0%	0%	0%

% reduction in INDIRECT damages (implemented as a % reduction standard multiplier applied to direct damages)

It is assumed that the impact on indirect damages is in direct proportion to the reduction in direct damages. Therefore no additional reduction is applied to the indirect damages (they simply reduce because the direct damages reduce).

E.4 Insurance and experience

The availability and implementation of flood insurance is not considered here as a "lever" driving flood risk, or reducing risk where it is applied, mainly because flood insurance does not lessen risk necessarily by itself, but simply redistributes the effects of risk in terms of compensation to flood victims for the damages that they incur. This redistribution occurs as a result of the majority of policy owners not making claims at any one time, or indeed not making claims at all, resulting in a subsidy for those who do make claims.

Nevertheless we are not ignoring flood insurance here. This is because we know that under Flood-Re insurance premiums will rise so that full actuarial pricing comes into being after 25 years. This could well have a substantial effect on the occupation of flood risk areas, thereby reducing risk as some people choose not to live in areas where premiums for flood insurance are as high as they need to be to cover the compensation claims that are made.

Therefore, we understand that flood insurance can provide a signal and thereby alert people to risks that they face, which in turn can encourage householders to take up property level protection measures, which are treated here as a driver of flood risk going forward. The changes in the behaviour of those at risk may also be triggered by flood insurance payments, and flood insurance may also provide a signal that people should remove valuable items from the threat of flooding.

Our approach is, first, to use the property level protection lever as described above to characterize the propensity of people to install risk reducing measures themselves, on the basis of the variety of information available to them including the availability of - and signal from - the fact that most property owners have flood cover within their insurance contracts. Secondly, we intend to investigate the possible effect of a more risk-reflective flood premium insurance regime, post Flood Re, on flood damage potential after we have modelled flood risk using just the levers that we describe in this report as the basis for that risk assessment. As such this assessment of flood insurance will be largely qualitative rather than quantitative, and in the form of a narrative discussion, but we consider this appropriate at this stage of our understanding of the relationship between flood insurance and flood losses going forward.

Characterization within the Future Flood Explorer (FFE)

Insurance issues are not quantified within the FFE. TA discussion of the impact of insurance is however provided in the Main Report.

E.5 References

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