Present and future flood vulnerability, risk and disadvantage

A UK assessment

Prepared for Joseph Rowntree Foundation, Climate Change and Communities Programme

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EXECUTIVE SUMMARY

Overview

Developing a better understanding of the relationship between social vulnerability and exposure to flood risk across different communities is a prerequisite to delivering a socially just (*i.e.* fair) approach to prioritising flood risk management efforts within national policy and funding structures. The Future Flood Explorer (UK-FFE, Sayers *et al.,* 2015) has been used here to assess present day social vulnerability to flooding and resulting flood disadvantage across the UK and how this may change in the future in response to exogenous influences (*e.g.* climate change and population) and endogenous influences (*e.g.* flood management policy and its broader impacts on issues such as insurance). In doing so, a *Neighbourhood Flood Vulnerability Index* (NFVI) is introduced and used to compare risks between more and less flood vulnerable neighbourhoods (where vulnerability is characterised in terms of communities experiencing a loss in wellbeing when floods occur) and a *Social Flood Risk Index* (SFRI) is used to identify where vulnerability and exposure coincide to create flood disadvantage.

The results highlight significant variation in flood disadvantage across the UK. For example, ten local authorities account for fifty percent of the socially vulnerable people that live in flood prone areas (those living in the 5% most vulnerable neighbourhoods according to the NFVI). Coastal areas, declining urban cities and dispersed rural communities are also highlighted as representing the greatest concentrations of disadvantage (as measured by the *Social Flood Risk Index*, SFRI[1]). When income and insurance penetration are considered, the *Relative Economic Pain*[2] (a metric defined here as the ratio between uninsured loss and income) is significantly in vulnerable communities than elsewhere.

Re-analysis of the Environment Agency's Long-Term Investment Scenarios (LTIS) (for England), which are used to support the case for investment in flood risk management, suggest there is a robust economic case for improving protection afforded to socially vulnerable communities. The reason for this is unclear but nonetheless suggests that there is both a utilitarian imperative (that seeks to maximise return on investment) as well as a Rawlsian rationale (that preferentially targets the most vulnerable) to reduce flood risk in the socially vulnerable communities.

Low income and poor health are important drivers of flood vulnerability and are more influenced by broader planning and welfare policy than flood risk management policy. Delivering flood risk management (FRM) more effectively therefore requires greater effort to bring together, and be supportive of, multiple government and private sector investment streams to achieve overall policy goals. This includes preferentially selecting interventions to both reduce flood risk and have wider

[1] Defined here as the product of the NFVI, the number of people exposed, the flood probability.

[2] In recognition of the varying coping capacity between more affluent and lower income households, this metric captures the relationship between uninsured economic damages and household income – Discussed further in Section 3 of the report.

health and wellbeing benefits (for example, green infrastructure approaches) and support other policy agendas.

Study focus

Social vulnerability in the context of floods relates to how flooding impacts on and creates losses in people's wellbeing. Delivering socially just FRM thus requires two central issues to be addressed. The first relates to addressing **geographic flood disadvantage** (places where many socially vulnerable people are exposed to flooding) and requires an understanding of where the most socially vulnerable communities are located and their exposure to flooding. The second relates to addressing **systemic flood disadvantage** (the degree to which the socially vulnerable communities are disproportionally affected by flooding) and requires an understanding of the degree to which FRM policy (and its implementation in practice) successfully delivers socially just outcomes (as expressed by the comparative risks faced by more and less vulnerable communities).

To better understand the geographic and systemic nature of flood disadvantage the analysis here seeks to:

(i) Identify those neighbourhoods at greatest flood disadvantage now and in the future (through to the 2020s, 2050s and 2080s) across the UK;
(ii) Assess the degree to which FRM can be considered socially just; and
(iii) Identify policy gaps and recommend policy changes to improve flood resilience and reduce disadvantage.

Key findings: Flood disadvantage now and in the future

The Future Flood Explorer (FFE) has been used to quantify present and future flood risk for the whole of the UK through to the 2080s, based on two climate futures (+2°C and +4°C), two population growth scenarios (high and low) and assuming current levels of adaptation (CLA) continue. The key findings from this analysis are presented below.

Floodplain population, vulnerability and exposure to frequent flooding

- Socially vulnerable neighbourhoods are over-represented in areas prone to flooding (all sources), but most significantly in areas prone to coastal (and tidal) flooding.
- The proportion of people living in the most vulnerable neighbourhoods is much greater in Northern Ireland than elsewhere in the UK.
- Over 50% of those exposed to flooding and living in the most vulnerable neighbourhoods are in just ten local authorities.
- By the 2080s more and less vulnerable neighbourhoods will both experience more frequent floods.

Today approximately 6.4 million people live in flood prone areas, with around 1.5 million (or 23.4% of these people), living in the 20% most vulnerable neighbourhoods. Within all neighbourhoods, 31% (2 million people) are exposed to frequent flooding from either fluvial (river), coastal or surface water sources (with a return period of 1:75 years or more frequent). Of those, 6.1% live within the 5% most flood vulnerable neighbourhoods (ranked in the top 5% by Neighbourhood Vulnerability Index (NFVI), a measure of the propensity of those that live in a neighbourhood to experience a loss of well-being should a flood occur). This is a factor of 1.2 (20%) higher than would be expected (assuming exposure to flooding to be equally distributed between more and less vulnerable neighbourhoods). Of the 1.8 million people living in the coastal floodplain, 33% are within the 20% most vulnerable neighbourhoods and 10% in the 5% most vulnerable neighbourhoods (top 5% by NFVI). This is a significant over-representation. In Northern Ireland 55% of the population exposed to flooding live in the top 20% of neighbourhoods by NFVI (almost double the UK average) and 25% of the total population exposed to frequent flooding are in the 5% most vulnerable neighbourhoods (almost five times the UK average); with the most significant disadvantage seen in Belfast (a finding that also reflects the higher levels of poverty that exist in Northern Ireland compared to other parts of the UK).

Seventy-five local authorities (approximately one fifth of the UK total) account for 50% of those living in flood prone areas. The concentration becomes more marked when the most vulnerable neighbourhoods (top 5% by NFVI) are considered, with over 50% of people exposed to flooding in the most vulnerable neighbourhoods located in just ten local authorities (Hull, Boston, Belfast, Birmingham, East Lindsey, Glasgow, Leicester, North East Lincolnshire, Swale District, and Tower Hamlets).

The number of people living in flood prone areas is set to increase by 45% to 10.8 million people by the 2080s, assuming high population growth. Combined with a +4°C climate future, and assuming current approaches to adaptation continue, 6.4 million people will be exposed to frequent flooding, up from 2 million today (an increase of over 200%). In the most vulnerable neighbourhoods the increase is equally dramatic, again more than trebling, from 451,000 today to 1.4 million by the 2080s (an increase of over 200%). The greatest increases are experienced in England and in areas prone to surface water and fluvial flooding.

Expected annual damage (EAD) and the influence of income and insurance

- At a UK scale EAD is dominated by England, but from the perspective of the most vulnerable neighbourhoods the contribution from other nations is greater.
- In England and Northern Ireland, the average EAD per person is highest in the most vulnerable neighbourhoods.
- Today, vulnerable neighbourhoods contribute two-thirds of the EAD in Northern Ireland, but their future contribution raises fastest in Scotland.
- At the coast, socially vulnerable neighbourhoods experience disproportionally high levels of EAD, today and in the future.
- Lower income and lower levels of insurance penetration heighten the 'relative economic pain' of flooding in vulnerable neighbourhoods (across all sources of flooding).
- EAD is set to rise, from £351 million today, residential direct damages only, to £1.1 billion by the 2080s[3].

[3] Assuming *a* +4°C climate future, high population growth and a continuation of current adaptation approaches.

Residential EAD from flooding across the UK is £351 million (residential property only). These headline figures also mask the disproportional risks faced by vulnerable communities in all four nations. In Northern Ireland, the 20% most vulnerable neighbourhoods account for 67% of the EAD (in Scotland the equivalent figure is 22%, in England 22% and Wales 26%). This reflects a significant contribution from Belfast.

At the coast, the 5% most vulnerable neighbourhoods account for 10% of the EAD; the 10% most vulnerable contribute 19% and the 20% most vulnerable 32%. This implies that the risk experienced by the socially vulnerable communities is much higher than the average; a disproportionality that persists into the future.

Those living in flood prone areas in Scotland experience the highest EAD per person (on average, £113 per person); this is over double that of England (on average, £50 per person). By the 2080s (assuming a +4^{o}C climate future and high population growth) the EAD per person in Scotland increases to £183 per person (compared to £95 per person in England) with the risk in socially vulnerable neighbourhoods (top 20% by NFVI) increasing twice as quickly as elsewhere (increasing from £93 to £206 per person). This is not the case in England, Wales and Northern Ireland where more and less vulnerable neighbourhoods experience a similar rate of increase in EAD per person.

Low incomes and low levels of insurance penetration means the REP associated with flooding is much greater in vulnerable neighbourhoods than elsewhere. In areas prone to coastal/tidal flooding, for example, socially vulnerable neighbourhoods (top 5% by NFVI) experience over twice the REP of less vulnerable neighbourhoods; in fluvial floodplains, it is three times higher. By the 2080s (under all scenarios) the increase in EAD translates to significant increases in the REP across the UK and all sources of flooding, particularly for the most vulnerable neighbourhoods.

Urban and rural influences on flood disadvantage

- Many socially vulnerable people live in urban areas prone to flooding, however vulnerable people living in rural settings are often exposed to more frequent flooding (and hence, on average, higher levels of EAD per person).
- By the 2080s, all neighbourhoods experience significant increases in EAD, with the most vulnerable neighbourhoods in more dispersed settings (both urban and rural) experiencing slightly greater increases than elsewhere.

At a UK scale, people living in more vulnerable neighbourhoods in the fluvial and coastal floodplains are mostly in urban settings (840,000, over 90% of the total 900,000 of the people exposed to flooding in more vulnerable neighbourhoods) whereas the remaining 60,000 in rural settings are exposed to more frequent flooding (reflected in an EAD per person, on average, of £76 compared to £42 in urban settings).

By the 2080s, assuming a continuation of CLA, there is a significant increase in risk across all settlement types. In many settings, more and less vulnerable neighbourhoods experience similar increases. In dispersed urban and rural settings however, the most vulnerable neighbourhoods experience slightly higher percentage increases in risk when compared to less vulnerable neighbourhoods.

Local authorities and flood disadvantage

- Clusters of high social flood risk exist in local authorities across the UK.
- In some cases, flood disadvantage is highly localised, in others it is widespread.
- In most cases, local authorities that experience the highest level of flood disadvantage today continue to do so in the future. There are however several exceptions where the increase is much faster than elsewhere.

The SFRI provides the most direct measure of flood disadvantage (where exposure to flood risk and social vulnerability coincide) and highlights Hull, Boston, Belfast, East Lindsey, Glasgow, Swale, Newham, Leicester, Shepway, North East Lincolnshire, and Birmingham as the ten most flood disadvantaged local authorities in UK.

Flood disadvantage typically reflects areas where a large number of vulnerable people are exposed to flooding (such as in Hull). In such situations, conventional flood defences are more likely to be feasible (technically and economically). Elsewhere, however, flood disadvantage may be highly localised and reflect the exposure of a small number of vulnerable people to frequent flooding. When considered from this perspective, other areas emerge as experiencing high levels of disadvantage, such as West Somerset, for example, where highly localised (individual and community based) approaches may be needed to manage flood risks.

Across the Highlands of Scotland, Cardiff, Enfield, North Somerset, Tower Hamlets and Haringey the rate of increase in SFRI is significantly higher than elsewhere. In these authorities, the SFRI in the future is much greater than today.

Cities in decline and their influence on flood disadvantage

- City regions in relative economic decline tend to experience levels of flood disadvantage above the UK average; suggesting flood risk could undermine economic growth in areas that need it most.
- Belfast, Grimsby, Glasgow and Hull are all examples of struggling cities where the flood disadvantage is much higher than the UK average.

Sixteen of the 24 cities classed as in relative decline by Pike *et al.* (2016) experience levels of flood disadvantage above the UK average. This reflects a combination of influences but is driven by higher than average levels of vulnerability (as shown by the NFVI) and a greater than average number of people exposed to frequent flooding (in Glasgow, for example, those living in the floodplain are almost twice as likely to experience frequent flooding than the UK average). When income and insurance penetration are considered, the '*relative economic pain'* associated with flooding is significantly higher in these sixteen cities, reflecting the lower levels of income (on average) and lower levels of insurance.

Suitability of 'deprivation' as a guide for FRM investment

- The Index of Multiple Deprivation (IMD) fails to identify all areas of greatest flood vulnerability; with flood risk in the most vulnerable areas (defined by the NFVI) consistently greater than that in deprived areas (defined by the IMD).

The UK government collects data on deprivation across a range of domains (including income, health, housing quality, availability of services) associated with geographic areas. These are then combined into a measure of multiple deprivation (the Index of Multiple Deprivation, IMD) and used across government to understand the distribution of social inequalities associated with a neighbourhood and to inform resource allocation. The IMD is not however a measure of 'flood vulnerability' per se and flood risk in the most vulnerable areas (as defined here using the Neighbourhood Flood Vulnerability Index) is consistently greater than in deprived areas (as defined by the IMD). This suggests that the IMD fails to identify all those areas that are at greatest flood disadvantage. Given the role of the IMD in FRM policy across the UK (including supporting the identification of investment priorities in England through the FDGiA) these differences may be significant and raise questions over whether the IMD is the most appropriate measure for promoting Rawlsian principles within FRM investment decisions.

Recent developments in vulnerable neighbourhoods (England)

- Recent developments (2008-14) in areas prone to frequent coastal and surface water flooding (1-in-75 years or more frequent) have disproportionally taken place in the most vulnerable neighbourhoods.
- By the 2080s all developments built between 2008-14 will experience a significant increase in exposure to flooding. Across all sources of flooding the increase is greatest in those developments built in the most vulnerable neighbourhoods (but this is particularly the case in coastal floodplains).

Analysis by the Adaptation Sub-Committee (ASC) of new developments built between 2008-14 found that floodplain development continues (ASC, 2015). Further review of this analysis highlights that of the 1,199,000 new residential developments built in the period 2008-14 (ASC, 2015), 225,000 (or 20%) were built in flood prone areas (across all sources) with one in four of those properties being built in the 20% most vulnerable neighbourhoods. Vulnerable neighbourhoods in coastal and surface water floodplains have experienced greatest disproportionality in development. For coastal floodplains and surface water prone areas, new properties are ~20% more likely to be in areas prone to more frequent flooding (1:75 or greater) for the 20% most vulnerable neighbourhoods than for all neighbourhoods.

By the 2080s all developments built between 2008-14 will experience a significant increase in their exposure to flooding. Across all sources of flooding the increase is greatest in those developments built in the most vulnerable neighbourhoods; a discrepancy that is most significant at the coast.

Long-term investment in England: Evidence for greater investment in vulnerable neighbourhoods

- There is strong evidence to support improving the protection provided to the most vulnerable neighbourhoods.

Reanalysis of the optimised investment scenario in England within the LTIS (used to support the case for investment in flood risk management, Environment Agency, 2014) highlights a long-term economic case for improving the protection afforded to vulnerable communities, suggesting there is both an economic and a social justice argument for improving protection. It is also clear that income (and consequently health) are important drivers of flood vulnerability and are directly influenced by broader welfare, social and economic policy. The opportunity to enhance FRM outcomes, broader policy areas will be required to address localised flood disadvantage. This will include recognising the linkage between green infrastructure responses, such as Sustainable Urban Drainage Systems (SUDS), and the wider health and wellbeing benefits they provide. It will also be increasingly important to recognise the role of planning/welfare or other social policy interventions play in either increasing or offsetting flood disadvantage (by putting more people into areas exposed to risk in the case of planning or increasing vulnerability through cuts to welfare benefits affecting incomes).

Policy gaps and recommendations

Two important policy findings emerge from the analysis: (i) the distribution of flood risk today suggests that, in general, vulnerable neighbourhoods have fared no differently compared to less vulnerable neighbourhoods and, in some instances, are at greater risk today, and (ii) the distribution of flood risk in the future suggests the largest increases in flood risk will, in many instances, be experienced by those areas which are currently most vulnerable. This does not imply that the current policy framework is wholly inadequate; there are many good examples of the progressive policy statements across the UK that acknowledge the need to reduce flood risk for vulnerable communities and often refer to prioritising vulnerable groups. Despite these high level aims a new approach is needed that requires FRM policy to more effectively support broader socio-economic goals (including inclusive and sustainable growth). Doing so will require a stronger Rawlsian approach to positive discrimination (in support of the most vulnerable) to be adopted alongside utilitarian and egalitarian goals.

Seven policy recommendations are made to aid this transition, namely:

#1 Introduce new metrics that better reflect the nature of flood vulnerability and the risks faced by vulnerable neighbourhoods.

The research presented here reinforces the inability of existing metrics to capture the differential nature of the flood risks faced by socially vulnerable communities. To overcome the deficiencies in existing approaches, the three (new) metrics are introduced here which should be considered in FRM decision-making: **Neighbourhood Flood Vulnerability Index** (NFVI) – to better identify the most vulnerable communities; **Social Flood Risk Index** (SFRI) – to better understand the combination of probability, exposure and vulnerability; and **Relative Economic Pain** (REP) – to better understand how issues of lower income and less effective insurance impact the significance of flood risk.

#2 Reconfigure outcome measures to monitor flood disadvantage based upon a better understanding of flood vulnerability.

To some degree FRM policies across the UK promote the notion of targeting effort towards managing the risk for the most vulnerable populations; yet there is no routine assessment of the extent to which policies achieve this (notwithstanding that in England outcomes for households in deprived areas are monitored). To do so, alternative approaches could include assessing levels of systemic flood disadvantage (by routinely recording a comparison of the risk faced by the more and less vulnerable) as well as geographic flood disadvantage (focusing, for example, on the number of homes protected in the most vulnerable neighbourhoods defined by NFVI and ranking local authorities by SFRI with clear targets to reduce risk in the worst affected neighbourhoods).

#3 Embed positive discrimination in FRM investment decisions to target support to the most vulnerable communities.

Many FRM policy documents across England, Wales, Scotland and Northern Ireland refer to reducing vulnerability. The only formal mechanism for targeting investment towards the most vulnerable neighbourhoods however is in England (through the preferential weighting given to protecting households protected in deprived areas, as defined by the IMD). This process appears to have had some success, with the systemic flood disadvantage lowest in England (when viewed at a national scale for each UK nation and based on the number of people exposed to frequent flooding). Across the UK however these headline findings mask areas where disadvantage remains significant, including at the coast, in urban areas in relative economic decline, and many dispersed rural communities.

Further work is needed to formalise approaches that help vulnerable people to reduce their flood risk. This may involve formalising the preferential targeting of investment towards helping the vulnerable people in a way that recognises the context of the communities in which they live (for example, this may require a reframing the partnership funding formula in England to better reflect the differential ability to pay between businesses located in more and less vulnerable neighbourhoods). In doing so, it should also be recognised that flooding has a significant impact on the public purse, including significant and long-term physical and mental health impacts (Waite *et al.*, 2017), which also support the investment case for reducing flood risk for the most vulnerable.

#4 Ensure FRM actively supports inclusive growth, the delivery of multi-functional and resilient developments whilst continuing to deliver flood risk reduction benefits.

Low income and poor health are important drivers of vulnerability to flooding. These are most directly influenced by agendas outside of FRM policy (including economic and welfare polices as well as sustainable development initiatives such as those promoted by Local Enterprise Partnerships). Ensuring FRM policy plays a proactive role in supporting broader agendas, and promote interventions that not only deliver risk reduction but also co-benefits for health, wellbeing and amenity (for example, by using green infrastructure responses where possible).

#5 Improve take-up of appropriate property level measures and wider community level approaches in vulnerable neighbourhoods.

Government support has previously been made available to local authorities in the aftermath of a flood to provide support to householders to fund measures which improve a property's resilience or resistance to damage from flooding, over and above repairs that would normally be covered by insurance. Evidence from local case studies for this study however suggests the take-up of such grants is significantly lower in vulnerable communities than in the population as whole and highlights six issues that will be needed to improve the take-up of appropriate property level measures, including: (i) The need for an on-going grant scheme targeted towards supporting flood disadvantaged areas (not only in reaction to flood events); (ii) Streamlining access to grants for the most vulnerable; (iii) Removing/reducing the need for the most vulnerable to provide supplementary funding; (iv) Raising awareness of both the flood risks faced, the availability of grants and reputable contractors and products; (v) Supporting the role of intermediaries in enabling individual and whole communities to access financial aid, appropriately install and maintain measures (*e.g.* drawing upon the National Flood Forum, local resilience fora, flood action groups and other local routes); and (vi) Continuing to develop a complementary approach with insurance providers to incentivise/require appropriate property level measures to be in place.

#6 Improve access to appropriate insurance for the most vulnerable by developing an insurance mechanism that bridges the gap in take-up between the more and less vulnerable.

When income and insurance penetration (a function of tenure and income) are considered, the REP associated with flooding is significantly higher in flood vulnerable neighbourhoods than elsewhere. Addressing the complex issues that exist in providing effective insurance in vulnerable neighbourhoods (including those associated with affordability, excesses, capability, awareness, and tenure) imply the solution does not lie with flood policy alone and a greater coherence between wider housing and welfare policy together with flood insurance approaches will be required. In the short term this should include evolving insurance solutions for low income households (within the period of Flood Re) to better support affordable, and appropriate, insurance for vulnerable people.

#7 Better reflect the differential nature of the long-term flood risks faced in vulnerable neighbourhoods within national planning policy and local guidance.

To avoid exacerbating flood disadvantage through inappropriate new development, national planning policies and local planning approaches should be revisited to: (i) Take a long-term view that includes consideration of more extreme, but plausible, climate change; (ii) Ensure opportunities for blue-green responses are taken (*e.g.* sustainable urban drainage systems that promote green spaces and deliver additional health and well-being benefits that act to reduce flood vulnerability in addition to flood hazards); (iii) Ensure new developments are flood resilient; and (iv) Give greater consideration to the flood vulnerability of likely inhabitants of any new development. The opportunity provided through the Housing White Paper (*'Fixing our broken housing market',* DCLG, 2017) should be used to promote these goals and ensure greater account is taken of flood risk in light of climate change in the future development of vulnerable neighbourhoods.

#8 Ensure flood events do not divert significant funds inappropriately from managing risk in more vulnerable areas and do not foreclose more sustainable longer-term options.

It is well known that funding, in part at least, responds to public 'outrage'. This can lead to those with the loudest voice being prioritised over those with the greatest need. Investment made in response to a flood event should be additional investment, and not undermine established investment processes or divert funds that have been committed elsewhere. Where they are made, they must avoid foreclosing future choices (*e.g.* decisions made in haste may be counter to providing a longer-term solution including, for example, relocating communities when protection through conventional FRM approaches is no longer feasible). Understanding how to respond to emergencies whilst transitioning towards a more sustainable approach (that may require a transformative approach in the face of climate change) is a significant challenge. To do so in a socially just way will require a combination of community involvement and a policy imperative to establish objectives with communities and agree how these can be achieved to support a sustainable future (providing the procedural justice to ensure that those involved have their voice heard).

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Project Advisory Group

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- **Paul Cobbing:** National Flood Forum
- **Jacqui Cotton:** Environment Agency
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- **Manuela Di Mauro:** Committee on Climate Change
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- **Rhys Hobbs:** Environment Agency
- **Kate Kipling:** Environment Agency
- **Sarah Lindley:** University of Manchester
- **Tim Maiden:** CAG consultants
- **Paul Murby**: Defra
- **Amanda Nobbs OBE:** Chair of Thames Regional Flood Defence Committee
- **Tim Preece:** Defra
- **Stacy Sharman**: Defra
- **Laura Hughes:** Association of British Insurers
- **Clare Twigger-Ross:** Collingwood Environmental Planning

Policy meetings: Stakeholders engaged

England

- **Robbie Craig:** Defra
- **Paul Murby:** Defra
- **Jose Poncela Blanco:** Defra
- **Tim Preece:** Defra
- **Stacy Sharman:** Defra
- **Mike Steel:** Environment Agency
- **Mary Stevens:** Defra

Northern Ireland

- **Linda MacHugh:** Department of Infrastructure
- **Jonathan McKee:** Rivers Agency

Scotland

- **Carol Brown:** Scottish Government

- **Debi Garft:** Scottish Government
- **Kirsty Irving and Paul Laidlaw:** Scottish Flood Forum
- **Mark McLaughlin and Marion Shoote:** Scottish Environment Protection Agency

Wales

- **Joanne Amesbury:** Welsh Government
- **David Thomas:** Welsh Government

Sayers and Partners Team

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1.0 INTRODUCTION

1.1 Context and objectives

Developing a better understanding of flood vulnerable communities and the risks they face is a prerequisite to delivering a socially just (*i.e.* fair) approach to prioritising flood risk management (FRM) efforts within national policy and funding structures. Such an approach emphasises Rawlsian principles of preferentially targeting risk reduction for the most vulnerable, and avoids a process of prioritisation based upon strict utilitarian or purely egalitarian principles (Johnson *et al.,* 2007).

Social vulnerability in the context of floods relates to how flooding impacts on and creates losses in people's wellbeing (Tapsell *et al.,* 2004, Lindley *et al.*, 2011). Delivering socially just flood risk management (FRM) thus requires two central issues to be addressed. The first relates to the **geographic flood disadvantage (GFD)**. GFD enables those communities where high levels of social vulnerability combine with a large number of people exposed to flooding to be identified and resources appropriately directed. The second relates to the **systemic flood disadvantage (SFD)**. SFD compares the flood risks faced by more and less vulnerable communities. In doing so, SFD enables the degree to which FRM policy (and its implementation in practice) can be considered successful in delivering socially just outcomes.

The analysis presented here builds upon previous research funded by the Joseph Rowntree Foundation (JRF) (England and Knox, 2015; Lindley *et al.,* 2011) to understand both geographic and systemic aspects of flood disadvantage and how these may change in the future in response to exogenous influences (*e.g.* climate change and population change) and endogenous influences (*e.g.* FRM policy and its broader impacts on issues such as insurance). To do so, future changes in GFD and SFD (through to the 2080s) are also explored through a combination of quantified analysis at a UK scale (using the Future Flood Explorer, UK FFE, Sayers *et al.,* 2016) and engagement with national and local stakeholders. Based on this evidence a series of policy recommendations are made with the aim of promoting social justice and improving resilience in the most vulnerable communities across the UK.

Objectives

To better understand the geographic and systemic nature of flood disadvantage the analysis seeks to:

(i) Identify those neighbourhoods at greatest flood disadvantage now and in the future (through to the 2020s, 2050s and 2080s) across the UK;
(ii) Assess the degree to which FRM can be considered socially just; and
(iii) Identify policy gaps and recommend policy changes to improve flood resilience and reduce disadvantage.

1.2 Rationale for a UK scale approach

National assessments of flood risk are widely recognised as providing important evidence to inform policy decisions. Such assessments have been pursued actively by the Environment Agency since 2002 (covering England and Wales, Sayers *et al.,* 2002) and their predecessors since 1998, and more recently by Scottish Environment Protection Agency (SEPA) since 2011. This importance arises because of the role of a national level determination of risk in setting the pace of adaptation and shaping the policy response and resource inputs (*e.g.* Defra, 2011). This importance has been further strengthened through the Climate Change Act 2008 that's requires a *UK-wide Climate Change Risk Assessment* (CCRA) to be undertaken on a five-yearly cycle that is independent of national leads but influences the scale and focus of adaptation measures (CCC, 2016).

The evidence provided to policymakers (either at a UK or national scale) has, to date, included very limited insight into flood disadvantage. The assessment of future flood risk as part of the CCRA (Sayers *et al.,* 2015), for example, suggests that in a +4^{o}C climate future (a high, but plausible assumption), flood risk is likely to increase despite on-going efforts to adapt and the adoption of an 'enhanced whole systems' approach to adaptation. Although the CCRA highlights the issue of current flood disadvantage in the discussion of cross cutting concerns, (Chapter 8, Street *et al.*, 2016) it says little about future flood disadvantage or the policy responses that may be needed to specifically target vulnerable communities. In England, the Environment Agency's programme of flood and coastal erosion risk management sets out a six-year investment plan (2015-2021) for capital spending on FRM, which includes £2.5 billion of public investment[4]. There is, however, limited alignment between planned investment and areas where high levels of vulnerability and exposure combine (England and Knox, 2015). This is despite an initial analysis of the Environment Agency's *Long-Term Investment Scenarios* (LTIS) (Environment Agency, 2014a) suggesting that, based purely on an optimised cost/benefit appraisal, the most deprived communities (as defined by the Index of Multiple Deprivations, IMD) should be prioritised (Sayers *et al.,* 2016).

The focus of FRM is also changing, away from a narrow economic risk focus towards a broader resilience focus. The national Flood Resilience Community Pathfinders Scheme (2013-15), for example, sought to stimulate innovative approaches to community FRM and enable communities exposed to flooding to work with key partners to develop innovative local solutions (Defra, 2013). An early review of this programme however highlights some of the difficulties in understanding what is meant by resilience, and how this understanding shapes the nature of the solutions proposed, noting *'the way resilience is framed will lead to different actions and emphases'* (Twigger-Ross *et al.,* 2014). Within this report, resilience is considered in the context of 'flood risk' (a combination of vulnerability, exposure and probability) and how these risks may change in time. To avoid traditional economic bias (a criticism often levied at a narrow risk-based approach), conventional risk metrics have been supplemented with those that seek to capture the broad nature of community flood resilience (see Chapter 3). The Twigger-Ross *et al.,* studies also revealed the important role community networks (between members of communities and more formal organisations) play in both flood vulnerability and resilience; a finding supported by Fazey *et al.,* (2016) that highlights the interactions between household budgets and community capacity as pinch

[4] https://www.gov.uk/government/publications/programme-of-flood-and-coastal-erosion-risk-management-schemes. Accessed May 2017

points in the system and taken forward here in development of the Neighbourhood Flood Vulnerability Index (NFVI) (see Chapter 3).

The political framework within which FRM is delivered is also changing through the on-going process of devolution, a process that has the potential to alter the powers and competencies of local and national authorities as well as regions. These changes may alter the relationship between central and local Government and hence the way issues of social justice are embedded in FRM investment decisions as well as more generally in Local Enterprise Partnerships (LEPS) and broader welfare and social policy (including inclusive and sustainable growth).

1.3 Report structure

The research findings are provided through a Main Report (this report) and a series of supporting appendices (Figure 1-1).

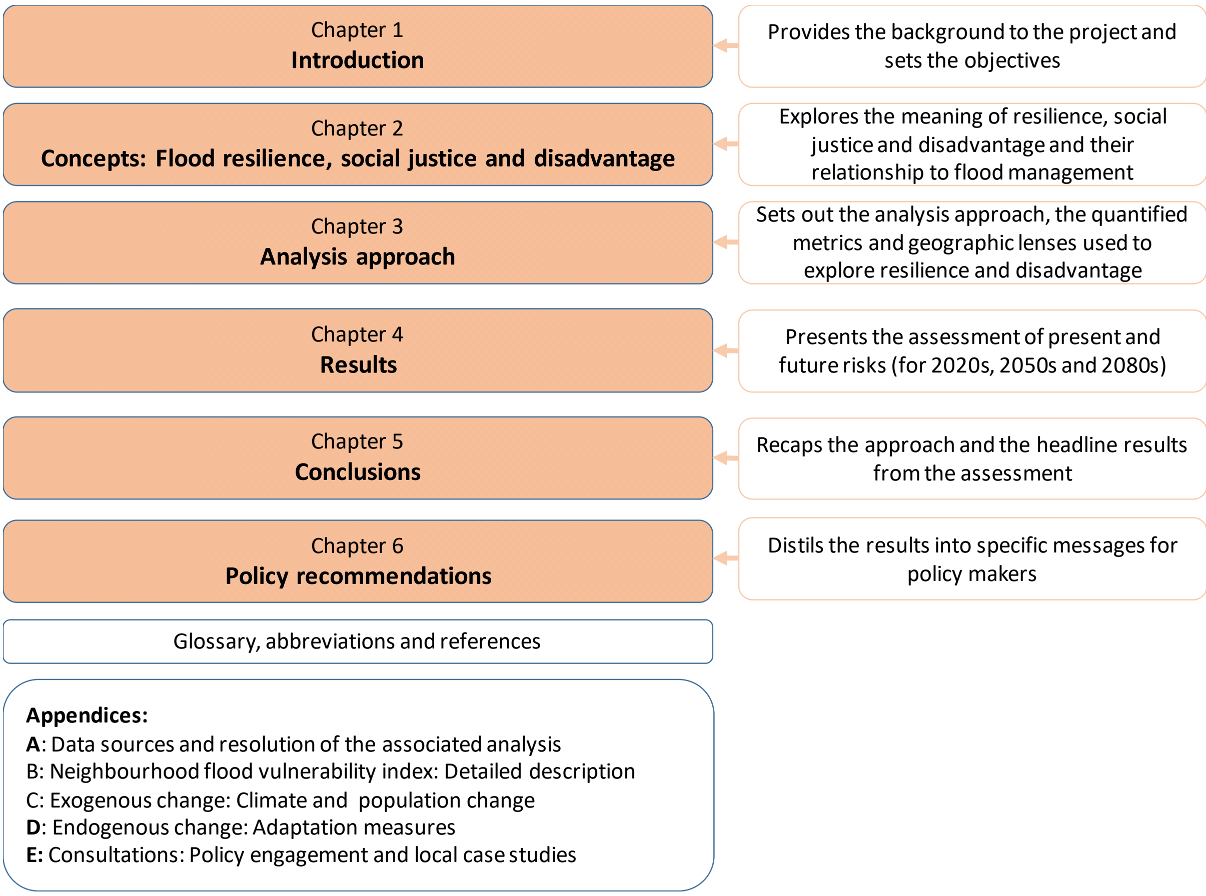

Figure 1-1 Report structure

2.0 CONCEPTS: FLOOD RESILIENCE, SOCIAL JUSTICE AND DISADVANTAGE

2.1 Flood resilience

Four characteristics of a resilient system

No blueprint is available as to what constitutes resilience in a practical sense. There is however an emerging consensus on the four characteristics of a resilient system that affect flood resilience (*e.g.* Sayers *et al.,* 2012; Twigger-Ross *et al.,* 2014), namely:

(i) **Resistance (an ability to resist):** *An ability to limit the immediate impact of a hazard (e.g. through the appropriate design of community and property level defences and ensuring flood warning services are effective) and prevent direct impacts, when they do occur, from cascading to secondary and tertiary impacts (such as longer term financial, physical or mental health issues or through business supply chains).* A focus on resistance can therefore both reduce direct flood impacts and help avoid their escalation through interdependent networks at a community, regional, national and even global scale (*e.g.* through economies, Rinaldi *et al.,* 2001, infrastructure networks, Hall *et al.,* 2013 and ecosystems, Sayers *et al.,* 2014). These interdependences also exist at a community level and act to either support or undermine an individual's ability to resist an immediate loss of well-being (*e.g.* due to loss of local support services or delay in receiving help). These interactions are however complex and remain a focus of research.

(ii) **Recovery (bounce-back):** *An ability of an individual or community to recover rapidly (return to normality) from a flood event with limited emergency aid.* Pre-event measures, such as insurance and emergency service provision, can significantly improve recovery times and make a legitimate contribution to resilience.

(iii) **Adaptation (adjusting to a new normal):** *An ability to modify existing approaches (physical defences, organisational structures, behaviour etc.) in response to a changing situation, recognising resilience as a dynamic and continuous process of adjustment.* Adaptability therefore refers to the ability to enact a process of on-going moderate change in approach (*e.g.* a household may choose to install property level protection measures when made aware of the flood risk they face, or planners could support adaptation measures being incorporated into new housing development).

(iv) **Transformation (step change):** *The foresight and ability to make radical changes to avoid future risks and grasp future opportunities (physical, social, ecological, economic) in a timely and just manner*. Numerous studies have highlighted the need for transformation (Evans *et al.*, 2004a&b, Fritze *et al.*, 2008; Sayers *et al.,* 2014). There are, however, many practical and political difficulties associated with implementing transformational change. For example, many Shoreline Management Plans in England promote a *'hold the line'* policy in the short term and a transition to *'retreat the line'* by the 2050s (ASC, 2013), but with limited understanding of how to make this transition in a way that is fair to the communities affected.

The first two characteristics support the notion of *'reactive resilience'* where the approach to the future is to maintain the status quo and the quest is for constancy and stability (Dovers and Handmer, 1992, cited in Twigger-Ross *et al.,* 2013). The last two characteristics support the notion of *'proactive resilience'* and the acceptance that change is inevitable and a resilient system is one that is capable of the necessary change (Dovers and Handmer, 1992 cited in Twigger-Ross *et al.,* 2013).

Integrated perspectives of resilience

To understand resilience all four of the aspects set out above must be considered together and in the broadest context possible. **Community resilience**, for example, reflects the local capability to plan and prepare for, respond to and recover from adverse events and background conditions in a way that reflects the context of wider social, economic and environmental change beyond floods. In doing so, community resilience has the potential to deliver multiple objectives, including climate mitigation and adaptation (for example, actively seeking multi-functional approaches that combine renewable energy and flood defence). Community resilience also requires the capability to learn, plan and adapt (and even transform) in ways that mitigate the impacts of adverse events in the longer-term future (Burchell *et al.,* 2017). The idea that a range of individuals, voluntary and community sector groups and other local organisations work together to increase the community's ability to prepare for, cope with and recover from adverse events or conditions is now well established (UK Cabinet Office, 2011). These activities tend to be led, in the UK but also elsewhere, by local authority emergency planners (within the context of a Local Resilience Forum) and often focus on managing short-term risks and, as a result, are less well positioned to adopt more strategic solutions (Burchell *et al.,* 2017). Such longer-term solutions are necessarily underpinned by 'systems thinking' and the identification of critical nodes that will affect outcomes including household budgets and community capacity (Fazey *et al.,* 2016).

This focus on emergency response is also reflected at national scale (as shown by the attention given to forecasting, warning and emergency response in the National Resilience Review (HM Government, 2016)and underpinned by the requirements of the Civil Contingencies Act, 2004) with limited attention given to the longer term, more difficult, transformative actions needed to build community and household agency, social networks, relationships and links between informal and formal governance structures, supporting capacity building, social learning and organisational change. **Infrastructure resilience** (*e.g.* Guthrie and Konaris, 2012), **economic resilience** (*e.g.* Briguglio *et al.,* 2008) and **ecological resilience** (*e.g.* Walker *et al.,* 2004, Sayers *et al.,* 2017) are also often used to focus attention on different aspects of human-natural systems.

Present and future social flood resilience

Hazard focused perspectives of resilience are also used to simplify the issue (*i.e.* resilience to a certain type of shock or long-term change, for example heat, drought etc.) and this is the context here; ***social flood resilience.*** Although it is recognised that it is not sufficient to consider resilience from the perspective of a single hazard, it is a necessary step to challenge traditional FRM practice to move away from the rather restricted focus on resistance and recovery to a more collective concept of resilience that involves interdisciplinary expertise and action, and to recognise resilience building as a process involving building relationships and responses across institutions, sectors, communities and individuals, that addresses interacting systemic risks and interdependencies (*e.g.* ENSURE, 2009; Cutter, 2010; Newman *et al.,* 2011; Liao, 2012 cited in Twigger-Ross *et al.,* 2013, Sayers *et al.,* 2014, Fazey *et al.,* 2016).

Within this report, the notion of social flood resilience is explored through a series of quantified metrics (discussed later in Section 3.3) evaluated at a neighbourhood level. In this context, it is assumed a prerequisite to enhancing resilience (across these perspectives) is the management of risk (and reducing hazard, exposure and vulnerability). Understanding the complex social dynamics and the broader evolution of resilience is outside the scope of this report.

2.2 Social justice

Policy legitimacy is an important consideration in the policymaking cycle, and issues of social justice can help to inform policymakers' approaches. This report considers how these concepts inform present-day approaches to FRM and how they may be used to guide future adaptation. Interpreting social justice in the context of flood risk management is not however straightforward. This is because 'justice' is often considered from the perspective of utilitarianism (as first proposed by Jeremy Bentham and John Mills), egalitarianism (rights based theories) and Rawlsian (John Rawls, 1971) approaches (Figure 2-1). The influence of each approach in the context of FRM is summarised in Table 2-1 and discussed below.

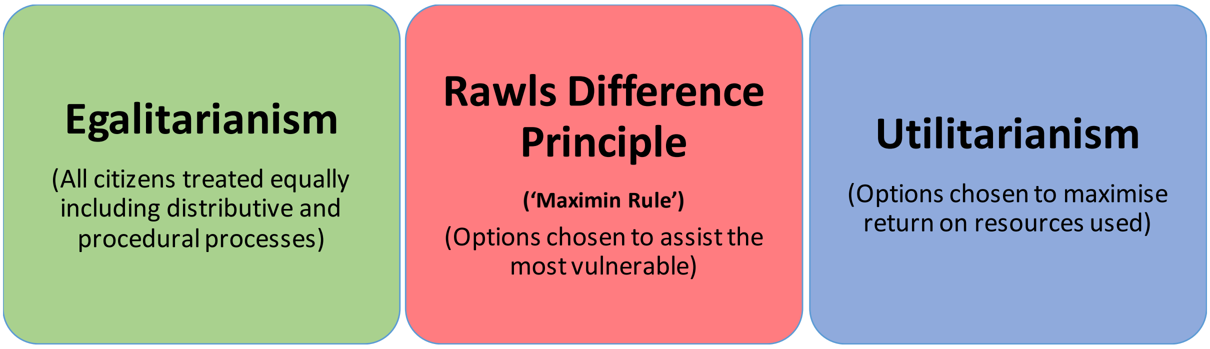

Figure 2-1 Three principles considered here to influence a socially just approach to flood risk management

Utilitarianism

Utilitarianism states that the action that leads to *'the best consequences is the morally preferred action'*, and that the 'consequences' of interest should have *intrinsic value* (*e.g.* beauty, love, health, friendship) and not simply *instrumental value* (*e.g.* money, that enables you to buy other things). In practice utilitarianism often default to a rather narrowly defined cost benefit approach (where only those benefits and costs that can be readily monetised are included). Such approach is often criticized because of this narrow focus but also because of its failure to include any notion of 'distributive justice' (see egalitarianism below). Applied in isolation, such an approach would often suggest that it is preferable to maximise the collective outcome for the many to the detriment of the few, thereby prioritising efficiency over effectiveness.

Table 2-1 Social justice and flood risk management

Justice principle (type)	Rule / Criteria	Meaning for flood risk management	Potential implications for future flood risk management
Egalitarian	Rights-based approaches that seek to ensure all citizens are treated equally.	Every citizen should have an equal opportunity to have their flood risk managed.	In some countries, such as the Netherlands, the principle of "solidarity" seeks to provide a common minimum level of protection to all individuals (*e.g.* van Alphen, 2014). The heterogeneity of the flood risk in England however means that such an approach, even if achievable is likely to be grossly inefficient (Defra, 2004). Instead a consistent decision-making process is sought, for example, enabling those at flood risk a fair chance of receiving tax funded investment.
Rawlsian	An approach based on **positive discrimination** that seeks to direct resources to those least able to help themselves.	Options are chosen that target the most flood vulnerable members of society (even when greater economic returns can be found elsewhere).	The most vulnerable individuals and communities need to be identified and plans developed that specifically cater for their needs. Policy and planning processes to incorporate bias to ensure preference is given to managing flood risk for most vulnerable individuals and communities. Although many policy goals promote preferential targeting of the most vulnerable, the only formal expression of this (known to the authors) within the decision-making process is England's Flood Defence Grant-in-Aid scheme, although Scotland and Wales have more informal processes.
Utilitarian	The return on investment is maximised to ensure the greatest risk reduction per unit of resource input.	Assistance provided to those members of society to which the benefits offer the greatest gain to society.	A prioritised programme of investments that provides the greatest return (reduction of risk) for each unit of resource investment. The adoption of a common approach to the assessment of benefits and costs to identify those actions that yield the greatest return (*e.g.* Environment Agency, 2010a). Increasingly this process reflects whole-life-costs and the multi-benefits under multiple futures (although readily monetised benefits continue to dominate this process and potentially undermine the ability to maximise utility).

Source: Sayers et al., 2016, extended from Johnson et al., 2007; Sayers et al., 2014

Utilitarian views of justice, despite this shortcoming, are at the heart of government policy as this approach recognises public resources are limited and seeks to maximise the return on every unit of resource invested. In this context, FRM competes with alternative investments (*e.g.* hospitals, schools etc.) and thus 'efficiency' is a fundamental consideration in investment appraisal and decision-making across government (*e.g.* HM Treasury, 2003) and cascades to FRM scheme appraisal guidance. Although this varies in detail across the UK, all approaches are largely based on issues of utility - see for example Environment Agency (2010) and Welsh Government (2015).

The demonstration of efficiency relies on an ability to quantify costs and benefits for competing investment options. The ability to do so however varies across different FRM activities. For example, costs and benefits are less well understood for flood forecasting and warning systems and green infrastructure responses compared to traditional engineering solutions involving capital investment in flood defences. In part, this reflects the inability to attribute costs and benefits to different interventions and difficulties in both quantifying and monetising the full range of benefits they provide. In the case of flood warning, for example, the primary focus is on minimising injury and loss of life, as opposed to reducing material damage. This presents a problem in measuring efficiency, which typically (for reasons of ease) expresses instrumental values in monetary terms and may exclude less tangible, or less easily monetised, benefits.

In practice, this often leads to failure to take account of complex externalities, such as the impact of climate change on alternative FRM options and the wider social impacts of flooding (*e.g.* the significant costs of mental health impacts may still fall on the public purse but to other government departments) (Waite *et al.*, 2017). This is perhaps one driver of the development of multi-criteria approaches that seek to communicate intrinsic values and express consequential impacts in easily measurable units (hectares of habitat created, number of people protected, quality of life adjusted years (NIHCE, 2009) and monetise only those consequences where it is easily done (*e.g.* economic loss).

In England, the Long-term Investment Scenarios (LTIS) published by the Environment Agency (2014a) explore the long-term investment case for reducing flood risk in England based on optimising the Net Present Value provided by a simplified set of policy options stretching through to 2100. In doing so, LTIS considers the costs and benefits of alternative investment policy choices but with no consideration of who pays or the Flood Defence Grant-in-Aid (FDGiA) rules that seek to positively discriminate in favour of protecting the most deprived households (an element of a Rawlsian approach embedded within individual scheme funding approaches as discussed later in this Section). In this context, the LTIS investment analysis is based on the principle of 'utility', and although it does not attempt to set out priority short-term investments the LTIS does set the long-term direction of travel and informs the national funding settlement for England negotiated between Defra and the Environment Agency. The Environment Agency's published six-year programme of capital schemes for England is also largely derived from a prioritised programme of investments that provides the greatest return on those investments, although both egalitarian and Rawlsian influences (see below) play some part in determining this list (Environment Agency, 2014a).

In Scotland (Scottish Government, 2016) and Wales (Wales Audit Office, 2016) efficiency is also at the centre of the prioritisation process, although preferential weighting is, informally, given to prioritising the most vulnerable.

In Northern Ireland, there is a policy assumption that sufficient funds are available to meet all necessary flood defence schemes, and hence no formal process of prioritisation is reported to exist (personal communication with Jonathan McKee (Rivers Agency, 2016). Maintenance works are generally prioritised using a risk-based process that is largely utilitarian in nature.

Egalitarianism

Egalitarianism or rights based theories of justice, recognise that the framework of society (its laws, institutions, policies, etc.) give rise to variations in the distribution of benefits and burdens across the members of that society. Egalitarianism is therefore concerned with this distribution (**distributive justice**) and seeks to ensure that all citizens have equal opportunity to have their risk managed and have equal input to decision-making processes and governance (**procedural justice**). Both general propositions influence FRM as below.

Distributive equality (i.e. reducing everyone's flood risk equally). In some countries, such as the Netherlands, the principle of 'solidarity' seeks to provide a high level of flood safety for all individuals (*e.g.* van Alphen, 2014). In part, this has been adopted in the Netherlands (despite its achievability and desirability being increasingly questioned, Klijn *et al.,* 2015) because of the widespread severity of the flood hazard and the potential catastrophic consequences should a flood occur (as much of the country is below sea level) but also because of the homogeneity of the flood systems with few alternative options available, other than structural protection. The heterogeneity of the flood risk across the UK means that such an approach, even if achievable, would be either grossly inefficient (diverting resources from more beneficial activities) or not meaningful for those affected (*e.g.* if the minimum level of safety would need to be set very low, to be practical everywhere (Defra, 2004)).

In England, 'equality' in the sense of delivering a uniform flood risk standard is therefore considered impractical and not necessarily desirable when resources are constrained (Defra, 2004). This does not mean however that no effort is made to maximise the number of people that have their risk managed. The incremental Benefit:Cost Ratio (iBCR) test applied in England, for example, examines the marginal increase in benefits compared with the marginal increase in costs associated with delivering a progressively higher standard of protection (Defra, 2014b). This approach attempts to support utilitarian efficiency and distributive equality by directing limited national investment towards maximising the number of people provided with a minimum degree of protection, and away from providing higher standards in a few locations (despite the latter achieving a greater economic return).

Procedural equality (i.e. focused on the decision-making process and how well it provides everyone with an equal opportunity to have their flood risk managed) is a more practical aspect of equality in the context of FRM and can be seen in various policies. For example, all development applications are subject to the same spatial planning process (*e.g.* in Wales, TAN 15, Welsh Government, 2004), investments in flood forecasting are generally provided for everyone on national scales and "blue light" services provide the same operational role and responsibilities irrespective of the local social context (although the local devolution of powers mean priorities and resources will inevitably vary at a local level, despite similar national policy structures, leading to different local planning decisions for example). The approach to the application for funding is also typically transparent and based on agreed and standard decision rules (derived from HM Treasury 2003). The biases within these rules (expressed through the priorities given to economic, environmental and social outcomes, *e.g.* Environment Agency, 2010a) are clearly expressed and agreed by national Governments. In general, the process is open and consistently applied.

Political imperatives can however circumvent these processes. Some areas, where the degree of public 'outrage' towards the risk faced is high or in the aftermath of a particularly severe flood, often receive favourable treatment from the government. Following the severe flooding in 2013/14, for example, £60 million was earmarked (although as of 2016 yet to be delivered) by the Treasury to help meet the cost of the previously stalled Thames Scheme (Environment Agency, 2016). Significant resources were also directed towards the largely rural communities within Somerset following widespread flooding in 2013/4; an allocation that was largely outside the appraisal system for managing risk. Following repeat flooding in 2015/16 similar aid was provided, with almost £50 million allocated directly to Cumbria to support the post flood recovery and additional funding awarded (or accelerated) in York, for example. Such interventions are a necessary response to devastating flood events, but similar flooding in Boston in Lincolnshire (where 803 properties were flooded during the 2013 storm surge) failed to receive similar attention (Environment Agency, 2014c). This discrepancy highlights that funding allocations are rightfully influenced by events, and the need to respond, but also that short term political imperatives can distort the established process for the assessment of risk and prioritisation of investment, and that not all affected places benefit equally after events.

Rawlsian

(Delivering positive discrimination towards the most vulnerable – also referred to as Difference Principle or 'Maximin Rule')

John Rawls (1921-2002) developed a theory of justice in which 'fairness' plays a central role (Rawls, 1971). Rawls argues that a 'fair' approach seeks to maximise the minimum outcomes by making the choice that produces the highest payoff for the least advantaged (the so-called *'maximin rule'*). This is a powerful concept and addresses the well-known short-coming of utilitarianism and suggests that even if considerations of efficiency indicate differently, it may be fair to spend taxpayers' money unevenly if it maximises the benefits for those who have little welfare resource. As such a Rawlsian approach focuses on the degree to which an action is effective in delivering socially just outcomes.

Across England, Wales, Scotland and Northern Ireland, high-level statements often refer to the need to support the most vulnerable members of society (although it is not always clear what is meant by vulnerability). In Scotland, the Scottish Government's publication *'Delivering Sustainable Flood Risk Management'* notes '*A reduction in the number of people, homes and property at risk of flooding as a result of public funds being invested in actions that protect the most vulnerable and those areas at greatest risk of flooding'.* In England, the outcomes from investment in FRM for the 20% most deprived households are explicitly monitored (*i.e.* Outcome Measures 2a[5]) and suggest that between April 2011-March 2015, 19,974 households in deprived areas were better protected from flooding in areas previously subject to a *'significant'* and *'very significant'* chance of flooding, compared to 82,971 households in less deprived areas[6]. No consideration, however, is currently given to degree to which this outcome is proportionally fair; only the number of properties protected. In Wales, the overarching goal of the Well-being of Future Generation Act (2015) seek to support the development of cohesive, resilient, healthier and wealthier communities[7] and are to be welcomed, but its impact on flood policy (and practice) is unclear.

Across the UK the delivery of on-the-ground services often reflect the need to support the most vulnerable. Flood warnings, for example, are typically provided in multiple languages and formats that best reflect the local context (Environment Agency, 2009). Most local authorities, agencies, and organisations also support the most vulnerable in preparing for and responding to flood events (*i.e.* by ensuring the emergency services are aware of special needs and community workers provide additional help where needed to complete claim forms). In Boston, Lincolnshire, for example, interviews with the Lincolnshire Fire and Rescue Service (Appendix E) confirmed that they are aware of the location of particularly vulnerable groups and individuals, and target their assistance during flood events accordingly. Despite this local targeting of action, and the many policy goals and good practice guides that promote the management of risk for the vulnerable, some vulnerable groups continue to experience discrimination. Gypsy and Traveller communities, for example, are often marginalised in the planning system, with housing opportunities provided in less popular or higher risk areas, including areas prone to flooding).

The only direct expression of Rawlsian principles within the FRM investment decision-making process is in England. The formula used to determine the maximum contribution to a FRM scheme from general taxation (the so-called Flood Defence Grant-in-Aid (FDGiA) formula, Defra, 2011) gives preferential weighting to schemes that reduce flood risk to deprived households (as defined by the Index of Multiple Deprivation)[8]. For households in the 20% most deprived areas (as defined by the IMD), the Grant-in-Aid is equal to the agreed payment rate per household protected (currently 20p for each £1 of benefit accrued[9]) multiplied by 2.25 (so 45p per £1 of benefit). In the 21-40% most deprived areas a multiplier of 1.5 is used (so 30p per £1 of benefit) and in the 60% least deprived areas there is no such uplift. This approach is supported by HM Treasury rules (HM Treasury, 2003) that govern all taxpayer investments, so allowing for the differential impacts on the most vulnerable to be included in the case for investment. Despite this, outside of the FDGiA process, national

[5] http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environment-agency.gov.uk/research/planning/122070.aspx Accessed Jan 2017

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/389952/FCERM_outcome__measures_Q2_2014_15__External.pdf Accessed Jan 2017

[7] http://www.legislation.gov.uk/anaw/2015/2/contents/enacted Accessed Jan 2017

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297377/LIT_9142_dd8bbe.pdf Accessed June 2016

[9] https://www.gov.uk/government/publications/fcrm-partnership-funding-calculator Accessed June 2016

averages that fail to differentiate vulnerability to harm continue to form the basis of the benefit analysis presented to justify investment (even though social class and hence income related indicators of flood damage are available, Penning-Rowsell *et al.,* 2013).

The availability of co-funding (from private sources) is also considered when determining government priorities in England. Although private-public partnerships are in general to be welcomed (extending finance available beyond the limited national funding), current implementation may undermine the targeting of resources to the most vulnerable communities as they may be unable to provide partnership funds. Under the Flood and Coastal Resilience Partnership Funding Policy (Defra, 2011), for example, central government contributes a proportion of total scheme costs. In those areas considered to be the most 'deprived' this could be 100% of the scheme cost. In this case, the benefit cost ratio (BCR) used to rank the scheme nationally would be based upon the full cost of the scheme. Elsewhere private contributions (at varying proportions of the overall scheme cost) are needed to support the justification of Grant-in-Aid funding. The partnership funding secured reduces the overall cost to the taxpayer. These reduced costs are then used in the estimate of the BCR and to improve the national ranking of the scheme. This may enable higher scheme costs (in support of a higher Standard of Protection or the inclusion of design enhancement, for example to improve amenity) to be justified without loss of national priority ranking. It may also enable schemes with a high proportion of private support to move up the ranking when compared to a similar scheme that relies upon 100% taxpayer funding. This implies that those areas with a greater ability to pay are more likely to receive national taxpayer support; an outcome that would be demonstrably unjust.

This aspect of the potential bias towards more affluent areas within the FDGiA process (not the formula per se) is reinforced through the lack of differentiation applied to businesses. No distinction is made between businesses operating in deprived areas and those in more affluent areas; in both cases businesses are expected to make a financial contribution to a scheme. This may be a particularly important influence when schemes provide flood protection to a mix of commercial and residential properties. In such settings, the economic income-generating infrastructure (such as the nature of the local businesses and potential mix of local small and medium sized enterprises compared to corporate multi-nationals) is given no advantage in more deprived areas over similar infrastructure in more affluent areas. This may be a significant barrier to securing funding in areas of mixed residential and non-residential properties, and may place an unnecessary brake on regeneration.

In Scotland, Wales and Northern Ireland policy there is no direct evidence within the investment prioritisation process of positive discrimination towards reducing risk for the most vulnerable. It is widely recognised that the process of implementation is reflected in the local context and this may include acting where possible to reduce risk in vulnerable areas; this process is not however formally defined in policy.

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2.3 Flood disadvantage

The three theories of justice introduced in the previous section have been explored in several projects (*e.g.* Johnson *et al.,* 2007; Nada-Rajah, 2010, Lindley *et al.,* 2011) and elements of fairness have been recognised as part of 'good' strategic FRM (*e.g.* Sayers *et al.,* 2014). Despite this there has been little quantification of the degree to which FRM delivers 'fair' or 'socially just' outcomes for vulnerable communities and how climate change may influence these outcomes. In part, this is because of the inherent natural spatial variation in the frequency and extent of flooding (reflecting the legacy of past interventions as well as natural processes) and the unequal impacts within affected areas due to differential vulnerability of those exposed to the flood. To understand the degree to which this inevitable spatial variation creates or reinforces existing disadvantage requires us to elaborate what we mean, in the context of this report, by 'flood disadvantage'.

Geographic Flood Disadvantage (GFD)

In previous work by Lindley *et al.* (2011), disadvantage is considered in the context of risk and is defined as a function of (a) the likelihood of exposure to a hazard, and (b) the individual or group vulnerability to such a hazard in terms of how likely this may be to lead to a loss in well-being. This definition provides an '**absolute**' interpretation of disadvantage and enables those locations where high levels of social vulnerability combine with a large number of people exposed to flooding to be identified. In this context disadvantage is '**geographic**' and as such can be estimated and mapped. This is referred to here as Geographic Flood Disadvantage (GFD) and provides insights into the nature of the distributional justice within present-day FRM and how this may change in the future.

Systemic Flood Disadvantage (SFD)

The term 'disadvantage' is extended here to consider the degree to which the most vulnerable neighbourhoods are disproportionally affected by flooding when compared to less vulnerable neighbourhoods. This definition provides a '**relative**' interpretation of disadvantage and enables the disproportionality in the flood risk faced by the most vulnerable to be explored. In this context disadvantage is '**systemic**', and is estimated by comparing the risks faced by one community with another. This is referred to as Systemic Flood Disadvantage (SFD) and provides insights into the degree to which FRM can be considered 'fair' (as defined by Rawlsian principles) and how this may change in the future. This approach builds upon similar techniques applied to consider the comparative disadvantage faced by racial minorities or low-income households (for example as applied in a comparative analysis of the risks faced in Colorado city, Harner *et al.,* 2002).

3.0 ANALYSIS APPROACH

3.1 Overview

The analysis provides an estimate of present-day flood risk across the UK based on an assessment of the flood hazard, exposure and vulnerability. Estimates of future risks, through to the 2080s, are also presented and account for the influences of both endogenous and exogenous drivers on these three issues (Figure 3-1).

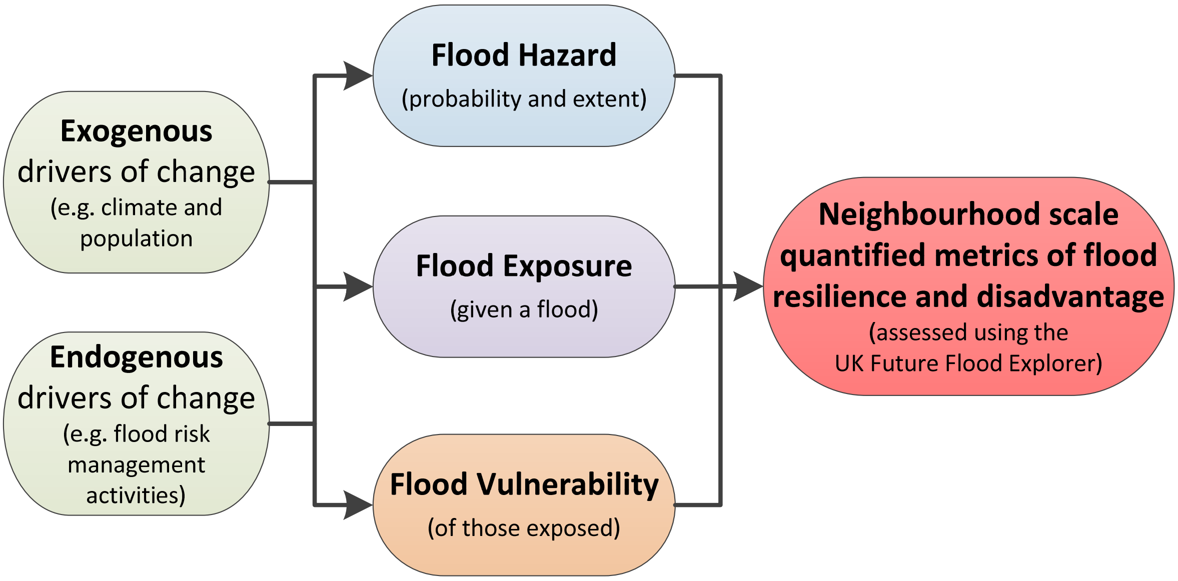


Figure 3-1 Framework of analysis

The scope of each aspect of the analysis is outlined below with additional information provided in the following section and, where appropriate, supporting appendices.

Flood hazard: Two aspects of the flood hazard, probability and spatial extent, are considered in the context of three sources of flooding; **fluvial** (river), **coastal** and **surface water** (pluvial) flooding. Further detail is provided in Appendix A.

Note: No consideration is given to groundwater flooding. This is because of the relatively low importance of groundwater flooding at a national scale when compared with fluvial, coastal and surface water (see Sayers *et al.,* 2015) and the difficulty of providing a credible assessment. Given the context of the study no consideration is given to the joint probability of flood sources – this is however a potential further extension although care will be needed to avoid adding unnecessary complexity to the analysis.

Flood Exposure: Residential property data (based upon national point datasets) together with locally representative household occupancy rates (from census data) are used to quantify the number of people that may be flooded during a given flood event and subject to a potential loss of well-being. Further detail is provided in Appendix A.

Flood Vulnerability: Census data is used to assess the susceptibility of individuals to experience a loss in well-being when exposed to a flood as well as their ability to prepare, respond and recover from a flood (without significant emergency support from the authorities). Further detail on the approach to estimating vulnerability is given in the following section and described in detail in Appendix B.

Exogenous future change: Two drivers of change, outside of FRM policy, are considered to influence future flood risk (climate change and population growth). These influences are summarised in Figure 3-2 with supporting information given in Appendix C.

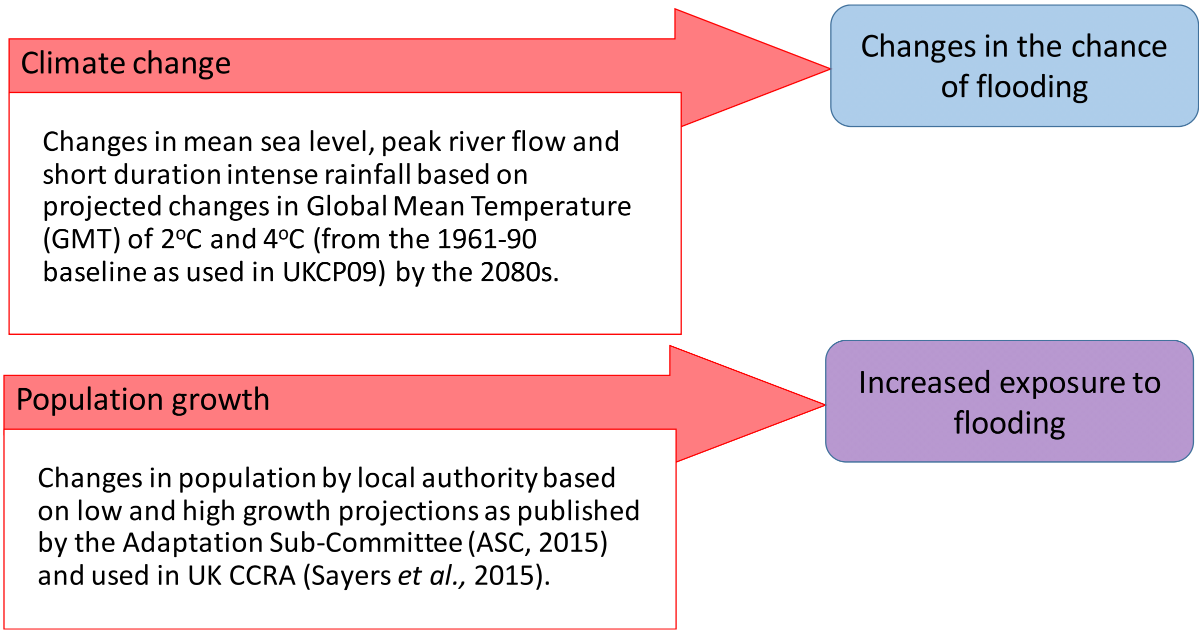


Figure 3-2 Exogenous drivers of future change in flood risk

Note: No consideration is given to economic growth. Exploring the influence of differential economic growth across social characteristics of flood disadvantage is beyond the scope of this study. It is therefore assumed that economic differentials remain unchanged in the future and monetary losses are expressed at present day values (without discounting).

No consideration is given to the potential expansion of the undefended floodplain in response to climate change, only the probability of flood changes.

Endogenous future change: Purposeful actions taken to directly control or strongly influence future flood risk increasingly include a broad range of responses (as advocated by various documents: Making Space for Water (Defra, 2005); Working with Natural Processes (Environment Agency, 2010b, 2014b); Delivering Sustainable Flood Risk Management (Scottish Government, 2011); CCRA Future Flooding Report (Sayers *et al.,* 2015)). This 'whole system' approach is reflected here through eight individual adaptation measures (Figure 3-3). To determine the effectiveness of each adaptation measure in managing future risk it is assumed that current **FRM policies continue to be implemented as effectively as they are today**. A detailed description of the individual adaptation measures, and an evidence based discussion of their assumed future effectiveness, is given in Appendix D.

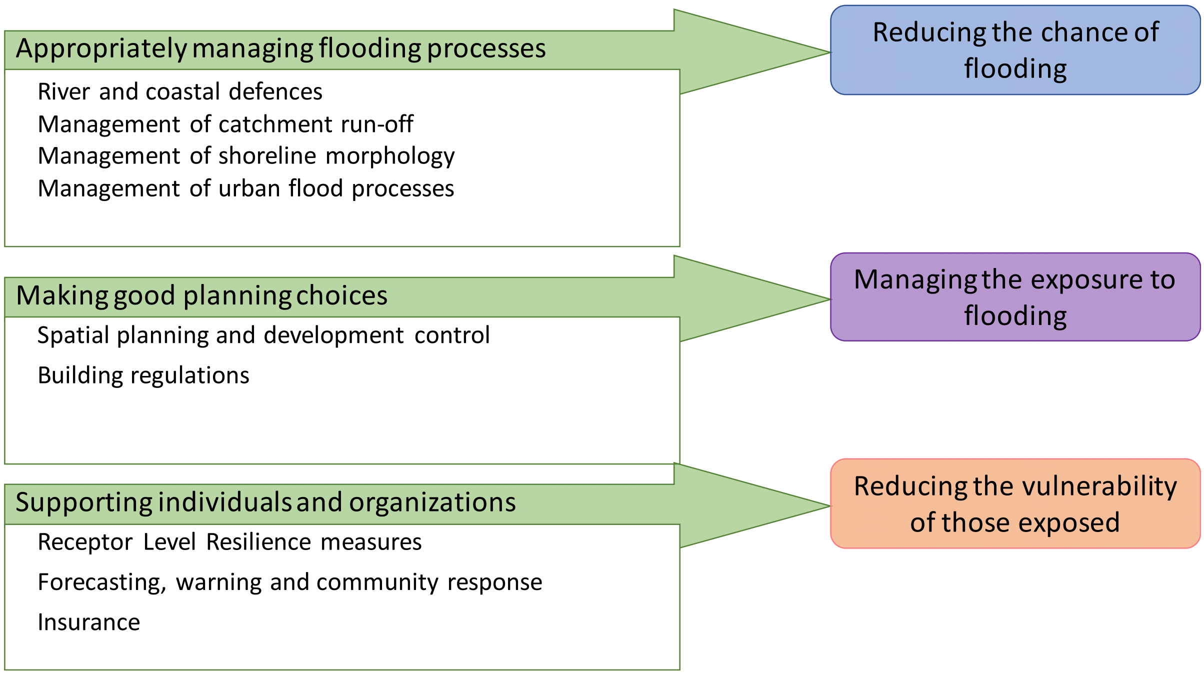


Figure 3-3 Endogenous change: Adaptation measures considered

Note: It is recognised that across the UK FRM takes place as a continuous process. Planned schemes and activities for specific locations, not yet completed, are not included here. Further detail on the forward plan can be obtained from the FRM leads for each part of the UK.

3.2 Analysis method

The spatial coverage of the analysis and the number of adaptation, population and climate scenarios of interest (as well as the multiple epochs, flood sources and risk metrics to be considered) mean that conventional modelling approaches are too computationally intensive to explore all combinations (a challenge recognised in Kwakkel and Pruyt, 2013). Instead, the approach used builds upon lessons from past national scale studies undertaken in the UK (*e.g.* Evans *et al.,* 2004a&b) and insights from international studies (*e.g.* Klijn, *et al.,* 2004, 2014; Bouwer, *et al.,* 2010) to allow a rapid evaluation of the effects of climate, population change and adaptation using the UK Future Flood Explorer (FFE) - the same modelling framework used in the UK Climate Change Risk Assessment, CCRA (Sayers *et al.,* 2015, 2016). The UK FFE uses available data on flood hazard, exposure and vulnerability to develop a credible representation of the behaviour of the UK flood risk system that can then be used to assess present day flood risks (for a range of metrics) and the change in risk given a range of influences (such as climate change, population growth and adaptation), including actions to manage the probability of flooding as well as those that influence exposure and vulnerability).

The high computational efficiency of the FFE allows a consistent assessment of flood risk across England, Wales, Scotland and Northern Ireland under the multiple scenarios of interest here (*e.g.* two climate change projections, +2°C and +4°C rise in Global Mean Temperature, low and high population projections and taking accounting of future adaptation).

Building upon the analysis completed for the CCRA, the FFE has nevertheless been revised and enhanced in three areas for application here: the spatial resolution of the analysis, the characterisation of flood vulnerability, and adaptation to flood risk differentiated by the vulnerability of the communities affected. The importance of these advances is discussed below.

Spatial resolution of the analysis

The underlying spatial resolution of the available flood hazard data varies across the UK and ranges from 2m-50m (depending upon flood source and location). The available data on exposure is based on residential point datasets and hence has the resolution of a single property. This does not however imply the results are credible at these scales. The concept of the 'neighbourhood' is therefore used as a small, but appropriately aggregated, spatial unit to bring together flood hazard and exposure with census based vulnerability data. Neighbourhoods correspond to Lower-level Super Output Areas (LSOAs) for England and Wales, Super Output Areas (SOAs) for Northern Ireland, and Data Zones (DZs) for Scotland. There are 42,619 neighbourhoods in the UK. The average population in each of these areas varies by country: 1600 in England, 760 in Scotland, 1600 in Wales and 2000 in Northern Ireland. This represents an evolution of the previous assessments of flood disadvantage for England and Wales (Lindley *et al.,* 2011, based upon Middle Layer Super Output Areas, MSOAs) and maintains the resolution of previous studies in Scotland (Kazmierczak *et al.,* 2015).

Neighbourhoods are used in aggregation and reporting of FFE outputs, and are also the basic unit at which census based vulnerability is calculated. The FFE itself operates at the scale of 'Census Calculation Areas' (CCAs). CCAs split each neighbourhood into (possibly overlapping) polygons associated with the different flood sources. The CCAs are the units for which impact curves are calculated (as in Figure 3-4). There are 842,864 CCAs in the UK, covering fluvial, coastal and surface water sources.

This also provides a significant increase in resolution from the analysis undertaken as part of the CCRA based upon the much larger Catchment Calculation Areas (CCA - defined solely using coastline and river boundaries to subdivide the floodplain and 1km squares for surface water). FFE outputs are not directly provided at CCA scale, as these represent widely varying areas and populations. Using neighbourhoods as the smallest aggregation area is better when comparing and ranking flood risk in different areas.

It is assumed that each CCA represents either coastal, fluvial or surface water flooding; some CCAs overlap allowing some areas to be subject to more than one source. To incorporate the effect of the many flood defences that affect the probability of flooding, each CCA is associated with a representative Standard of Protection (SOP) and Condition Grade (CG) based upon the standards and conditions of the individual defences that relate to it (Sayers *et al.,* 2015). For each CCA, an Impact Curve is generated relating the return period of a current or future flood event to the magnitude of the impact (*e.g.* economic damage or the number of properties that that would be flooded) (Figure 3-4). The Impact Curves are then manipulated to quantify the influence of climate and population change as well as adaptations on flood risk. For example, to represent climate change the Impact Curve is moved to the left along the return period axis. The raising of flood defences, however, would act to reduce risk by shifting the Impact Curve in the opposite direction.

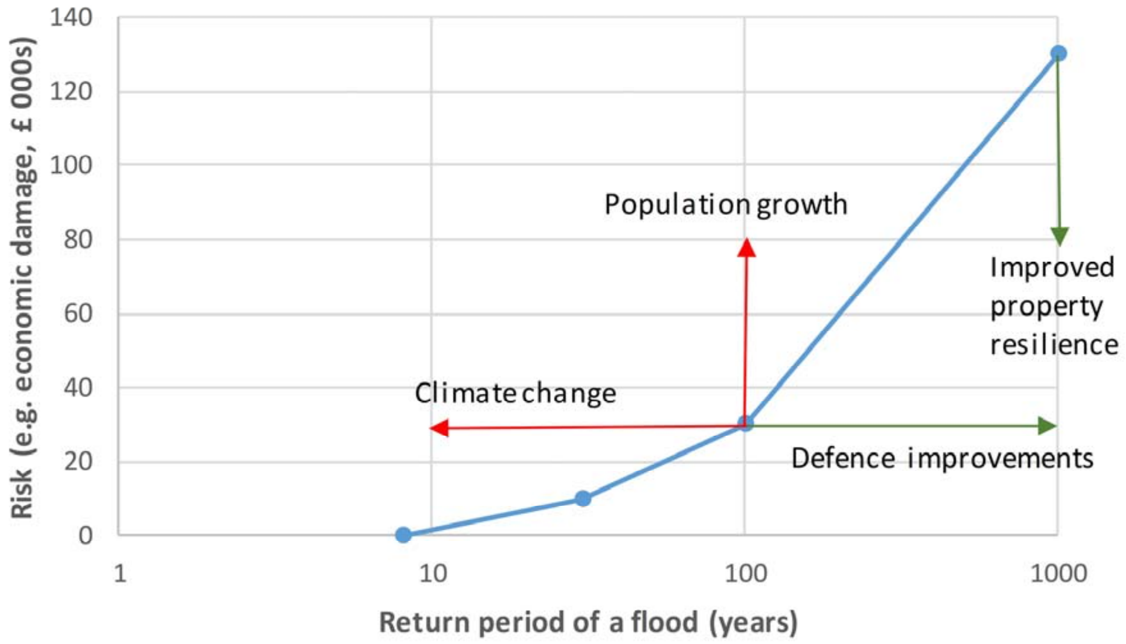


Figure 3-4 Impact curve: Example relationship return period vs. impact used within the FFE (Sayers et al, 2015)

Characterisation of flood vulnerability

FRM policy typically considers vulnerability through the lens of deprivation (as indicated by the Index of Multiple Deprivation) and this view provided the basis of the analysis presented in the CCRA (Sayers *et al.,* 2015). A focus on deprivation however does not necessarily reflect a community's vulnerability to a flood should it occur (although vulnerability is influenced by income deprivation, as clearly demonstrated by Tapsell *et al.,* 2002). To overcome this short-coming, and build on the characterisation of flood vulnerability advanced by Lindley *et al.,* (2011) and more recently by Kazmierczak *et al.,* (2015), a new measure is introduced here: the **Neighbourhood Flood Vulnerability Index** (NFVI). The NFVI is used to express the characteristics of an individual and the community in which they live that influence the potential to experience a loss of well-being when exposed to a flood and over which flood management policy has limited or no control. This understanding reflects previous studies (Tapsell *et al.,* 2002; Lindley *et al.,* 2011; Twigger-Ross *et al.,* 2014; Kazmierczak *et al.,* 2015) and requires consideration of five characteristics:

Susceptibility: Susceptibility describes the predisposition of an individual to experience a loss of well-being when exposed to a flood. It is widely evidenced that the dominant characteristics that influence susceptibility to harm relate to the age (the old and very young) and health of the individuals exposed.

Ability of an individual to prepare for a flood: Preparedness reflects the actions taken by an individual during normal conditions (*i.e.* in the absence of a forecast or actual flood) that are likely to reduce the harm they suffer when a future flood occurs. Although an area of continued research, an individual's ability to prepare is influenced by their income, capacity to act, local knowledge and property tenure.

Ability of an individual to respond to a flood: The underlying reasons why some individuals act more effectively in the run up to and during a flood is an area of continued research. There is however broad agreement that an individual's ability to respond is influenced by their income, capacity to access and use formal and informal information, local knowledge and physical mobility.

Ability of an individual to recover from a flood: Many flood events have highlighted the length of time it can take for individuals and communities to recover from a flood. The degree to which an individual can aid their own recovery is influenced by several factors, particularly their income, capacity to use information, and physical mobility.

The ability of the community to support individuals: The availability and quality of services provided by health and emergency services as well as broader care and social services are all important social facilities that have a real influence on the severity of harm caused by a flood. Despite a lack of quantified evidence, there is also strong anecdotal evidence that community support networks can help ameliorate vulnerability by providing support to affected groups and flood management policy is increasingly recognising the value of community networks (for example by supporting the national Flood Community Resilience Pathfinders schemes, Defra, 2012, 2015). As such, the presence or absence of community support is legitimately considered here as a component of vulnerability. A formal representation of community cohesion and its influence on flood vulnerability is not however available. In recognition of the importance of community support, but in the absence of more detailed insights, four indicators are considered to gauge the nature of this support: housing characteristics, the collective experience of past floods, the likely availability of community services in a flood (including emergency service provides, schools, GPs, care homes) and the social networks that exist. This is recognised as very much a first step and further research will be required to better quantify supportive community contexts.

The approach to estimating the Neighbourhood Flood Vulnerability Index (NFVI), and the specific indicators used, are set out alongside other metrics in Section 3.3.

Differential capacity to adapt

In the context of a national analysis, the effectiveness of individual adaptation measures is often considered to be independent of social vulnerability (as for example within the CCRA, Sayers *et al.,* 2015). To overcome this short-coming, the analysis presented here differentiates the effectiveness of individual adaptation measures based on vulnerability (where there is some evidence to do so). A detailed discussion of each individual adaptation measure, and the supporting evidence, is provided in Appendix D, with the findings summarised below:

Better manage flooding processes: **Flood and coastal defences:** In most cases, the availability of a government grant determines the likelihood that a flood protection scheme will go ahead. Despite the Flood Defence Grant-In-Aid (FDGiA) formula prioritising deprived areas in England and Wales (Defra, 2011) and supportive high-level statements that seek to prioritise the most vulnerable, there is some evidence to suggest that the most vulnerable neighbourhoods are not as well protected as others (England and Knox, 2015), investment focused in urban areas (and away from rural areas) and towards more affluent areas (and away from deprived areas). This is reflected here in the implementation assumed future adaptation of defence measures. **Retrofitting of Sustainable Urban**

Drainage measures: anecdotal evidence suggests that in inner-city areas (where urban flooding and drainage is significant) a differential take-up of retrofitting SUDS may exist – although no firm evidence can be found. Within the analysis here it is assumed that there is no take up in more vulnerable communities (compared to 10% elsewhere, ASC, 2014).

Make good planning choices: **Spatial planning and development control:** population growth and associated development are important drivers of future risk. Analysis of new developments (in England only) in the period 2008-2014 undertaken for this study suggests that the percentage of new dwellings built within the fluvial and coastal floodplain is around 14 per cent in more vulnerable areas (defined by the top 20 per cent of neighbourhoods by NFVI) and 11 per cent in less vulnerable areas. This differential in current planning outcomes is assumed to persist into the future and is therefore carried forward in the analysis here.

Support individuals and organisations: Property level measures, warning services and insurance all provide important contributions to supporting individuals and communities to manage their flood risk, but all three can be difficult for the most vulnerable to access. For example:

Property level measures: Evidence does suggest that the take-up by the most vulnerable in existing developments is likely to be significantly lower than in the population as whole. There may be multiple reasons for this including:

(i) Property level measures can be expensive which may rule out installation by people on low incomes (National Flood Forum, 2012);
(ii) The process of applying for a grant is bureaucratic and cumbersome (National Flood Forum, 2016);
(iii) Grants may not be enough to encourage take up by the most vulnerable (anecdotal evidence from the case studies undertaken here, see Appendix D)
(iv) Tenants in rented accommodation have a reduced ability and incentive to install property level measures; and
(v) Developing an awareness of flood risk within transient communities maybe more difficult.

In combination, these barriers mean it is likely that retro-fitting of property level protection (PLP) measures in the most vulnerable neighbourhoods may be significantly less than elsewhere (although limited quantified evidence exists); and this perceived differential is carried forward in the analysis here (as defined in Appendix D). There is however little evidence that suggests the take-up of such measures within new developments is any different in more and less vulnerable neighbourhoods.

Effectiveness of forecasting and warning services: There is some evidence to suggest that vulnerability influences a community's ability to respond to a warning. In part, this is reflected in the NFVI but vulnerability can also influence the effectiveness of such measures due to, for example:

(i) *Barriers to receiving the warning:* many households are no longer choosing to maintain a landline but instead rely upon mobile technologies. Although delivery of warnings through mobile networks is being explored this can create complications in trying to contact households to convey flood warnings.

(ii) *Accessing the content of warnings:* minority ethnic groups for whom English or Welsh is not their first language may be less able to respond (Thrush *et al.,* 2005).

(iii) *Awareness of the need to be 'flood aware':* one of the factors that has been shown to have the greatest impact on levels of "awareness" is lack of previous flooding experience (Thrush *et al.,* 2005).

In combination, these challenges are assumed to lead to lower rates of take-up of warning services and the action taken in response to the warnings to be less effective at reducing economic damage in more vulnerable neighbourhoods when compared to less vulnerable neighbourhoods (see Appendix D for details).

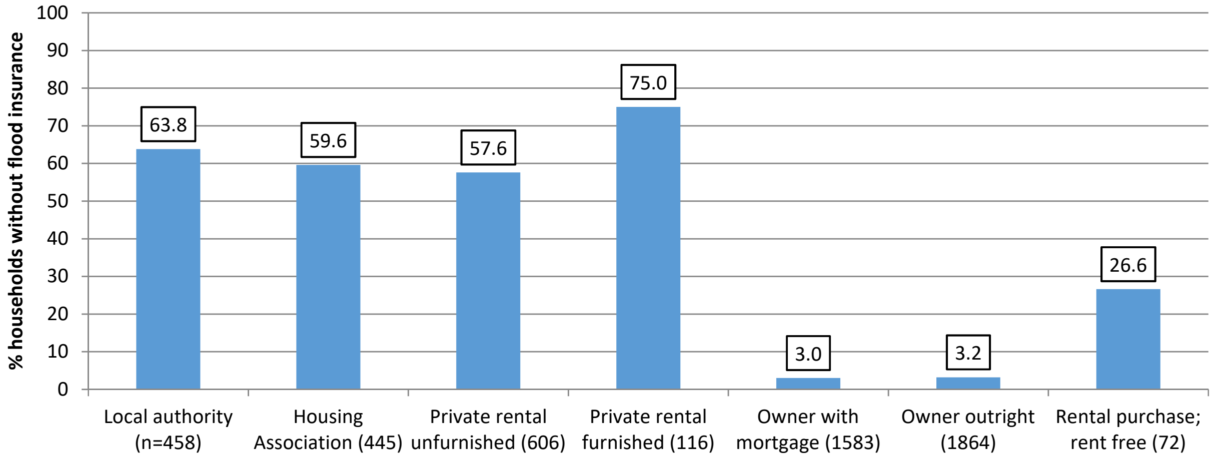
Flood insurance: Insurance underpins all other FRM policies in the UK, relieving the government of the obligation to pay compensation for the damage caused by flooding. This is one of the few FRM policies where measures are universally applied across the UK (National Flood Forum, 2012). Insurance take-up, however, is uneven. Based on the government's Household Expenditure Survey and evidence from its own members, the Association of British Insurers (ABI) estimate that the take-up of insurance in the UK is such that 93 per cent of all homeowners have buildings insurance that covers the structure of their home, but this falls to 85 per cent for the poorest 10 per cent of households purchasing their own property. In rented accommodation, some 75 per cent of all households have home contents insurance, but half of the poorest 10 per cent of households do not have this protection (ONS, 2015). This prompted Watkiss *et al.* (2016) to note that *"while most owner occupiers have building insurance, there are much lower levels of contents insurance among tenants, with many in the lowest income decile having no insurance at all"*.

To establish a credible representation of insurance, and how effective it may be in the most vulnerable neighbourhoods, several issues have been considered:

(i) *There is a lower level of insurance take up by lower income households:* There is a marked difference in penetration levels with different levels of disposable income, with a +47.5 per cent difference between the lowest and highest income deciles identified before the introduction of Flood Re (ONS, 2015). This differential forms the basis of the insurance adapation measure applied to building and contents losses – as set out in Appendix D.

(ii) *There are lower levels of penetration for households in rented accommodation:* Figure 3-5 shows that households in rented accommodation have a far greater chance of not being insured when compared to home owners. Local authorities and housing associations would typically be responsible for any structural repairs following a flooded, rather than the tenant, so the penetration figure here represents the penetration of contents insurance rather than domestic property insurance. Nevertheless, the difference between owner occupiers and tenants is striking, and is compounded by the fact that the private rented accommodation sector in the UK is growing quite rapidly, whereas owner occupation is declining proportionately (ONS, 2016). For structural repairs following a flood those in the private rented sector the insurance position of the landlord is what is critical rather than that of the tenant, and many local authorities self-insure rather than insure through the market.

(iii) *Under-insurance and excesses:* There is a perception that under insurance (*i.e.* insurance covering less than the likely loss) and large excesses (particularly for those previously flooded) are used to reduce premiums but can undermine the safety net provided by insurance at the time of need. The available information is however sparse and it is unclear if this varies with different tenure types and household income levels (as take-up does, Figure 3-5).



Note: Figures are based on analysis Pre-Flood Re. Source: (ONS, 2015)

Figure 3-5 The relationship between tenure and households with no flood insurance

Since April 2016 Flood-Re has created a pool into which all insurers contribute to subsidise the insurance premiums of those at greatest risk (Defra, 2014a). Householders purchasing flood insurance will not know whether they are in this pool or not, since they will deal with their conventional insurance company, but that company will cede the policy and the liability for claims to the Flood-Re pool if the cost of insurance exceeds certain thresholds and certain eligibility criteria are met (including being build before hey were built before 1st January 2009). The result is intended to make flood insurance affordable as it attempts to ameliorate some of these issues, including for example capped premiums linked to Council Tax bandings. However, in high risk areas, itis unclear whether Flood Re has been successful in improving insurance take-up in the most vulnerable neighbourhoods. It is also the case that Floods Re has a life of only twenty-five years after which flood insurance will become fully risk-reflective. Watkiss *et al.,*2016 discusses how this transition to market prices will, in the longer term, lead to substantially higher premiums for those at risk, and those at most risk will pay much more than at present. The transition to an actuarial accounting process could further discourage the most vulnerable for accessing insurance.

Important caveats

There are some important caveats that relate to representation of all adaptation measures within the analysis and the variation in national policies between England, Wales, Scotland and Northern Ireland as well as the local context within which risks are managed. These are summarised in Box 3-1.

Box 3-1 Individual adaptation measures: Important caveats

National policies and implementation vary: The contrasting FRM legislation and the approaches adopted across England, Wales, Scotland and Northern Ireland mean that the emphasis of past adaptations and the mix of future adaptation measures that may be used will differ (and perhaps markedly) across the UK. In developing the individual adaptation measures presented in this chapter it has been necessary to develop a single UK wide assessment of their effectiveness. In some instances, achieving this single view is difficult. For example, Scotland has a stronger policy focus on natural flood management than elsewhere in the UK. In England, however, take up of flood warning services is much more widespread. These, and many other differences (as set out in Appendix D), have been considered in developing a representative description of the effectiveness of each adaptation measure. In most cases a greater emphasis has been placed on policies that have the potential to influence risk the most. Any future development of the FFE could consider adaptation measure variations for each country (whilst continuing to analyse risk in a consistent way across the UK).

Actions outside of FRM: Although an increase in residential properties is assumed to occur alongside population growth, no consideration is given to broader developments that would be needed to reflect or support that growth (*i.e.* new schools, hospitals etc.) nor the actions taken by those providers to safeguard their services during a flood.

Local context is important: The applicability and effectiveness of a given mix of adaptations will reflect the local context within which they are applied. This local context is in part embedded within the description of the individual adaptation measures. For example, the degree to which climate change reduces the Standard of Protection provided to an area reflects the present-day standard in that area. This means that parts of the floodplain protected to a higher standard today continue to have more effort devoted to them in the future. The consideration of specific local constraints and opportunities that will determine the feasibility of specific adaptation measures at a local level is, however, out of scope.

3.3 Metrics of flood exposure, vulnerability and risk

Managing risk is a prerequisite to enhancing resilience (as discussed in Section 2.1). The degree of social flood resilience and disadvantage is therefore interpreted through a series of quantified expressions of exposure, vulnerability and risk (Table 3-1).

Table 3-1 Vulnerability and risk metrics used to determine the degree of social flood resilience

Metric	Insight provided
Exposure metrics	
Floodplain population (FP)	The scale of the potential exposure within a neighbourhood in the absence of defences.
Expected Annual Probability of flooding: Individual (EAI)	An individual's annual 'average' exposure to flooding, taking account of defences. Athough not representative of any specific individual this provides a means of comparing the 'average' exposure between neighbourhoods.
Number of People Exposed to Frequent Flooding (PEFf)	The number of people exposed to flooding more frequently than 1:75 years, on average.
Vulnerability metrics	
Neighbourhood Flood Vulnerability Index (NFVI)	The propensity of those living in a neighbourhood to suffer a loss of well-being should a flood occur.
Risk metrics	
Expected Annual Damages (EAD) - Residential only	The annual 'average' direct economic damages, in monetary terms, taking account of defences.
Expected Annual Damage: Individual (EADi)	The average (economic) risk faced by an individual living within the floodplain. Although not representative of the risk faced by any specific individual this provides a means of comparing risks between neighbourhoods.
Relative Economic Pain (REP)	The 'relative pain' of the economic risks faced by those exposed to flooding (expressed as the ratio between uninsured economic damages and household income).
Social Flood Risk Index (SFRI)	The level of social flood risk (a combination of exposure, vulnerability and probability of flooding), at a neighbourhood scale (SFRI) and as an individual 'average' (iSFRI).

These headline metrics include a combination of traditional risk metrics and new metrics developed here. Each metric is discussed in turn below.

Metrics of exposure

'Exposure' is defined here as the number of people that may be flooded, and thereby subject to potential loss of well-being. In assessing exposure, no consideration is given to the severity of the harm that may be caused (*e.g.* from shallower or deeper flooding or the degree of harm caused). Exposure is therefore a binary term; a person or property is either exposed to a given flood or not. Three approaches are used to provide an insight into 'exposure':

Floodplain population (FP): This is an estimate of the number of people living (not working) within the floodplain within a given neighbourhood. The estimate is made by combining the average occupancy rate of a household within a given neighbourhood and the number of residential properties that would be exposed to flooding with a return period of 1:1000 years or more frequent (in the absence of defences, where they exist). This metric also considers the number of people in areas exposed to surface water flooding with a return period of 1:1000 years or more frequent, even though these areas are not in what are traditionally thought of as floodplains.

Note: This metric does not change with climate change. This is because the floodplain extent, defined by the present day 1:1000-year return period flood, is assumed to remain unchanged in the future (although flood probability within the floodplain does change). This is not a true representation, as floodplains are likely to extend further (in the absence of defences) with climate change, but is considered reasonable given the most significant impact of climate change on surface water and fluvial floods is likely to be the change in probability of flooding. At the coast this assumption is more challengeable under more extreme sea level rise assumptions (beyond those considered here) and was explored in the CCRA (Sayers *et al.,* 2015a). This metric does, however, change with population growth.

Expected annual probability of flooding: Individual (EAI): The expected annual probability of an individual experiencing flooding is calculated by combining the spatial variation in the annual probability of flooding to any depth with the location of individual residential properties and neighbourhood average occupancy rate. In doing so, the EAI is used to provide a people-focused annual 'average' exposure to flooding.

Note: EAI is calculated at a neighbourhood level and is an average value for those living within the 1:1000-year floodplain (or surface water equivalent) within that neighbourhood and is not associated with a specific individual.

Number of People Exposed to Frequent Flooding (PEFf): A focus on expected values alone (*e.g.* EAI above) can mask important differences in the profile of the risk faced between neighbourhoods. For example, an area with many people exposed to very infrequent flooding would yield the same estimate of EAI as an area where only a few people are exposed to frequent flooding. This metric (PEFf) therefore focuses on the number of people exposed to flooding more frequently than 1:75 years (on average). To enable a valid comparison between areas the PEFf is expressed as an average value per head of those living within areas exposed to a probability of flooding of 1:1000 or greater (and within the aggregation area of interest).

Note: To quantify exposure to flooding, only those living on ground floor or basement properties are considered in England and Wales; for Scotland, all properties are included; for Northern Ireland ground floor properties only are included, and additional multiple properties within the same building footprint are not counted. These differences in the treatment of properties stem from the different data sets used in each country. No distinction is made between those living in a basement flat and those living on the ground in terms of exposure. It is however assumed that basement properties suffer more economic damage (by a factor of 1.5 owing to likely greater impact of a flood on household inventory items stored there: personal communication with Edmund Penning-Rowsell) compared to an equivalent ground floor property experiencing the same return period flood (see risk metrics).

In some texts, the term 'exposure' incorporates the chance that a person will be present when a flood occurs (*e.g.* Hartford and Baecher, 2004). Under this more nuanced interpretation fewer people may be exposed in a predominantly residential floodplain during the day because they are away at work, or because they have successfully evacuated the area in response to a warning. This is not done here.

Metrics of vulnerability

Neighbourhood Flood Vulnerability Index (NFVI): A new index, Neighbourhood Flood Vulnerability Index (NFVI), is used to provide insight into the social vulnerability of a neighbourhood should a flood occur. The NFVI combines the five domains of vulnerability (set out in Section 3.2) based upon a subset of twelve 'vulnerability indicators' (Figure 3-6). In this context, a 'neighbourhood' is defined by census geographies (*i.e.* Lower Layer Super Output Areas (LSOA) in England and Wales, Data Zones (DZ) in Scotland and Super Output Areas (SOA) in Northern Ireland). This represents a natural evolution of the previous analysis for England and Wales (Lindley et al., 2011) based on Middle Level Super Output Areas (MSOAs); a scale that can cover very heterogeneous socio-economic conditions, and maintains the resolution of previous studies in Scotland (Kazmierczak et al., 2015) whilst also taking advantage of an improved understanding of the flood hazard and exposure. The data used to calculate each indicator (in Figure 3-6) are summarised in Table 3-2. The supporting evidence for the selection of each vulnerability indicator, and how they have been combined to derive the NFVI, is set out in detail in Appendix B.

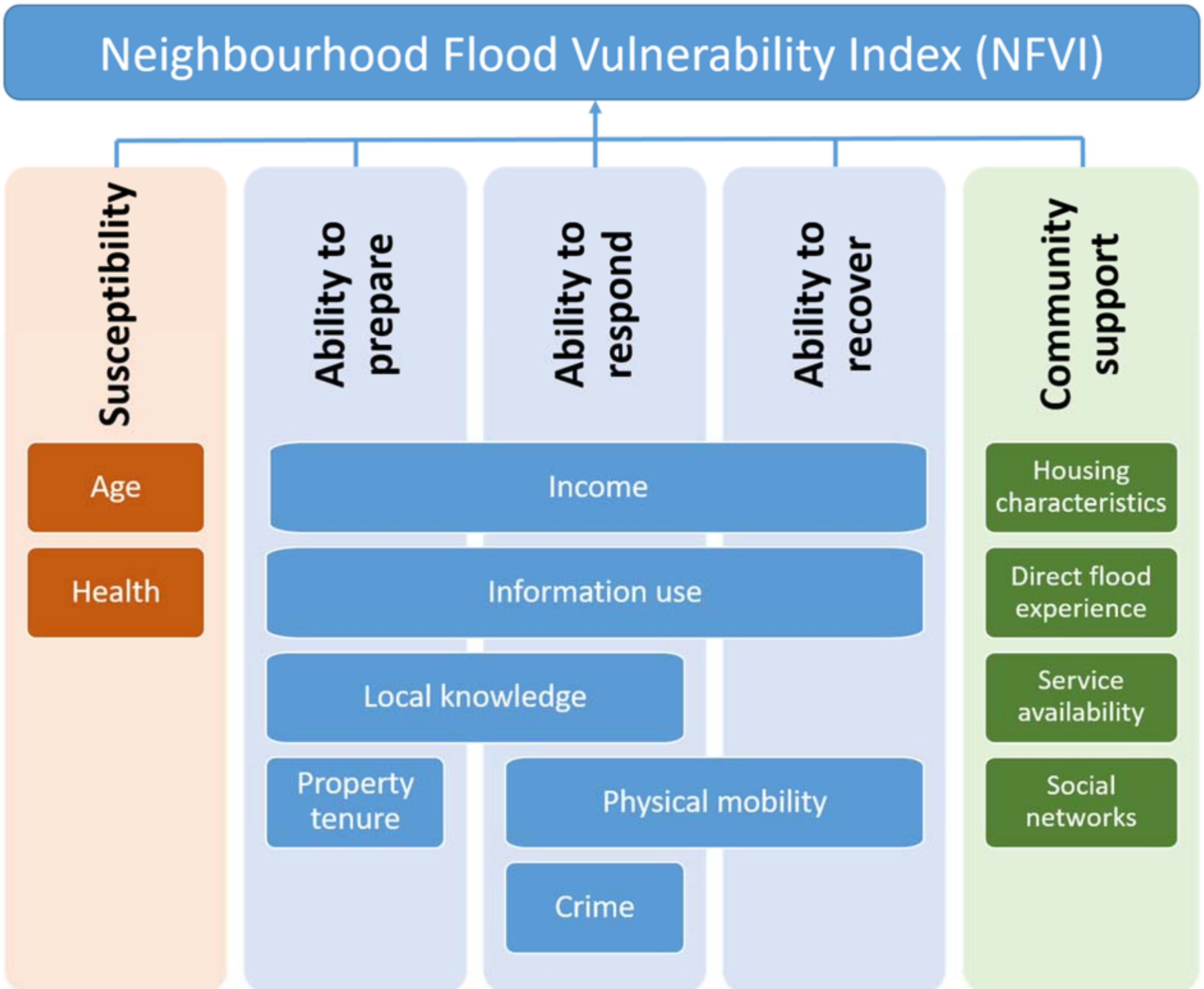


Figure 3-6 Neighbourhood Flood Vulnerability Index: Influential domains and indicators

Table 3-2 Neighbourhood Flood Vulnerability Index: Indicators and supporting variables

Indicator	Supporting variables	
Age	a1	Young children (% people under 5 years)
	a2	Older people (% people over 75 years)
Health	h1	Disability / people in ill-health (% people whose day- to-day activities are limited)
	h2	Households with at least one person with long-term limiting illness (%)
Income	i1	Unemployed (% unemployed)
	i2	Long-term unemployed (% who are long-term unemployed or who have never worked)
	i3	Low income occupations (% in routine or semi-routine occupations)
	i4	Households with dependent children and no adults in employment (%)
	i5	People income deprived (%)
Information use	f1	Recent arrivals to UK (% people with <1-year residency coming from outside UK)
	f2	Level of proficiency in English
Local knowledge	k1	New migrants from outside the local area (%)
Tenure	t1	Private renters (% Households)
	t2	Social renters (% households renting from social landlords)
Physical mobility	m1	High levels of disability (% disabled)
	m2	People living in medical and care establishments (%)
	m3	Lack of private transport (% households with no car or van)
Crime	c1	High levels of crime
Housing characteristics	hc1	Caravan or other mobile or temporary structures in all households (%)
Direct flood experience	e1	No. of properties exposed to significant flood risk (%)
Service availability	s1	Emergency services exposed to flooding (%)
	s2	Care homes exposed to flooding (%)
	s3	GP surgeries exposed to flooding (%)
	s4	Schools exposed to flooding (%)
Social networks (non-flood)	n1	Single-pensioner households (%)
	n2	Lone-parent households with dependent children (%)
	n3	Children of primary school age (4-11) in the population (%)

Metrics of flood risk

Flood risk is widely accepted to be a function of both the probability of the flood hazard and the associated consequences should that flood occur (*e.g.* Sayers *et al.,* 2002). In this context, the assessment of *'probability'* reflects not only the chance of the meteorological event but also the hydrological and hydraulic response as well as performance of the flood defences where they exist. *'Consequence'* is considered as a function of the potential to experience a loss of well-being when a flood occurs (exposure) and the degree of harm that may result if exposed (vulnerability). *'Flood risk'* is therefore a combined term that is typically expressed as either an *'annual expectation'* (an integration of the annual exceedance probability of a range of flood events and the associated consequences) or associated with a given *'event'* (the loss of social well-being that may result from a single given flood event). Both provide a useful perspective on the nature of the risks faced and are reflected in the risk metrics used:

Expected Annual Damages (EAD): This provides the conventional view of risk that estimates the Expected Annual Damages in national economic terms. The assessment of EAD used here combines the annual probability of a residential property being flooded and the associated direct economic damages. It uses the Weighted Annual Average Damage (WAAD) methodology (Penning-Rowsell *et al.,* 2013; Sayers *et al.,* 2015) to estimate the direct economic damage to residential properties with an uplift of 1.5 applied to the proportion of properties with basements (as determined through the 2005 census data).

Note: The focus is on economic loss to the UK and not the financial loss that may be incurred by an individual. Wider social impacts (such as monetisation of mental health impacts) are also excluded. No consideration is given here to indirect damages (such as the consequential costs on the public purse of supporting short- and long-term recovery) or wider impacts, such as the valuation of the health impacts (physical and mental).

Expected Annual Damage: Individual (EADi): This provides an estimate of the average (economic) risk faced by an individual living within the floodplain with a given neighbourhood. Although not representative of the risk faced by any specific individual, this provides a valid means of comparing risks between areas.

Relative Economic Pain (REP): In recognition of the varying coping capacity between more affluent and lower income households, this metric captures the relationship between uninsured economic damages and household income. The REP is used to express the 'relative pain' of a risk and is defined here as:

REP = (1- insurance penetration) x Expected Annual Damages (direct residential) per household within the floodplain / Average income per household within the neighbourhood.

Note: As previously noted (see EAD), the damages calculated here are economic losses, whereas the impact of flooding on uninsured households is related to the financial losses. The *REP* metric should therefore not be viewed as directly representing the impact on household finances, but is nevertheless a useful metric relating losses to income and insurance take-up. No consideration is given to issues of excess, deductibles or exclusions (including uninsured impacts, such as long-term physical or mental health that may be associated with a flood).

In assessing the REP, household income is taken from the appropriate census data sources for each constituent county. These are generally available at a larger spatial scale than the census areas used in this study (*e.g.* MSOA for England and Wales rather than LSOA), and are therefore sampled down to the appropriate scale. Values for Northern Ireland are only available at Local Government District level, and therefore do not, for example, differentiate between richer and poorer areas of Belfast.

Social Flood Risk Index (SFRI): A third new risk metric, the SFRI, is used to identify those areas where the largest number of the most vulnerable people are exposed to frequent flooding. The SFRI therefore directly supports an understanding of Geographic Flood Disadvantage and is estimated at both a neighbourhood scale and as an individual 'average' as follows:

- SFRI helps identify those areas where many vulnerable people, as defined by the NFVI, are exposed to flooding and is calculated as follows:

  SFRI = Expected Annual Probability of Flooding: Individual (EAI) x Number of people within the floodplain (FP) x Neighbourhood Flood Vulnerability Index (NFVI).

- *Social flood risk index: Individual* (iSFRI) helps identify those neighbourhoods where the vulnerability of those exposed is high (even when only a few people may be exposed) and is calculated simply by dividing the SFRI by the floodplain population, to give:

  SFRI Individual = Expected Annual Probability of Flooding: Individual (EAI) x Neighbourhood Flood Vulnerability Index (NFVI).

Note: The SFRI is a relative index and has no units; the greater the value, the higher the level of social flood risk.

3.4 Geographies of flood disadvantage

The resilience metrics (introduced in the previous section) are explored through four geographic lenses that range in scale and the perspective on the results they provide:

Administrative region: Four administrative scales are used to view aggregated flood resilience metrics: (i) **UK**; (ii) **National:** England, Wales, Scotland and Northern Ireland; (iii) **Regional**: England, Environment Agency Areas; Wales, Flood Risk Management Administrative Areas; Scotland, Local Flood Risk Management Plan Districts, and Northern Ireland, River Basin Districts; (iv) **Local:** Local authorities as defined in the Ordnance Survey Boundary Line (covering the 391 Council Areas in Scotland, District Council Areas in Northern Ireland, and Districts, Unitary Authorities and London Boroughs in England and Wales) dataset.

Flood source: Areas impacted by each source of flooding are used to aggregate and view the flood resilience metrics, including: (i) **Coastal** (including tidal); (ii) **Fluvial**; (iii) **Surface water** floodplains.

Note: Coastal and tidal flood areas are treated in the same way, and therefore coastal risk includes some areas we might think of as being well inland: the tidal Thames and Trent, for example.

Settlement type: The Office for National Statistics (England and Wales), Scottish Government and the Northern Ireland Statistics and Research Agency all produce urban/rural classifications, but use different classifications. Producing a consistent classification across the UK is therefore not straightforward but is necessary in the context of the analysis presented. The classification for England and Wales is therefore used as a basis and the classifications used in Scotland and Northern Ireland subjectively mapped onto this (Table 3-3).

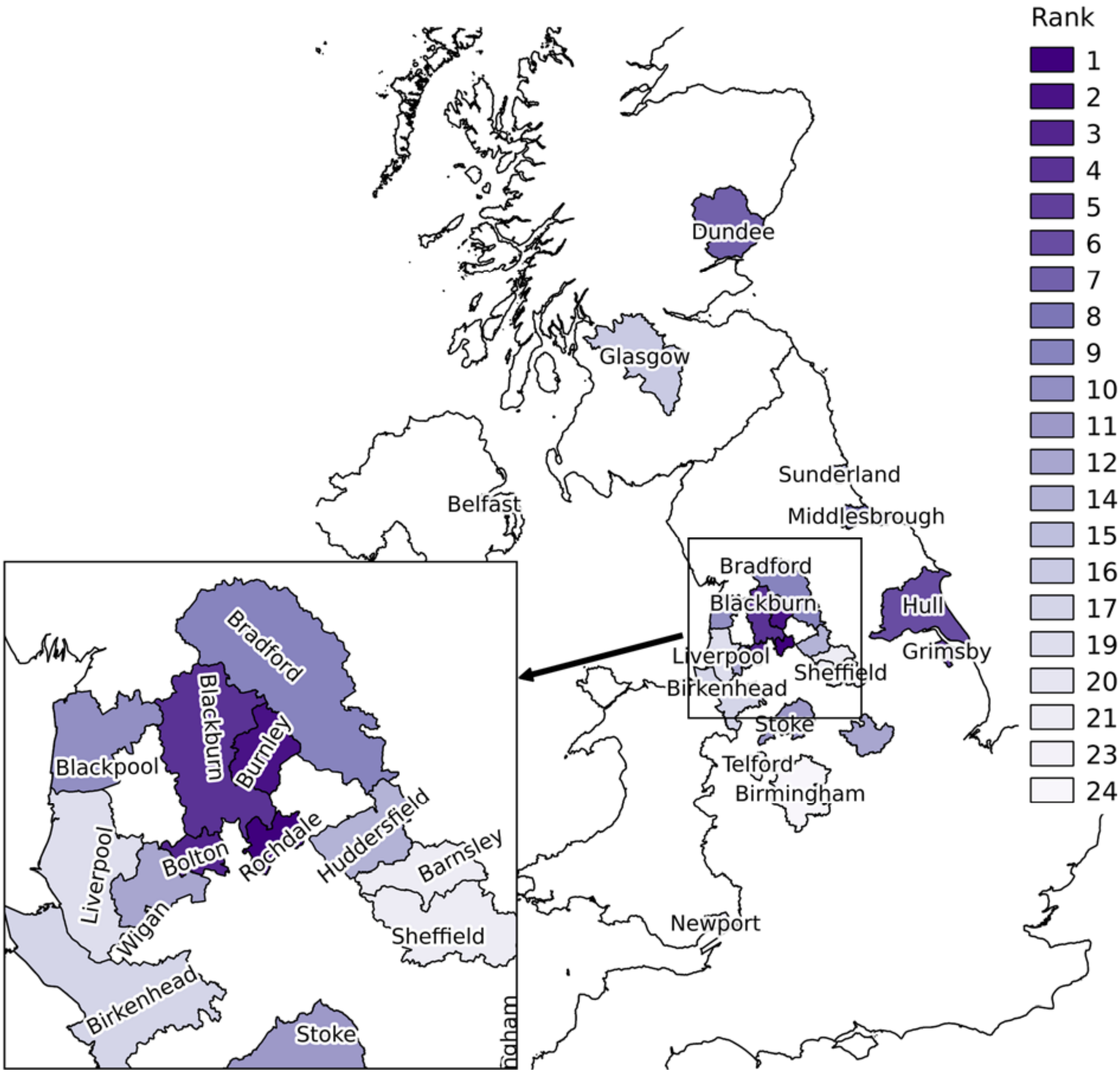
Table 3-3 Settlement types used in the UK

	England and Wales (ONS, 2011)		**Scotland** (Scottish Government, 2010, 2016)	**Northern Ireland** (NISRA, 2015)
Urban	Major Conurbation	Majority live in settlements with population >10,000	Large Urban Areas	Urban
	Minor Conurbation	Majority live in settlements with population >10,000	Other Urban Areas	
	City and Town	Majority live in settlements with population >10,000		
	City and Town in a Sparse Setting	Majority live in settlements with population >10,000, with a low-density profile in the surrounding area	Remote Small Towns	
Rural	Town and Fringe	Majority live in settlements with population <10,000	Accessible Small Towns and Accessible Rural Areas	Mixed urban/rural
	Town and Fringe in a Sparse Setting	Majority live in settlements with population <10,000, with a high population density but a low-density profile in the surrounding area	Very Remote Small Towns	
	Village and Dispersed	Majority live in settlements with population <10,000	Remote Rural Areas	Rural
	Village and Dispersed in a Sparse Setting	Majority live in settlements with population <10,000 with a low-density profile in the surrounding area	Very Remote Rural Areas	

Economic setting: The lens of 'economic setting' considers flood disadvantage in areas that are predisposed towards being more vulnerable. Two lenses are considered:

(i) ***Cities in decline***: While city growth is a key concern of UK policy some economic regions are falling behind national trends (Pike *et al.,* 2016). Flood disadvantage is considered in the 24 most struggling cities/major towns (as defined using the index of 'relative decline' proposed by Pike *et al.* (2016), shown in Figure 3-7). Across these economic regions unemployment is likely to be high and social provision low, and all the necessities for rapid recovery from flooding are at a low ebb.

(ii) ***Deprived neighbourhoods*** (as defined by the 20%ile of the Index of Multiple Deprivation): The IMD is used in England and Wales to identify 'deprived households' and hence the payment rate used within the Flood Defence Grant-in-Aid (FDGiA) formula for each household better protected. The IMD therefore has a significant influence on the allocation of resources. Considering flood disadvantage through this lens provides an opportunity to explore whether the IMD is a good representation of flood vulnerability and social flood risk, and the degree to which the FDGiA and its predecessors have been successful in targeting resources in the most deprived areas. IMDs are also defined in Scotland, Wales and Northern Ireland, all with slightly different definitions.



Cities are shaded by rank with 1 indicating the biggest decline; Belfast and Birkenhead are joint 17th (there is no 18th place).

Figure 3-7 Economic setting: Cities in relative decline (Pike *et al.,* 2016).

3.5 Validity of approach

The validation of any analysis of risk is difficult, in part because flood events are rare and flood systems (the climate, the defences, the socio-economic setting etc.) are changing. It is therefore difficult, if not impossible, to determine the accuracy of an estimate of risk through comparison to measured data alone (Sayers *et al.,* 2016). The validity of any analysis therefore relies upon assumptions and limitations being acknowledged (as highlighted throughout the report) and gaining confidence that the analysis is credible at the scales of interest (as set out in Section 3.4) and in the context of the objectives of the analysis. To provide appropriate confidence in the analysis presented here, three important aspects are discussed below:

Credibility of the input data: It is assumed here that the input data used by the FFE (including, but not limited to, flood hazard, defence standards and conditions, property, census data) is credible at the scales of interest (as set out in Section 3.4) and in the context of the study objectives. This is reasonable given all the datasets are routinely used by various national and local organisations, despite recognised controversy regarding the absolute values of some of the datasets (such as data based upon the National Flood Risk Assessment in England, Penning-Rowsell, 2014, 2015, 2016).

The skill of the FFE as an emulator: To provide valid estimates the FFE must provide a faithful reproduction of the underlying data. To provide confidence that this is the case the results of the FFE have been previously compared to standalone estimates of the number of properties at significant risk and the EAD (as produced, for example, by Environment Agency's National Flood Risk Assessment and the Scottish Environmental Protection Agency, SEPA), confirming the ability of the FFE to produce known results (Sayers *et al.,* 2015).

The credibility of new results**:** To provide confidence in the extension of the analysis to represent neighbourhood vulnerability and social flood risk indices, three additional activities have been undertaken:

(i) **Engagement with an Advisory Group:** Progressive drafts of the analysis have been scrutinised as they have emerged by an extensive Advisory Group. This process has provided useful links to additional data sources and as well as giving confidence that the results reflect their experience.

(ii) **Engagement with national policy leads:** Policy leads from England, Wales, Scotland and Northern Ireland have each been engaged to discuss the role of social justice in current policy approaches to FRM and the anticipated direction of travel.

(iii) **Local case studies and review:** Three local case studies (in Boston, Cumbria and Blaenau Gwent) have been used to ground-truth the estimates of vulnerability and social flood risk. Local stakeholders from each case study were shown simple maps of the assessment of NFVI and SFRI and asked to comment on the degree to which they recognised the spatial patterns. In all cases the local stakeholders confirmed the NFVI represented the spatial variation in vulnerability well, although they found it more difficult to comment upon the more abstract notion of the SFRI. These discussions provided confidence that the relative distribution of vulnerability reasonably represents local understanding and presented an opportunity to explore 'on-the-ground' barriers to adaptation and the barriers faced by the most vulnerable communities (that in turn shaped the representation of the individual adaptation measures used here, as set out in Section 3.2).

Further discussion of the policy engagements and case studies is provided in Appendix E.

4.0 ANALYSIS RESULTS: FINDINGS AND DISCUSSION

4.1 Floodplain population, vulnerability and exposure to frequent flooding

Summary findings

- The most vulnerable neighbourhoods are over-represented in areas prone to flooding (all sources) and significantly over-represented in areas prone to coastal (and tidal) flooding.
- The number of people living in the most vulnerable neighbourhoods is significantly greater in Northern Ireland than elsewhere in the UK.
- Over 50% of those exposed to flooding and living in the most vulnerable neighbourhoods are in just ten local authorities.
- By the 2080s vulnerable neighbourhoods see a significant increase in exposure to more frequent floods; an increase that is in line with those living in less vulnerable communities.

Discussion

Present day: Today approximately 6.4 million people in the UK live in areas exposed to flooding (from fluvial, coastal or surface water sources) with a frequency of 1:1000 years or more frequent (in the absence of defences). Around 1.5 million of these people (23.4%) live in the 20% most vulnerable neighbourhoods (Table 4-1). Fluvial and coastal floodplains are home to 1.7 million and 1.8 million people respectively. The number of people living in areas prone to surface water flooding is much higher (2.8 million), with 590,000 (21%) of these living in the 20% most vulnerable neighbourhoods.

Of those living in flood prone areas, 2 million (31%) are exposed to frequent flooding (with a return period, on average, of 1:75 years or more frequent); with the majority, 1.3 million (67%), living in the most vulnerable neighbourhoods (top 20% by NFVI). Of the 1.8 million people living in the coastal floodplain, 33% are within the 20% most vulnerable neighbourhoods and 10% in the 5% most vulnerable neighbourhoods (top 5% by NFVI) - Table 4-1.

The proportion of vulnerable neighbourhoods exposed to flooding varies across the four nations. In Northern Ireland, for example, 55% of the population exposed to flooding live in the top 20% of neighbourhoods by NFVI and 25% of the total population exposed to frequent flooding are in the most vulnerable neighbourhoods (the top 5% by NFVI) - Table 4-2. This represents a significant systemic disadvantage. The disproportionality is less evident elsewhere (in Scotland 9% of the floodplain population live in the top 5% by NFVI; in England 5%; and in Wales 3%). The drivers of neighbourhood vulnerability are, in general, similar across all sources of flooding. In coastal settings, however limited *service availability* plays an enhanced role and is a key contributor to the high levels of vulnerability observed, along with *physical mobility* and *information use* (Figure 4-1).

Seventy-five local authorities (approximately one fifth of the UK total) account for 50% of those living in flood prone areas. The concentration becomes more marked when the most vulnerable neighbourhoods (top 5% by NFVI) are considered, with over 50% of the population exposed to flooding in the most vulnerable neighbourhoods located in just ten local authorities (Hull, Boston, Belfast, Birmingham, East Lindsey, Glasgow, Leicester, North East Lincolnshire, Swale District, and Tower Hamlets). Figure 4-2 illustrates this clustering and highlights concentrations of people in vulnerable neighbourhoods on the floodplain in Scotland's central belt, Belfast, the Humber, Lincolnshire, Birmingham, South Wales, and the Severn and Thames Estuaries.

In the future: The number of people living in flood prone areas is set to increase by 45% to 10.8 million people by the 2080s (assuming high population growth combined with a +4^{o}C climate future, and assuming current approaches to adaptation continue, Figure 4-3), 6.4 million people will be exposed to frequent flooding, up from 2 million today (an increase of over 200%). In the most vulnerable neighbourhoods the increase is equally dramatic, again more than trebling, from 451,000 today to 1.4 million by the 2080s (an increase of over 200%). The greatest increases are experienced in England and in areas prone to surface water and fluvial flooding. In Wales, Scotland and Northern Ireland and coastal settings the increases are just as significant in terms of the relative increase from present day.

Given a future 2°C temperature increase under climate change, high population growth and a continuation of the CLA, the number of people living in the most vulnerable neighbourhoods exposed to frequent coastal, fluvial or surface water flooding (with a return period of more frequent than 1:75 years) increases from 122,000 today to 279,000 by the 2080s. This represents an increase of 129%.

At the national scale the proportional increase in exposure of vulnerable neighbourhoods is similar to less vulnerable neighbourhoods (*i.e.* the contribution from both less and more vulnerable neighbourhoods is similar in the future as it is today). The disproportional exposure of those living in vulnerable neighbourhoods, particularly in Northern Ireland (and to a lesser extent Scotland and Wales), and those living in coastal settings therefore continues to persist into the future (Figure 4-4). Those living in the most vulnerable neighbourhoods exposed to fluvial flooding see their risk increase at a faster rate (increasing from 24,000 to 63,000; +263%). Less vulnerable communities, across all sources of flooding, also experience a significant increase, rising by 138%.

Table 4-1 Present day: Population of flood prone areas

	All neighbourhoods (000s)	Vulnerable neighbourhoods (000s)					
		Top 20% by NFVI		Top 10% by NFVI		Top 5% by NFVI	
By country							
UK	6,398	1,497	23%	788	13%	397	6%
England	5,508	1,216	22%	635	12%	316	6%
Wales	378	107	28%	45	12%	13	3%
Scotland	376	99	26%	56	15%	32	8%
Northern Ireland	136	74	55%	52	38%	37	27%
By flood source							
All sources	6,398	1,497	23%	788	12%	397	6%
Coastal (and tidal)	1,809	604	33%	340	19%	179	10%
Surface water	2,869	594	21%	293	10%	148	5%
Fluvial	1,720	299	17%	155	9%	71	4%

Table 4-2 Present day: People exposed to frequent flooding (1:75 years or more frequent)

	All neighbourhoods (000s)	Vulnerable neighbourhoods (000s)					
		Top 20% by NFVI		Top 10% by NFVI		Top 5% by NFVI	
By country							
UK	1,985	451	23%	239	12%	122	6%
England	1,612	335	21%	174	11%	88	5%
Wales	117	36	30%	15	13%	4	3%
Scotland	200	51	26%	29	15%	17	9%
Northern Ireland	55	29	53%	20	35%	14	25%
By flood source							
All sources	1,985	451	23%	239	12%	122	6%
Coastal (and tidal)	489	164	33%	95	19%	50	10%
Surface water	870	103	21%	92	11%	48	5%
Fluvial	626	184	16%	52	8%	24	4%

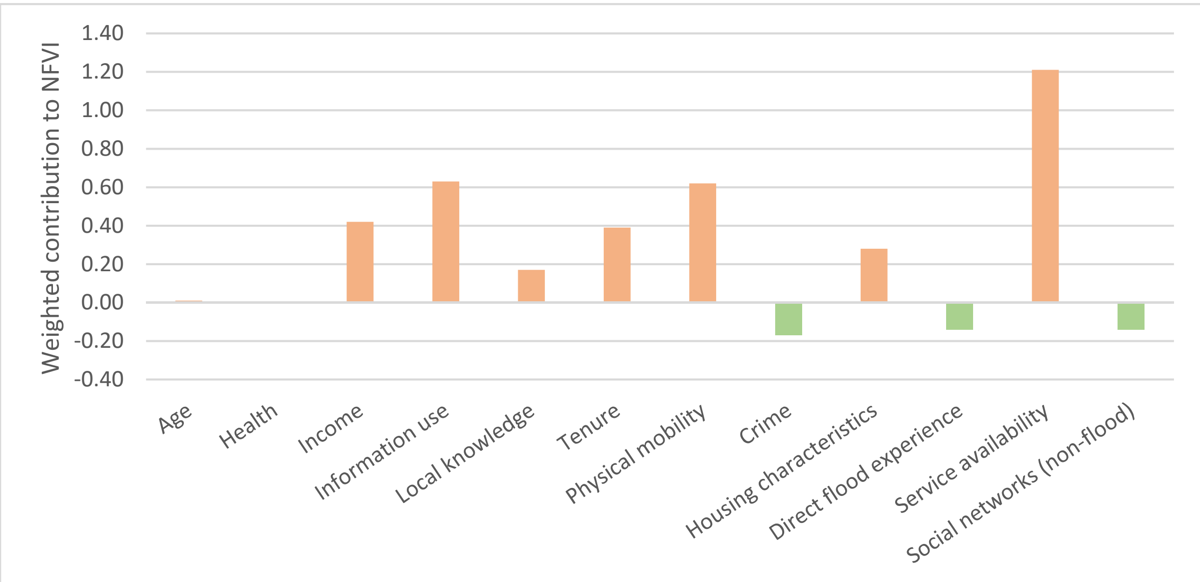
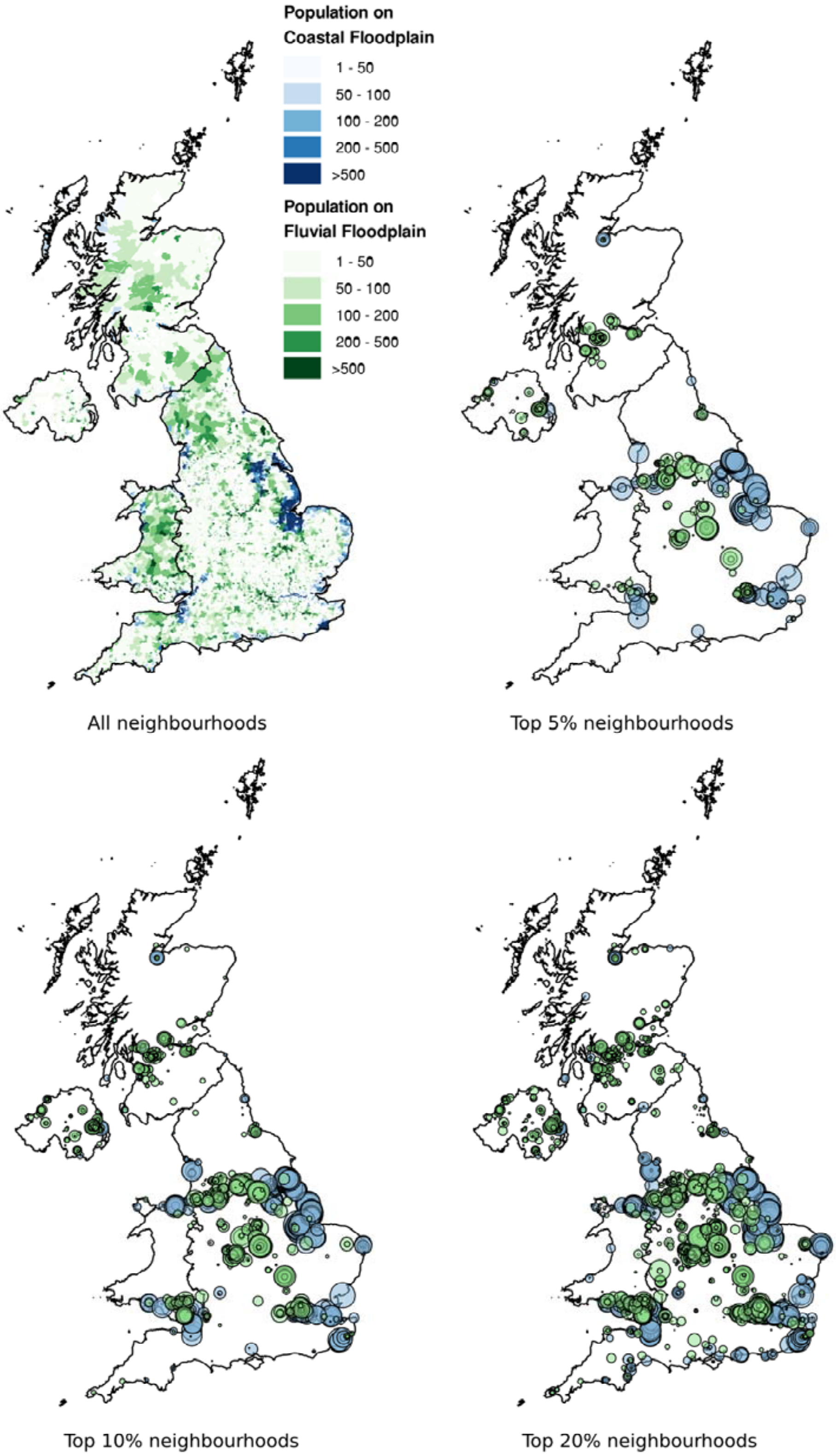


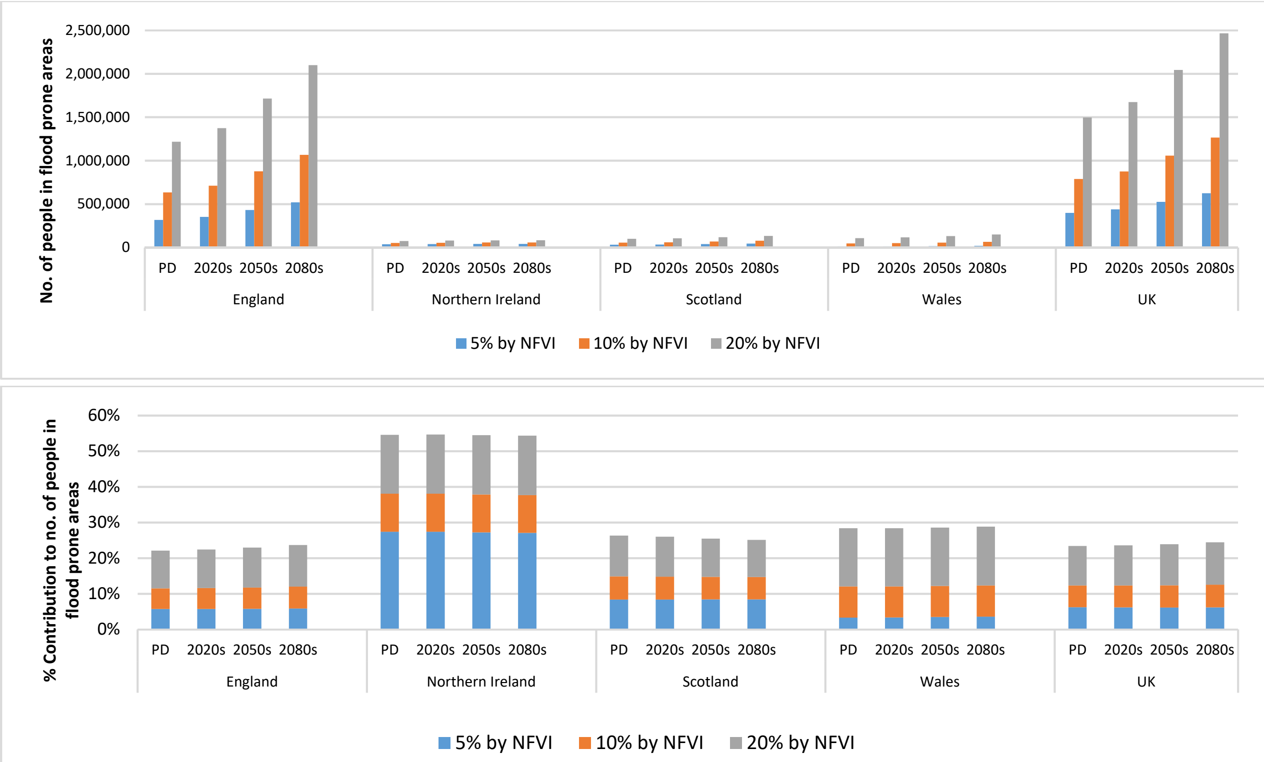
Figure 4-1 Present day: Drivers of neighbourhood vulnerability at the coast



Circle diameters are proportional to magnitude of the values.

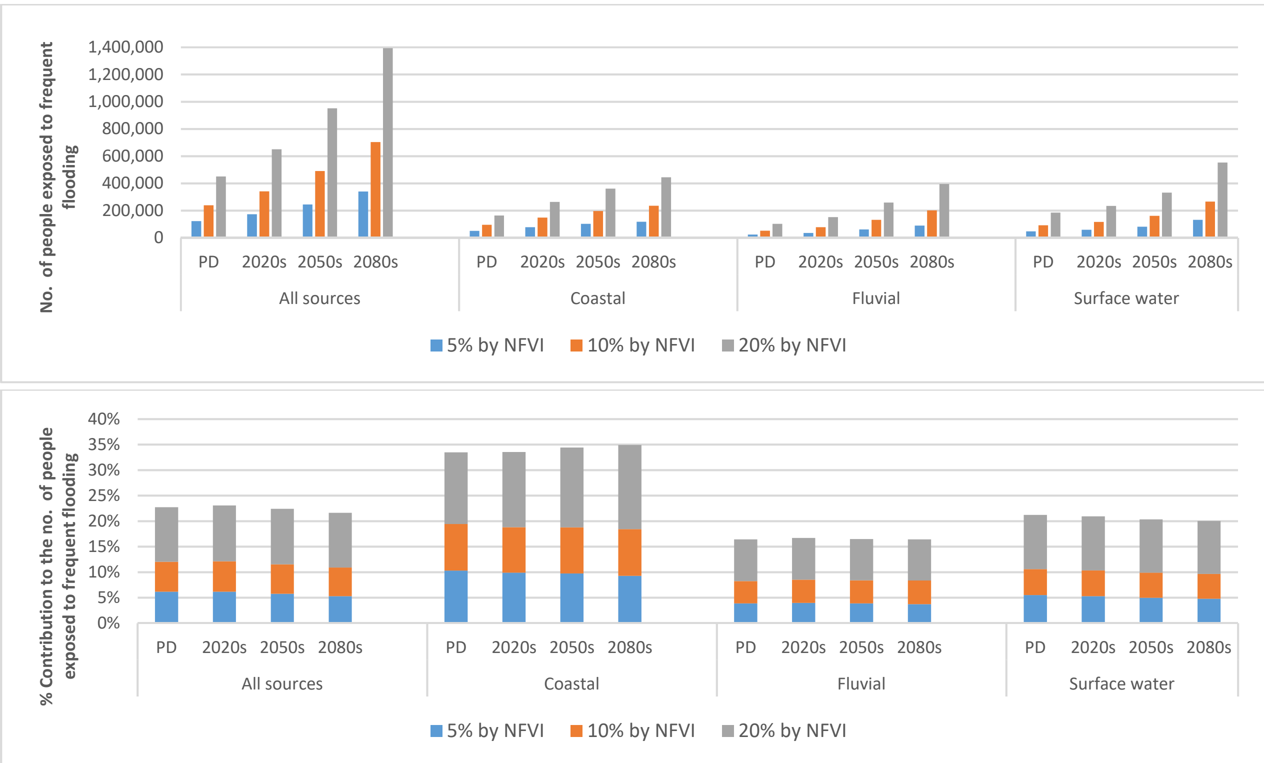
For all neighbourhoods (top left), and for neighbourhoods classified by NFVI (all others).

Figure 4-2 Present day: Concentration of people living in the floodplain



Assuming a continuation of current adaptation, +4°C climate future and high population growth. PD= present day.

Figure 4-3 Future change: No. of people in flood prone areas: By country



Assuming a continuation of current adaptation, +4°C climate future and high population growth

Figure 4-4 Future change: Exposure to frequent flooding: By flood source

4.2 Expected annual damages and the influence of income and insurance

Summary findings

- At a UK scale, EAD is dominated by England, but the contribution from elsewhere in the UK is more significant when considered in the context of the most vulnerable neighbourhoods.
- In Northern Ireland, vulnerable neighbourhoods contribute two-thirds of the EAD.
- At the coast, the most vulnerable neighbourhoods experience disproportionally high levels of EAD, today and in the future.
- EAD per person is greatest in Scotland and rises fastest in vulnerable neighbourhoods.
- Low income and low levels of insurance penetration significantly impact the REP of flooding in vulnerable neighbourhoods (across all sources of flooding).

Discussion

Present day: Expected Annual (economic) Damage (EAD) across the UK is £351 million (residential property only). England contributes 79% (£277 million), Scotland 12% (£43 million), Wales 6% (£23 million) and Northern Ireland 2% (£8 million) to this overall number (Figure 4-5).

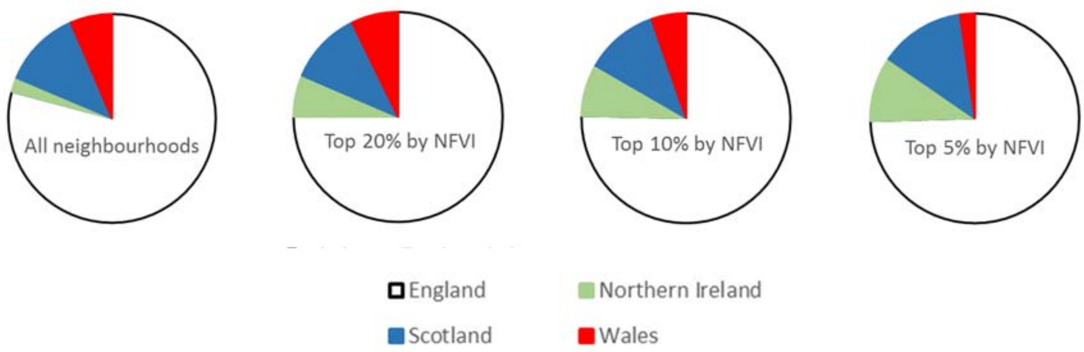


Figure 4-5 Present day: Contribution to Expected Annual Damages - By country

The contribution from elsewhere in the UK is however more significant when considered in the context of the most vulnerable neighbourhoods. This is most significant in Northern Ireland where the 20% most vulnerable neighbourhoods account for 67% of the EAD (in Scotland the equivalent figure is 22%, in England 22% and Wales 26%). Therefore, although Northern Ireland accounts for only 2% of the UK EAD when all neighbourhoods are included, when considered from the perspective of only the most vulnerable neighbourhoods (the top 5% by NFVI) the contribution from Northern Ireland increases substantially to 10% of UK EAD.

When considered from the perspective of the source of flooding, coastal and fluvial flooding dominates the EAD at a UK scale (Figure 4-6). The most significant systemic disadvantage is experienced at the coast, with the most vulnerable neighbourhoods (top 20% NFVI) accounting for 32% of the coastal risk (expressed as EAD) - Figure 4-7. There is no significant disproportionality experienced in fluvial and surface water flood prone areas when viewed in the context of EAD (although this changes in the future – see later).

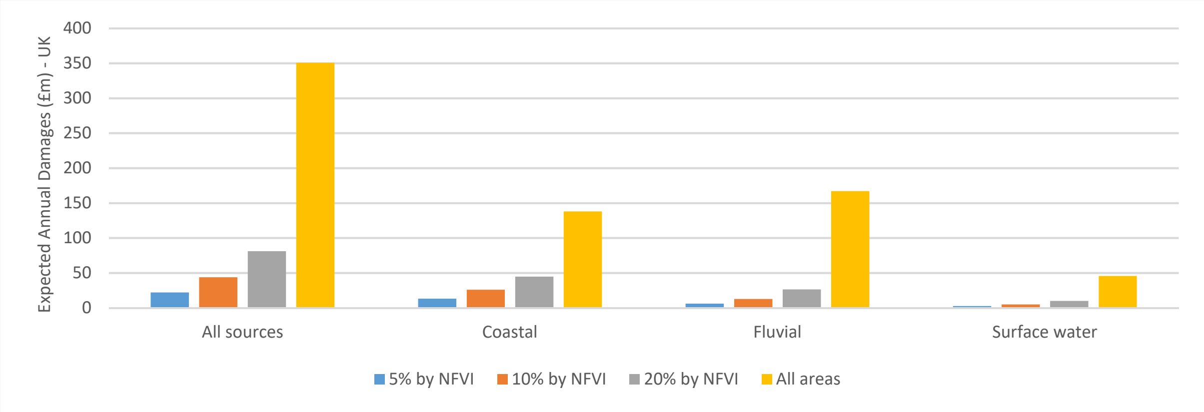


Figure 4-6 Present day: Expected Annual Damages - By flood source

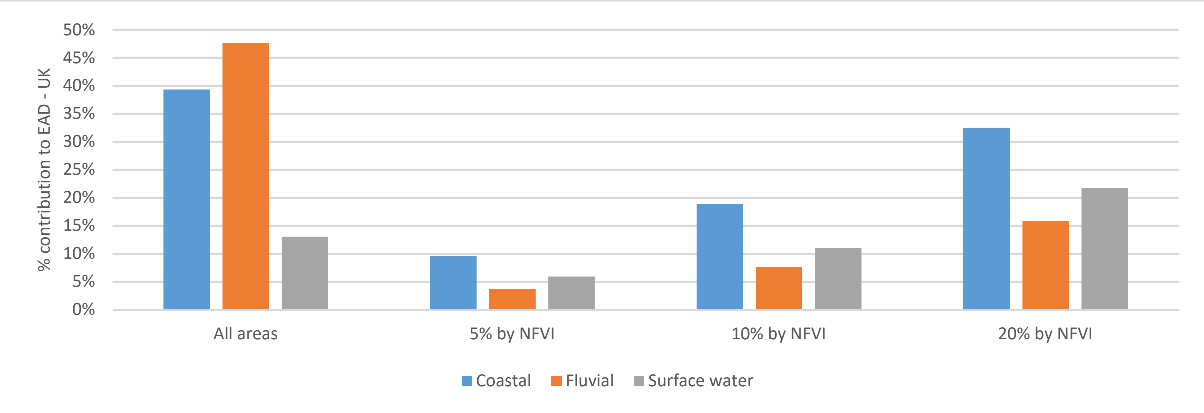


Figure 4-7 Present day: Contribution to Expected Annual Damages - By flood source

When normalised by population, those living in flood prone areas in Scotland experience the highest EAD per person (on average, £113 per person) and over double that of England (on average, £50 per person) (see Figure 4-8).

When considered by flood source, the most significant EADs are experienced in fluvial (£97 per person) and coastal (£76 per person) floodplains (in areas prone to surface water flooding the value is much less, £16 per person). In many cases, these estimates change little between more and less vulnerable neighbourhoods. There are two exceptions to this. The first relates to areas prone to surface water flooding where the most vulnerable neighbourhoods (top 5% by NFVI) experience much greater EAD per person when compared to the average (£18.30 per person, 15% higher than the average). The second relates to Wales, where the most vulnerable neighbourhoods (5% by NFVI) are at a much lower risk (on average, £40 EAD per person) compared to the average in Wales (£60 per person).

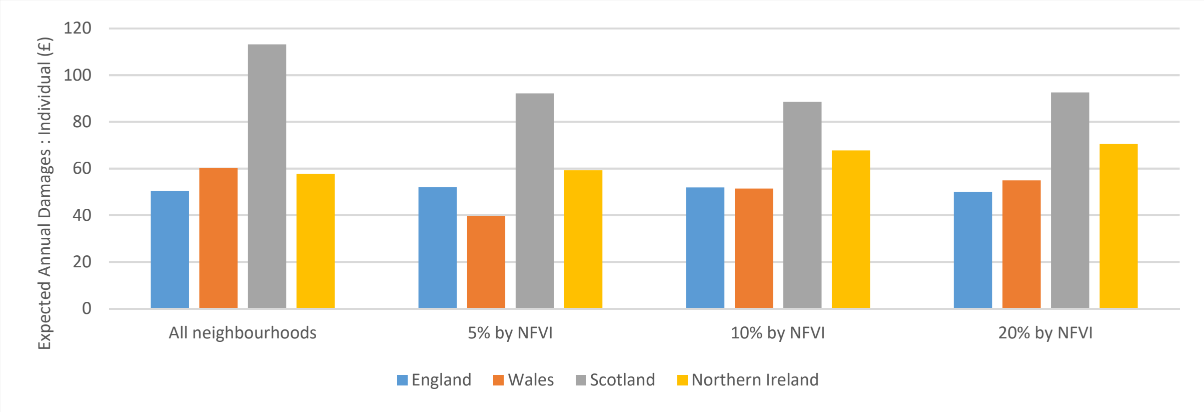
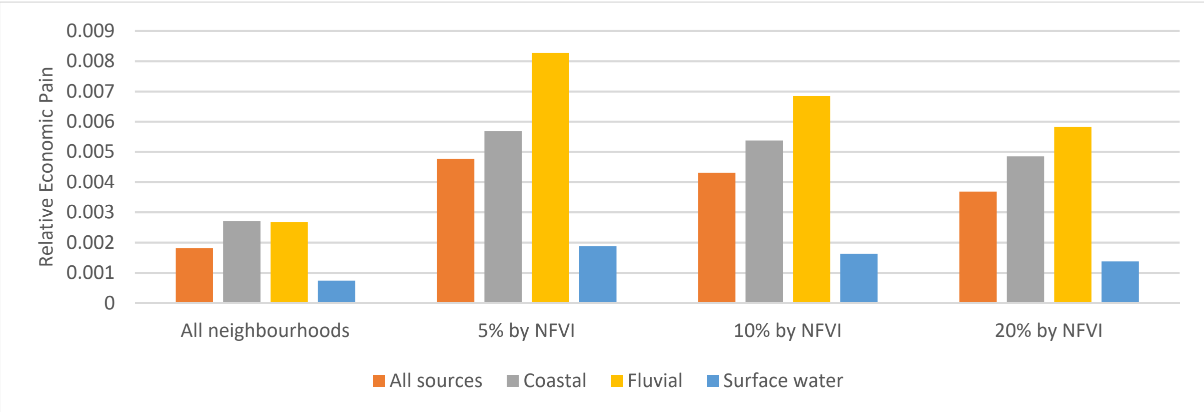


Figure 4-8 Present day: Expected Annual Damages: Individual - By country

Lower incomes (approximately £7,500 per head in most vulnerable neighbourhoods compared to approximately £10,500 on average[10]) and low levels of insurance penetration (between ~20-40% in the most vulnerable areas, depending on tenants and source of flooding, compared to the national average of ~60-75% - see Appendix D) mean the REP associated with flooding is much greater in more vulnerable neighbourhoods than elsewhere. In coastal/tidal floodplains, for example, when income and insurance penetration are considered, the most vulnerable neighbourhoods (5% by NFVI) experience over twice the REP compared to the average. In fluvial floodplains, the REP is three times higher (Figure 4-9).

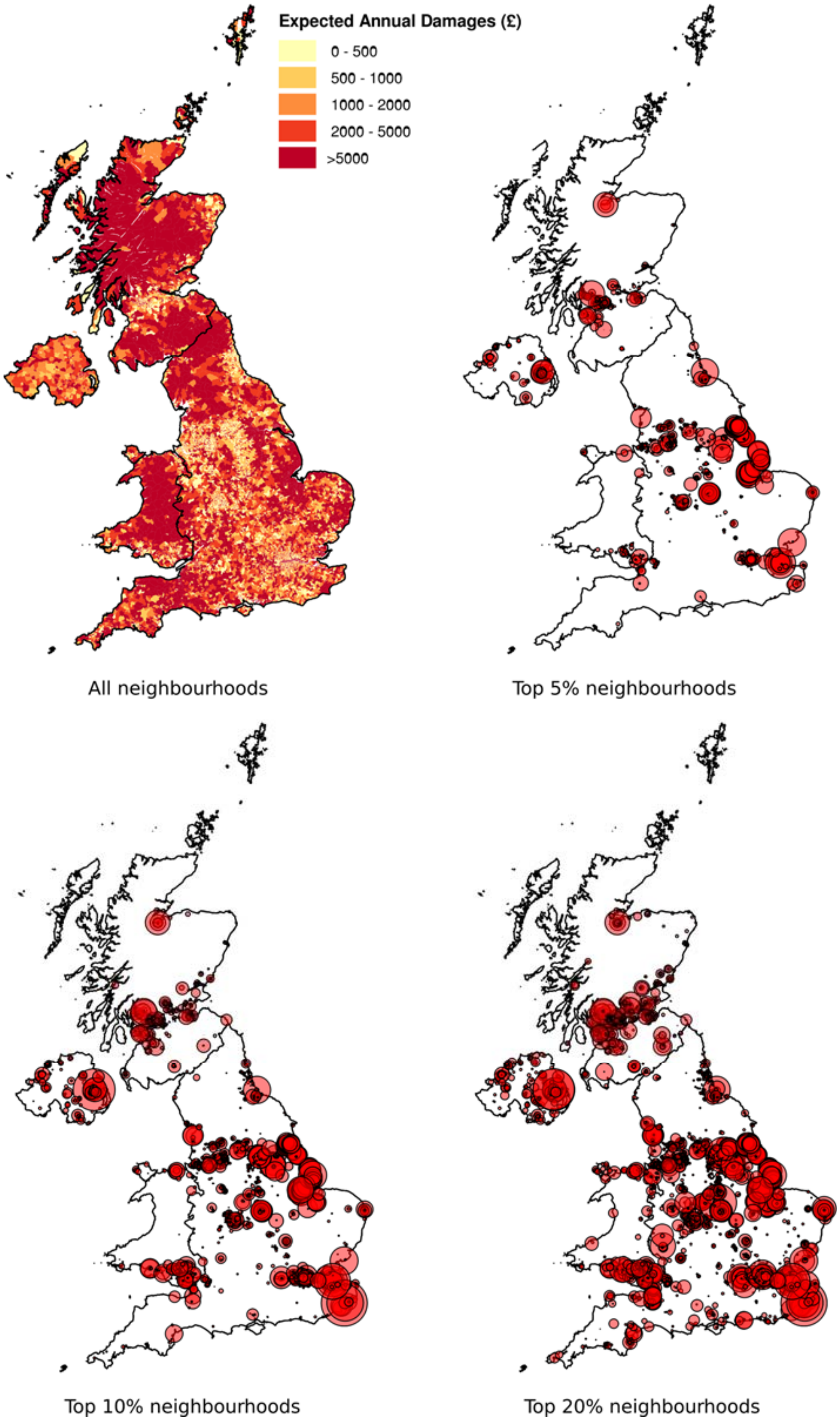


A value of '0' implies expected annual flood losses are fully covered by insurance. A value of '1' implies expected annual uninsured flood losses are equal annual income.

Figure 4-9 Present day: Relative economic pain - By flood source

An illustration of the spatial distribution of the present day EAD is provided in Figure 4-10.

[10] This is an average across all those living in a neighbourhood not just those of working age.



Top left: For all neighbourhoods – note neighbourhoods are scaled to have an approximately equal population, hence the pattern of risk tends to highlight rural areas as well as urban areas.
Clockwise from top right: Selected neighbourhoods classified by NFVI.

Figure 4-10 Present day: Spatial distribution of Expected Annual Damages (EAD)

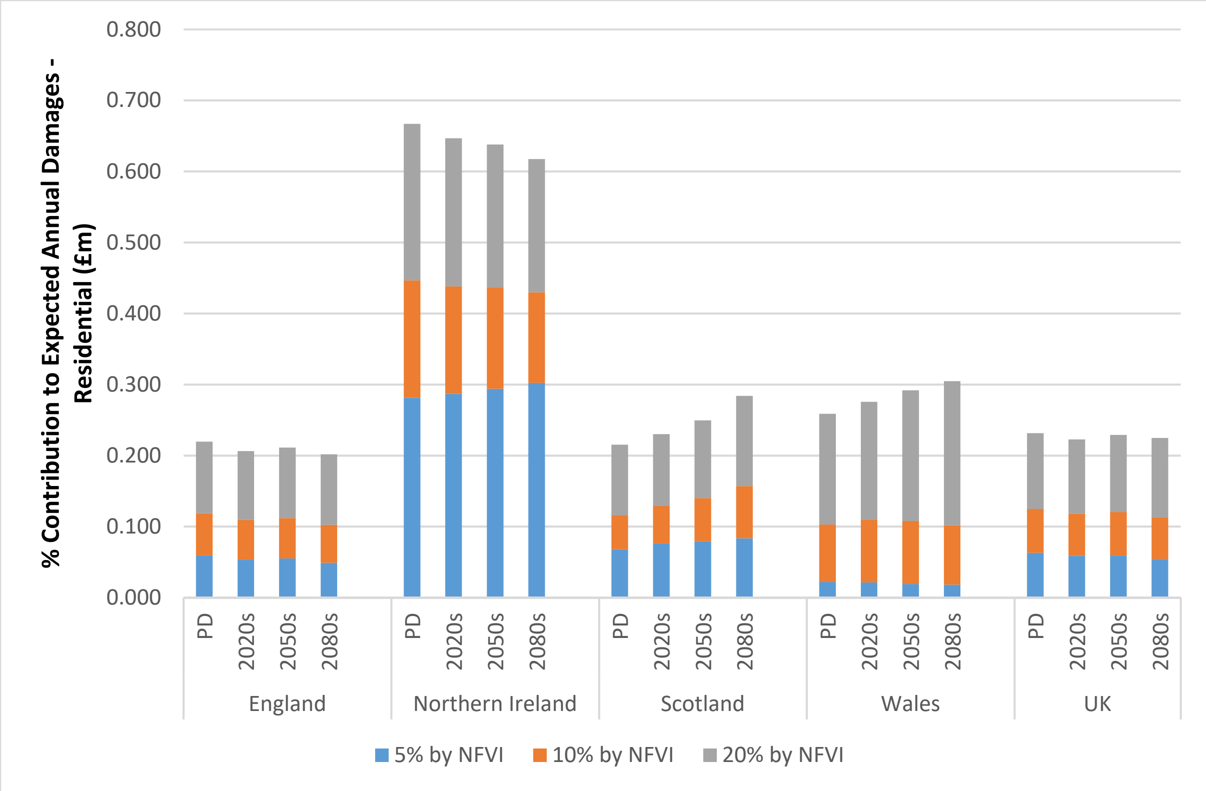
Note: Given all neighbourhoods are of similar population, the mapping highlights some rural areas at more significant risk. This may reflect the higher 'average' probability of flooding in those areas.

In the future: The EAD associated with flooding are set to rise (from £351 million today, residential direct damages only, to £1.1 billion by the 2080s, assuming *a* +4°C climate future, high population growth and a continuation of current adaptation approaches). At a UK scale the increase in EAD within vulnerable neighbourhoods (20% by NFVI) is, in general, in line with this overall increase; rising from £81 million today to £250 million by the 2080s (slightly greater than 20%). This is not the case in Scotland however, where the contribution to EAD from the 20% most vulnerable neighbourhoods increases from 22% today to 29% by the 2080s.

The disproportionality of the risk of damages faced in coastal areas persists (with very significant, but similar, increases experienced by all those living in the coastal floodplain). A similar pattern is projected within fluvial and surface water floodplains (with the disproportionality of EAD remaining as today).

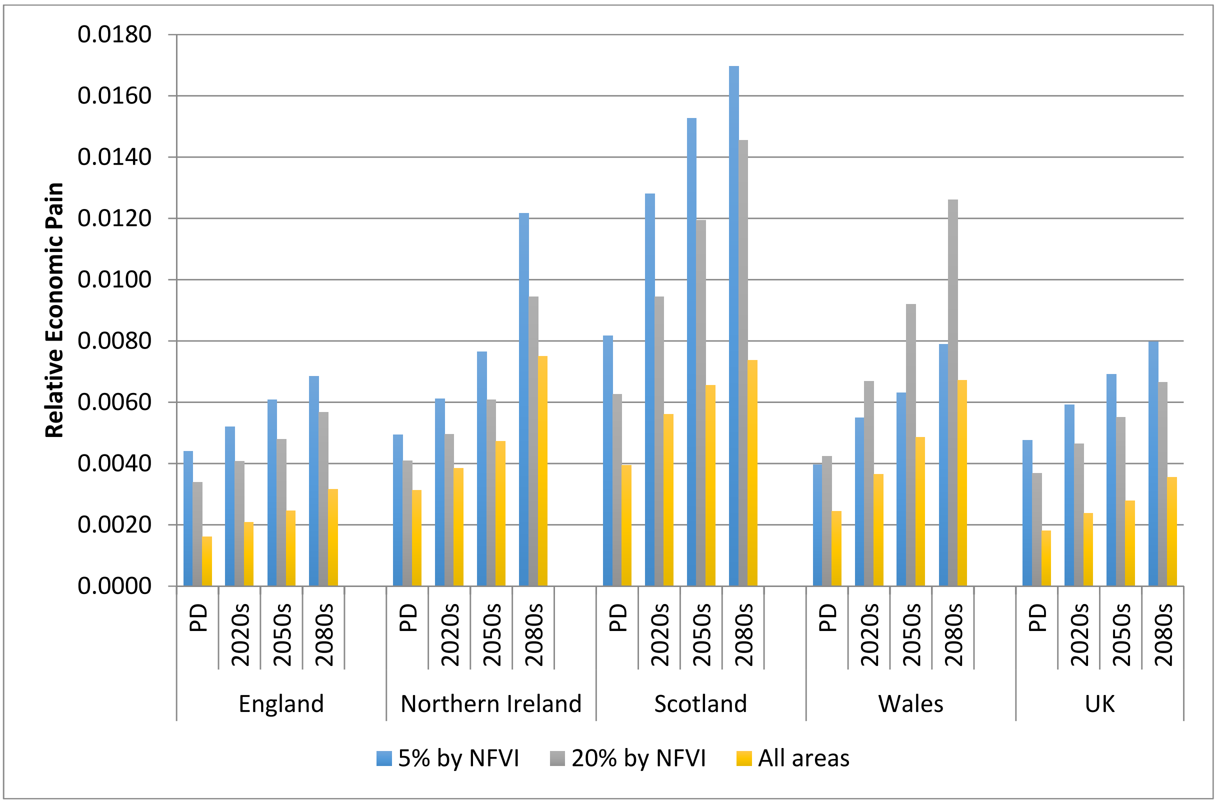
The EAD experienced by an individual, on average, also increases (Figure 4-11). By the 2080s (assuming *a* +4°C climate future and high population growth) the EAD per person in Scotland increases to £183 per person (compared to £95 per person in England) with the risk in the most vulnerable neighbourhoods (top 20% by NFVI) increasing twice as quickly as elsewhere (increasing from £93 to £206 per person). This is not the case in England, Wales and Northern Ireland where more and less vulnerable neighbourhoods experience a similar rate of increase in EAD per person.

When income and insurance are considered, the increase in EAD translates to significant increases in the REP across the UK and for all sources of flooding, particularly for the most vulnerable neighbourhoods (Figure 4-12).



All neighbourhoods: +4⁰C climate future, high population growth and a continuation of current adaptation

Figure 4-11 Future change: Expected Annual Damages - By country



All neighbourhoods: 4⁰C climate future, high population growth and a continuation of current adaptation

Figure 4-12 Future change: Relative economic pain - By country

4.3 Urban and rural influences on flood disadvantage

Summary findings

- Many socially vulnerable people living in the floodplain are in urban settings, however those in rural settings are, in general, exposed to more frequent flooding.
- By the 2080s, all neighbourhoods in both rural and urban settings experience significant increases in risk, with the most vulnerable neighbourhoods in more dispersed settings (both urban and rural) experiencing slightly greater increases than elsewhere.

Discussion

Present day: At a UK scale, urban settings dominate flood risk, accounting for £264 million (75%) of present day EAD and 5.2 million (82%) of the people exposed to flooding (Figure 4-13). When considered from the perspective of vulnerable neighbourhoods (top 20% by NFVI), however, the flood risks in rural neighbourhoods are more significant; accounting for 45% of the total £47 million EAD and 30% of the people exposed to flooding. When the most vulnerable neighbourhoods are considered (top 5% by NFVI), the contribution from rural settings is even greater, accounting for £11 million of the EAD (73% of the total £15 million) and 128,000 people (58% of the total 221,500) living in flood prone areas.

The disproportionality in the risks faced in rural communities is most noticeable when normalised by population. This highlights that the EAD experienced by an individual is, on average, higher for those living in a rural setting compared to those in an urban setting (Figure 4-13).

This is however a complex picture and suggests that although many vulnerable people living in the floodplain are in urban settings, those in rural settings are, on average, exposed to more frequent flooding. This may reflect a combination of the varying natural geographies of rural and urban floodplains and the higher standards of protection typically provided in urban settings (and the technical difficulties in providing higher levels of protection in rural settings). It may also suggest that insufficient focus has been given to addressing risk in vulnerable rural areas within FRM policy and practice.

Future risk: Assuming a continuation of current levels of adaptation there is a significant increase in risk across all settlement types by the 2080s. In most settings, more and less vulnerable neighbourhoods experience similar increases (Figure 4-14).

The greatest increases are seen in *urban major and minor conurbations* (experiencing an increase in EAD of 200% and 350% under a +2^{o}C and +4^{o}C climate future respectively) and *rural town and fringe in a sparse setting* (increasing by 200% and 400%). In these settings, the most vulnerable neighbourhoods experience slightly higher percentage increases in risk when compared to less vulnerable neighbourhoods. This suggests, although the reasons for this are difficult to determine, that most vulnerable neighbourhoods in more dispersed settings (both urban and rural) may be particularly difficult to address within the current approach to adaptation and investment frameworks.

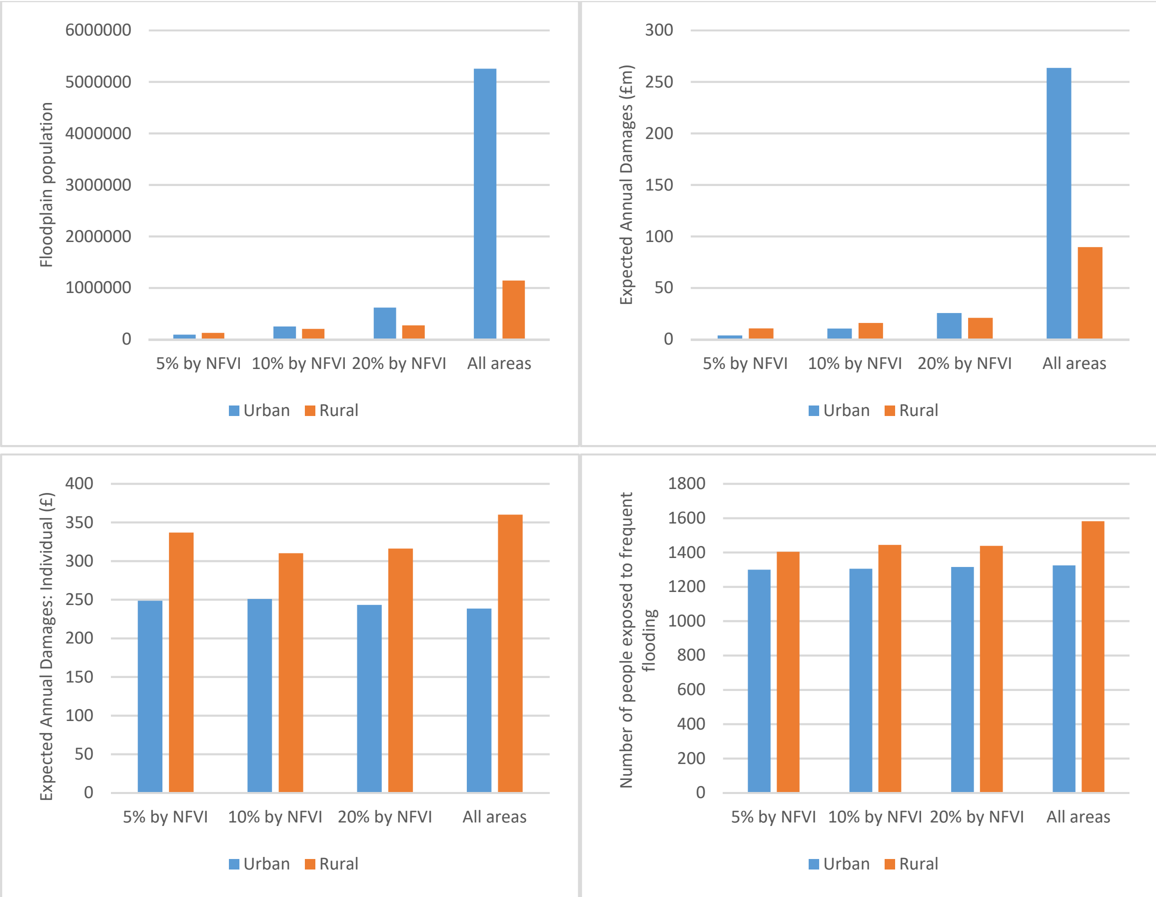


Figure 4-13 Present day: A comparison of flood risk in rural and urban settings

+4°C climate future, high population growth and a continuation of current adaptation

Figure 4-14 Future risks: Change in Expected Annual Damages (£m) by settlement type

4.4 Local authorities and flood disadvantage

Summary findings

- Clusters of high social flood risk exist in local authorities across the UK.
- In some local authorities flood disadvantage is highly localised, in others it is widespread.
- In most cases, local authorities that experience the highest levels of flood disadvantage today continue to do so in the future. There are however several exceptions where the increase is much faster than elsewhere.

Discussion

Present day: The SFRI provides the most direct measure of flood disadvantage (where exposure to flooding and vulnerability coincide) and highlights Northern Ireland, the coastal areas from the Wash to Humber, South and North Wales, and the lowlands of Scotland as areas of high flood disadvantage (Figure 4-15: Left). These clusters are most noticeable when the SFRI is normalised by population to provide a representative *'individual'* value (the *SFRI: Individual*). This metric also highlights many similar areas as those identified with the standard SFRI measured, but with the addition of many areas where flood disadvantage is highly localised (including more rural areas); a message supported by case studies reported in Appendix E.

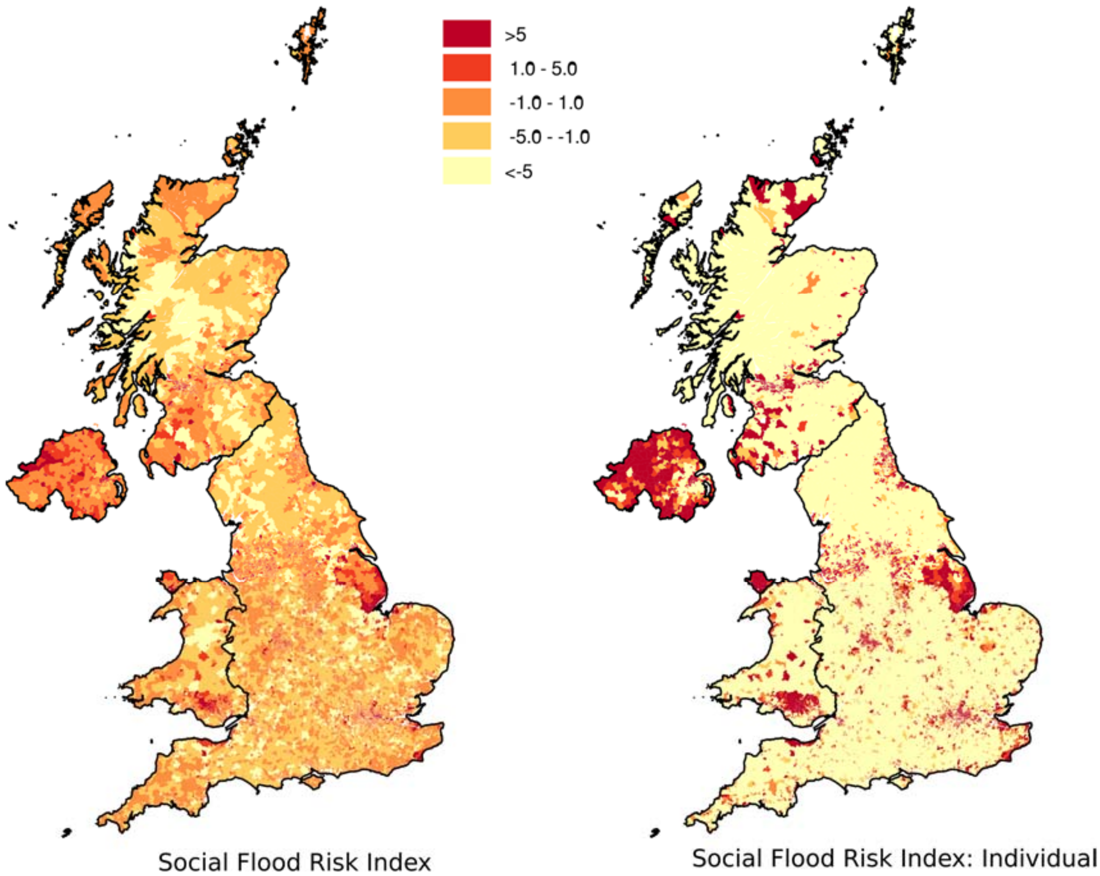


Figure 4-15 Present day: Social flood risk index (SFRI)

Across the UK the local authorities that experience the greatest levels of flood disadvantage (as determined by the SFRI) include City of Kingston upon Hull; Boston; Belfast; East Lindsey; Glasgow;

Swale; Newham; Leicester; Shepway; North East Lincolnshire, and Birmingham (Table 4-3). For each local authority, their national ranking according to each resilience metric (introduced earlier in Section 3) is also provided. For example, although Kingston upon Hull is the most flood disadvantaged authority (according to the Social Flood Risk Index) and is ranked highest in the UK according to floodplain population, EAD (residential) and many other metrics, it is not the most socially vulnerable (ranking 20th by NFVI calculated as the population weighted average across all neighbourhoods exposed to flooding). This highlights the importance of considering multiple metrics to develop an understanding of risk and its drivers.

Table 4-3 Present day: Local authorities ranked by Social Flood Risk Index and their ranking against all other metrics

	Metric							
Local Authority (ranked top 25 by SFRI)	Social Flood Risk Index: Individual (iSFRI)	Floodplain population	Expected Annual Probability of flooding: Individual (EAPi)*	Number of People Exposed to Frequent Flooding (PEFf) (per 1000 on the floodplain)	Expected Annual Damages (EAD, £m) - Residential only	Expected Annual Damages: Individual (EADi, £)*	Relative Economic Pain (REP)**	Neighbourhood Flood Vulnerability Index (NFVI)***
City of Kingston upon Hull (B)	31	1	1	1	1	1	38	20
Boston District (B)	6	12	109	9	7	73	71	1
Belfast	1	27	39	18	1	55	13	2
East Lindsey District	21	9	7	14	12	105	77	5
Glasgow City	14	15	29	4	6	48	25	50
Swale District (B)	7	49	51	32	9	54	14	10
Newham London Borough	46	3	188	17	2	124	65	15
City of Leicester (B)	19	20	116	12	16	25	32	13
Shepway District	9	65	38	28	14	15	36	16
North East Lincolnshire (B)	34	10	14	19	11	97	21	19
Birmingham District (B)	47	8	111	7	17	129	66	22
West Dunbartonshire	2	184	4	73	26	6	4	18
Doncaster District (B)	52	11	113	5	9	79	30	64
Rhondda Cynon Taf - Rhondda Cynon Taf	25	37	17	25	58	107	147	14
Derry City and Strabane	5	169	58	109	136	43	43	3
Slough (B)	20	67	47	30	19	50	49	60
West Lindsey District	12	96	86	40	39	61	34	7
Hammersmith and Fulham London Borough	84	4	69	8	8	51	250	84
East Ayrshire	4	231	26	131	66	20	8	9
Southwark London Borough	82	6	179	26	3	90	132	67
Casnewydd - Newport	54	25	25	36	20	4	53	59
Greenwich London Borough	65	16	194	48	36	147	189	43
City of Bristol (B)	44	56	36	11	21	67	59	65
Barking and Dagenham London Borough	36	78	172	162	103	122	95	8
Waltham Forest London Borough	48	60	68	35	71	99	168	37

* The average value based on the population within the floodplain

** The direct estimate of the Index.

1	in the top 5 ranked nationally
10	in the top 10 ranked nationally
25	in the top 25 ranked nationally
26	outside of the top 25 nationally

Note: Ranking based on the total of 391 Council Areas in Scotland and District Council Areas in Northern Ireland districts (including Unitary Authorities and London Boroughs) in England and Wales

A ranking based on SFRI however can mask those areas where fewer vulnerable people are exposed to more frequent flooding; an issue highlighted throughout the supporting case studies in which interviewees confirmed the very local nature of vulnerability (to a single family or individual) – see Appendix E.

Although it is outside of the scope of this study to consider the vulnerability of specific individuals, analysis of the risks faced ‘on average’ by those living in a local authority area reveals a different distribution of disadvantage. Table 4-4 therefore ranks local authorities according to the *SFRI: Individual* (the SFRI normalised by floodplain population). Some authorities (e.g. Belfast and Boston) appear on both lists, highlighting the high chance of flooding, the large number of people exposed and their vulnerability in these areas. Others, such as West Somerset for example, appear only when considered from the perspective of an ‘average’ individual, highlighting that although there may be fewer vulnerable people living within those authorities, they are often exposed to frequent flooding.

Scottish local authorities tend to appear higher on the iSFRI list than in the SFRI list. This is likely to arise from a combination of factors. Firstly, the number of people living within neighbourhoods identified as vulnerable (according to the NFVI) is generally greater in Scotland than for the UK. Secondly, those living on the floodplain in Scotland, on average, are exposed to more frequent flooding than elsewhere. The lower SFRI ranking given to Scottish local authorities reflects the lower number of people living in flood prone areas that may in part reflects the relative balance between urban and rural communities in Scotland compared to elsewhere in the UK.

The distinction between the nature of the flood disadvantage in Hull (Ranked #1 according to the SFRI metric) and West Somerset (Ranked #24 according *SFRI: Individual* metric) is illustrated in Figure 4-16. The dense urban setting of Hull and the sparse dispersed setting of West Somerset drive these differences, and the nature of the FRM opportunities.

Table 4-4 Present day: Local authorities ranked by Social Flood Risk Index: Individual and their ranking against all other metrics

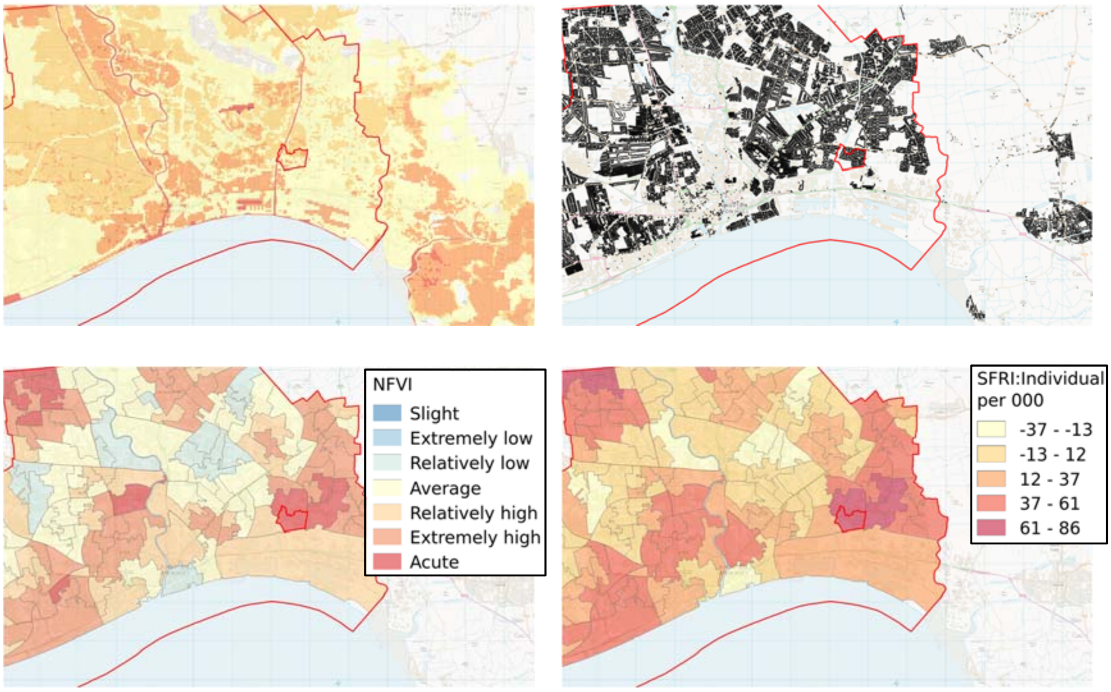
	Metric							
Local Authority (ranked top 25 by Individual SFRI)	Social Flood Risk Index (SFRI)	Floodplain population	Expected Annual Probability of flooding: Individual (EAPi)*	Number of People Exposed to Frequent Flooding (PEFf) (per 1000 on the floodplain)	Expected Annual Damages (EAD, £m) - Residential only	Expected Annual Damages: Individual (EADi, £)*	Relative Economic Pain (REP)**	Neighbourhood Flood Vulnerability Index (NFVI)***
Belfast	3	27	39	78	15	55	13	2
West Dunbartonshire	12	184	4	9	40	6	4	18
Inverclyde	49	380	10	10	244	36	5	21
East Ayrshire	19	231	26	29	80	20	8	9
Derry City and Strabane	15	169	58	52	150	162	43	3
Boston District (B)	2	12	109	173	7	73	71	1
Swale District (B)	6	49	51	144	23	54	14	10
Hartlepool (B)	46	345	43	140	160	25	2	66
Shepway District	9	65	38	62	14	15	36	16
Sir Ynys Mon - Isle of Anglesey	80	384	32	108	239	21	29	11
Mid Ulster	60	341	42	46	271	126	28	33
West Lindsey District	17	96	86	27	53	61	34	7
Dundee City	54	324	24	24	241	99	45	49
Glasgow City	5	15	29	26	6	48	25	50
Clackmannanshire	70	371	19	18	190	24	10	41
North Ayrshire	26	155	27	14	58	30	11	54
Weymouth and Portland District (B)	65	321	7	50	59	2	1	179
Dumfries and Galloway	31	174	5	13	36	8	7	74
City of Leicester (B)	8	20	116	76	30	144	32	13
Slough (B)	16	67	47	60	33	50	49	60
East Lindsey District	4	9	162	269	12	105	77	5
Renfrewshire	32	159	8	20	44	18	9	86
Blaenau Gwent - Blaenau Gwent	57	260	161	53	230	163	61	6
West Somerset District	77	330	41	69	129	19	44	40
Rhondda Cynon Taf - Rhondda Cynon Taf	14	37	172	99	72	226	147	14

* The average value based on the population within the floodplain

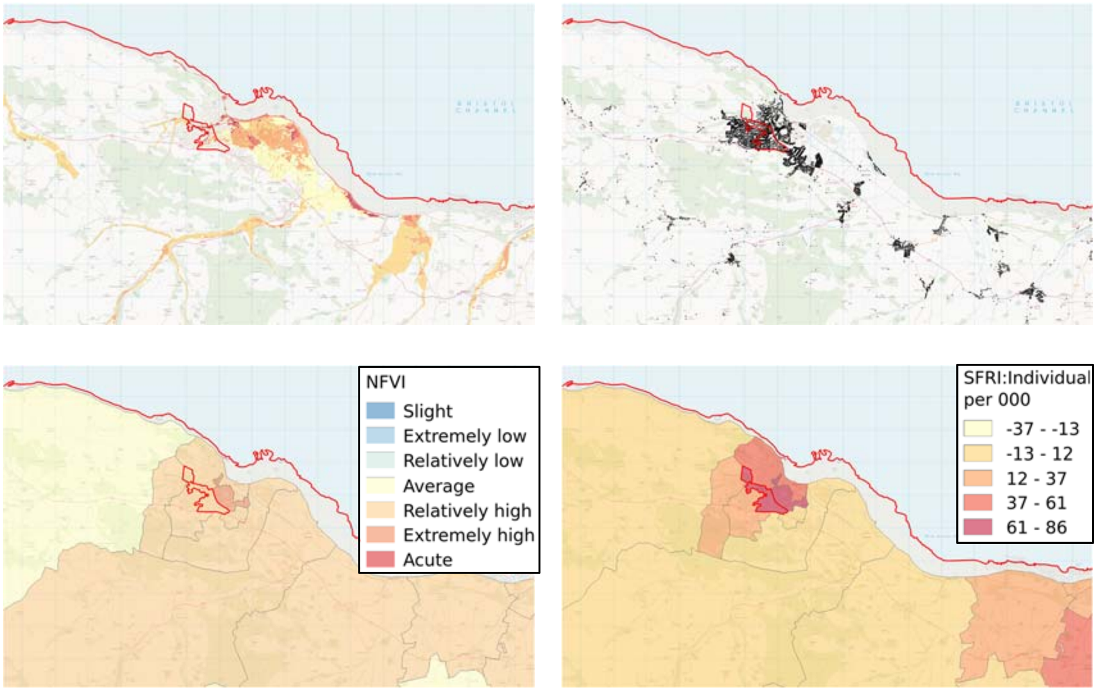
** The direct estimate of the Index.

1	in the top 5 ranked nationally
10	in the top 10 ranked nationally
25	in the top 25 ranked nationally
26	outside of the top 25 nationally

Note: Ranking based on the total of 391 Council Areas in Scotland and District Council Areas in Northern Ireland districts (including Unitary Authorities and London Boroughs) in England and Wales



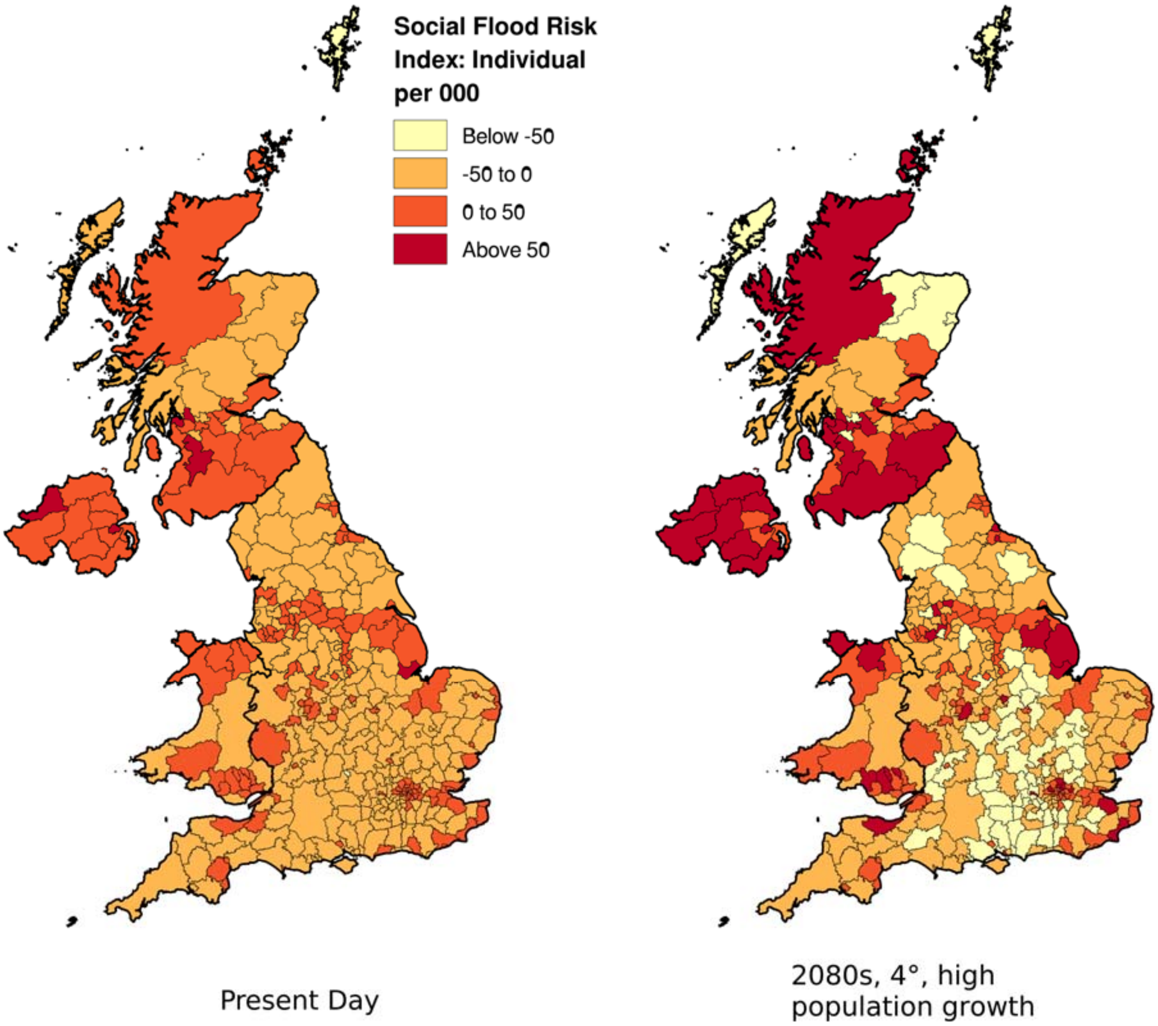
Hull: *High levels of Social Flood Risk arise from a large number of vulnerable people exposed to flooding*



Somerset: *High levels of Social Flood Risk (individual) arise because pockets of vulnerable neighbourhoods are exposed to flooding*

Figure 4-16 Hull and West Somerset: Contextual differences in the drivers of geographic flood disadvantage

Future risks: By the 2080s the number of local authority areas experiencing significant flood disadvantage (as defined here by *SFRI* above 50 per 1000) increases substantially by the 2080 (given a 4°C climate future) - Figure 4-17. Scotland, Northern Ireland, the north and south coasts of Wales and the east coast of England experience some of the most significant increases.



Left: Present day
Right: 2080s (4°C, high population growth, current levels of adaptation): Note: The increase in population acts to reduce the SFRI: individual index shown here but may increase the SFRI

Figure 4-17 Future risks: Changes in geographic flood disadvantage (SFRI: Individual)

Table 4-5 presents the twenty-five highest ranked local authorities by SFRI in the 2080s and their change in ranking from the present day. In many cases, those local authorities that experience the highest levels of flood disadvantage today continue to do so in the future. There are several notable exceptions, for example, the flood disadvantage increases more in the Highlands of Scotland, Cardiff in Wales, and North Somerset and the north London Boroughs of Enfield, Tower Hamlets and Haringey in England than elsewhere (increasing their relative ranking, as highlighted in Table 4-5). The underlying reasons for this are the variation in climate influences and the assumed approach to adaptation.

Table 4-5 Future risks: Local authorities ranked by Social Flood Risk Index (2020s, 2050s and 2080s)

		PD	2020s	2050s	2080s
Local Authority	**Country**	Ranking by SFRI			
Newham London	England	7	5	3	1
Boston	England	2	2	1	2
Hull	England	1	1	2	3
Glasgow	Scotland	5	4	9	4
Belfast	Northern Ireland	3	3	4	5
Highland	Scotland	72	15	5	6
East Lindsey	England	4	8	7	7
Leicester	England	8	6	8	8
Shepway	England	9	7	6	9
Birmingham	England	11	9	11	10
Swale	England	6	10	10	11
Barking and Dagenham, London	England	24	18	12	12
Enfield, London	England	48	30	17	13
Warrington	England	34	34	23	14
Southwark, London	England	20	17	13	15
North Somerset	England	372	359	276	16
Tower Hamlets, London	England	35	26	19	17
West Dunbartonshire	Scotland	12	12	15	18
Slough	England	16	13	16	19
Greenwich, London	England	22	20	18	20
Waltham Forest, London	England	25	22	21	21
Haringey, London	England	50	42	27	22
Salford	England	42	33	25	23
Rhondda Cynon Taf - Rhondda Cynon Taf	Wales	14	14	22	24
Caerdydd - Cardiff	Wales	33	25	20	25

** Local authority boundaries from Ordnance Survey OpenData Boundary Line*

4.5 Cities in relative decline and their influence on flood disadvantage

Summary findings

- Sixteen of the 24 city regions classed as in relative decline by Pike *et al.* (*.,* 2016) experience levels of flood disadvantage above the UK average, suggesting floods could undermine economic growth in areas that need it most and lead to a spiral of decline (if repeated floods occur).

Discussion

Sixteen of the 24 city region classed as in relative economic decline by Pike *et al.* (2016) experience levels of flood disadvantage above the UK average. This reflects a combination of influences but from the perspective of the analysis here, is driven by higher than average levels of vulnerability (as shown by the NFVI) and a greater than average number of people exposed to a frequent flood (in Glasgow, for example, those living in the floodplain are almost twice as likely to experience frequent flooding than the UK average). When income and insurance penetration are considered, the REP associated with flooding is significantly higher in these sixteen cities, reflecting the lower levels of income (on average) and lower levels of insurance (Figure 4-18).

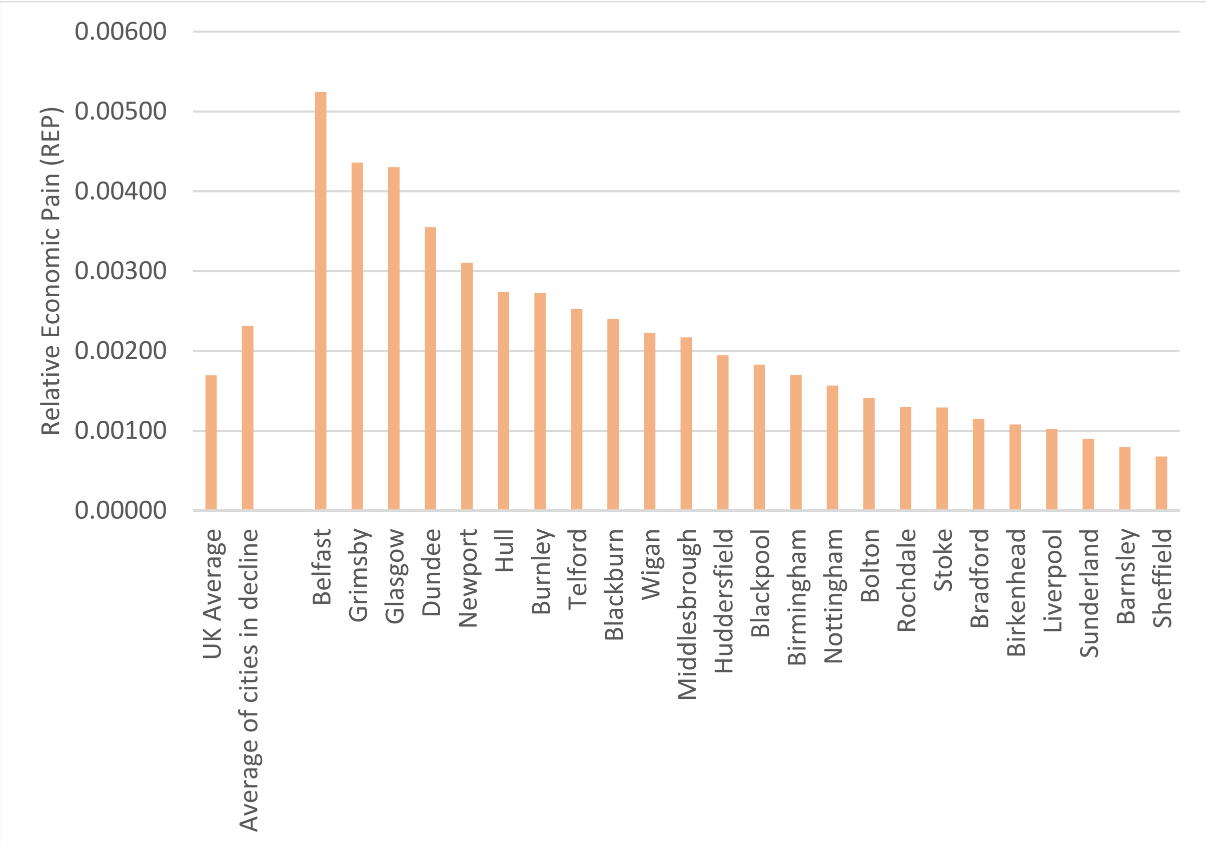


Figure 4-18 City regions in Relative Decline: Relative Economic Pain of flooding

4.6 Suitability of 'deprivation' as a guide for FRM investment

Summary findings

- The Index of Multiple Deprivation (IMD)Deprivations fails to all identify areas of greatest flood vulnerability; with flood risk in the most vulnerable areas (defined by the NFVI) consistently greater than that in deprived areas (defined by the IMD).

Discussion

The UK government collects data on deprivation across a range of domains (including income, health, housing quality, availability of services) associated with geographic areas. These are then combined into a measure of multiple deprivation (the IMD) and used across government to understand the distribution of social inequalities associated with a neighbourhood and to inform resources allocation. The IMD is not however a measure of 'flood social vulnerability' *per se*. This section explores the suitability of IMD as a guide by comparing the flooding risks in the most deprived areas with the most flood vulnerable neighbourhoods as defined by the NFVI.

Present day: Flood vulnerability (as defined by the NFVI) and areas of deprivation (as defined by the IMD) take account of many similar characteristics of a neighbourhood (including, for example, income). The NFVI, however, focuses more specifically on those characteristics that make a neighbourhood vulnerable to a loss in wellbeing following a flood rather than the more general expression of 'deprivation' provided by the IMD (for example, the NFVI includes the availability of community support networks during a flood).

Flood risk in the most vulnerable areas (the top 20% by the NFVI) is consistently greater than in the most deprived areas (the top 20% by the IMD) – Figure 4-19. This suggests that the IMD fails to identify all those areas at greatest flood disadvantage. Without future spatial comparison (outside the scope of this study), it is difficult to determine exactly which neighbourhoods drive this difference. Given the role of the IMD in FRM policy across the UK these differences may be significant and raise questions over whether the IMD is the best measure for promoting Rawlsian FRM investment decisions (notwithstanding the positive influence the IMD has had in targeting investment priorities in England through the FDGiA to date).

Future risks: Given the focus of the IMD on 'deprivation' these neighbourhoods are typically associated with lower incomes and hence reduced insurance penetration and increased REP experienced by those flooded. By the 2080s, therefore, significant increases in REP in the most deprived areas are projected.

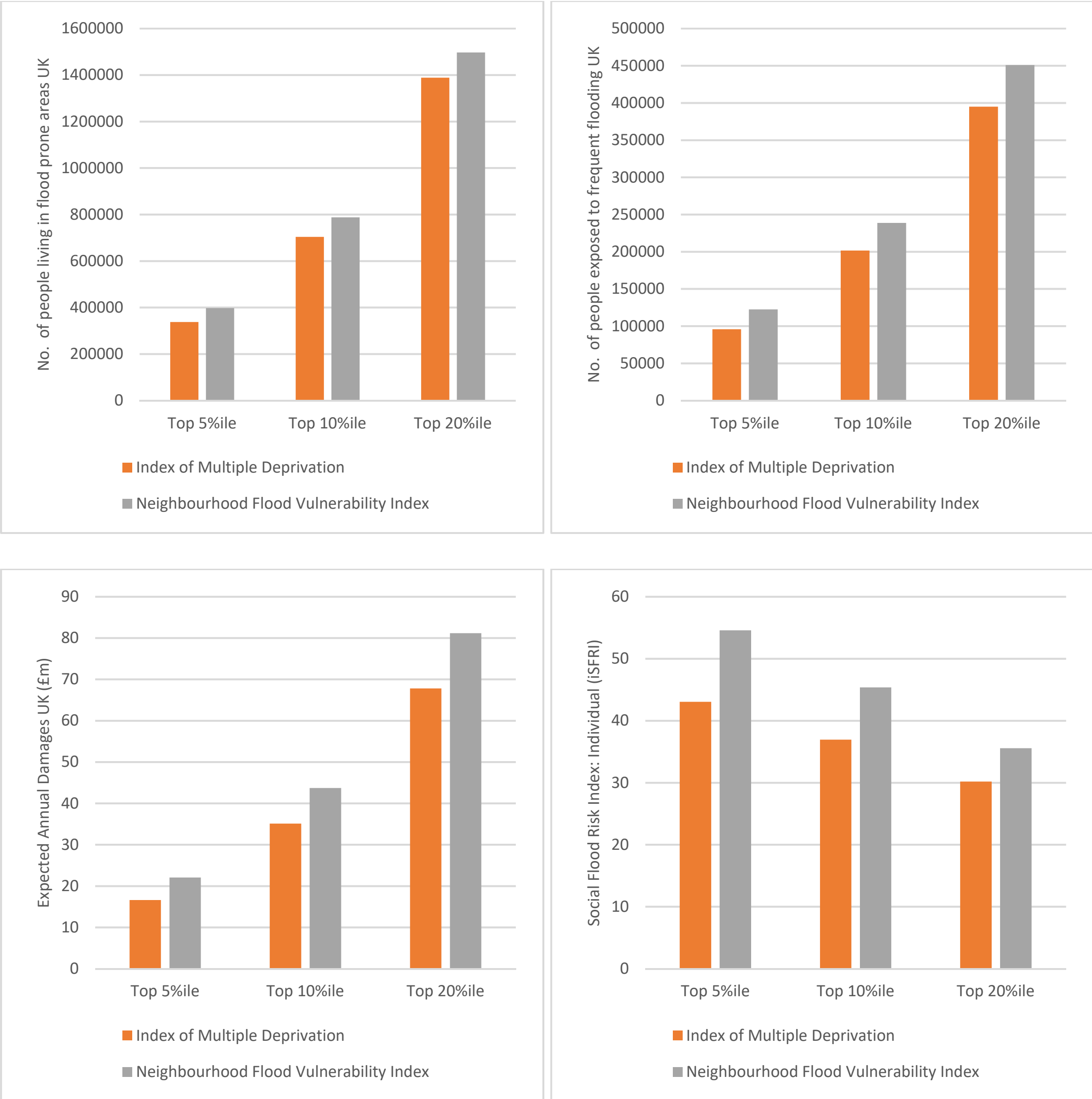


Figure 4-19 Present day: A comparison of risks in deprived and vulnerable neighbourhoods

4.7 Recent developments in vulnerable neighbourhoods (England)

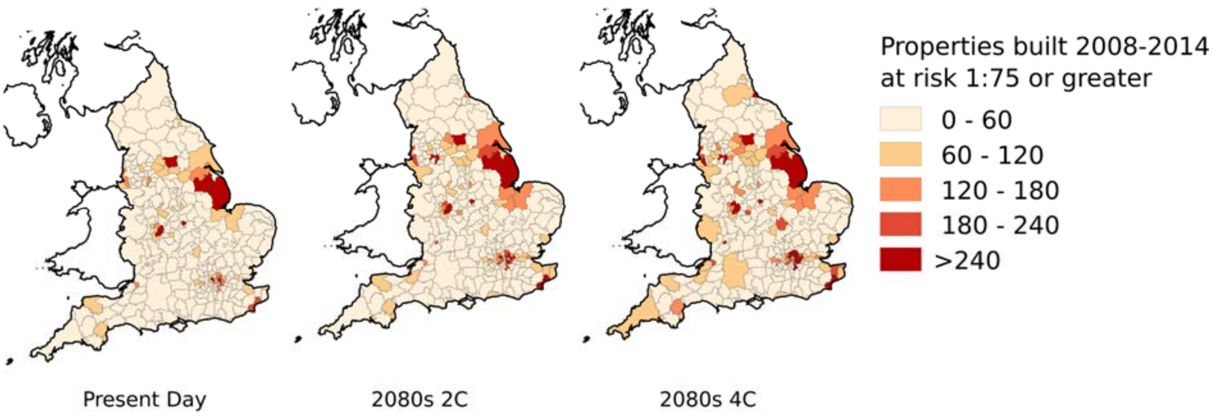
Summary findings

- Recent developments (2008-14) in areas prone to more frequent coastal and surface water flooding (1 in 75 years or more frequent) have disproportionally taken place in the most vulnerable neighbourhoods.
- By the 2080s all developments built between 2008-14 experience a significant increase in exposure to flooding. Across all sources of flooding, the increase is greatest in those developments built in the most vulnerable neighbourhoods (but this is particularly the case in coastal floodplains).

Discussion

This section explores the degree to which new development has taken place in vulnerable neighbourhoods exposed to flooding and how the risk in these developments may change in the future.

Present day: Current national planning policies across the UK (England: National Planning Policy Framework, Wales: Technical Advice Note 15, Scotland: Online Planning Advice, Northern Ireland: Planning Policy Statement 15) typically seek to avoid inappropriate floodplain development. However, analysis by the Adaptation Sub-Committee (ASC) of new residential development built between 2008-14 found that floodplain development continues (ASC, 2015). Further analysis of the data collated by the ASC here highlights that of a total of 1,199,000 new residential properties built in the period 2008-14, 225,000 (20%) were built in flood prone areas (across all sources), with 25% of those properties being built in the 20% most vulnerable neighbourhoods (Figure 4-20).



Future maps assume high population growth and a continuation of current adaptation

Figure 4-20 Present and future exposure of new developments to flooding

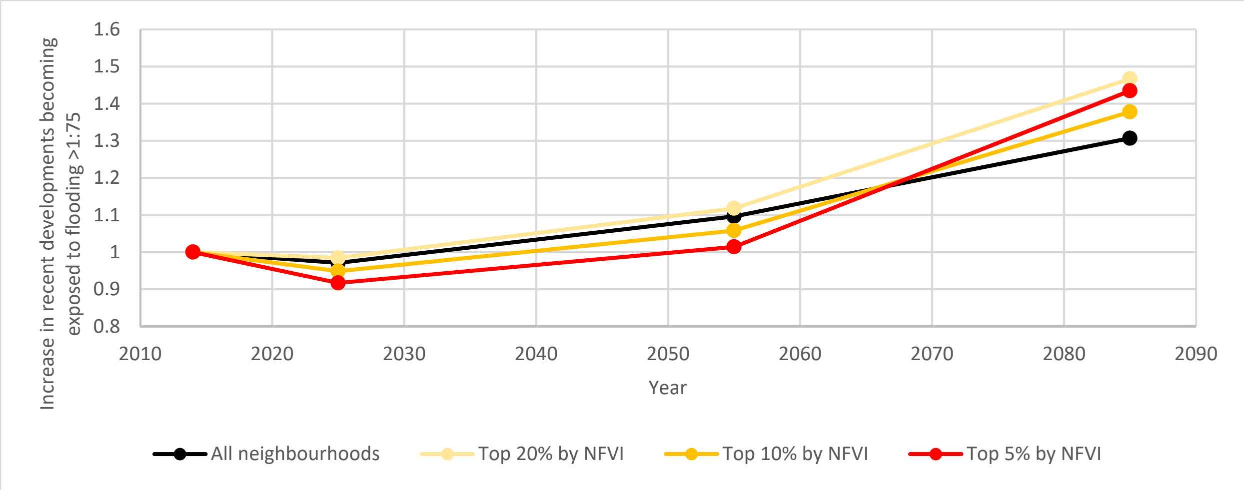
In coastal floodplains, 31% of all developments (22,241 properties) took place within the 20% most vulnerable neighbourhoods (Table 4-6). For areas prone to surface water flooding, 24% of recent developments (22,456 properties) have been built in the 20% most vulnerable neighbourhoods. However, there is no evidence to suggest that most vulnerable neighbourhoods are also subject to greater levels of development than elsewhere (18.7% of new developments occur in the top 20% of neighbourhoods by NFVI).

Table 4-6 Present day: New residential development in areas prone to flooding (built 2008-14) and vulnerability

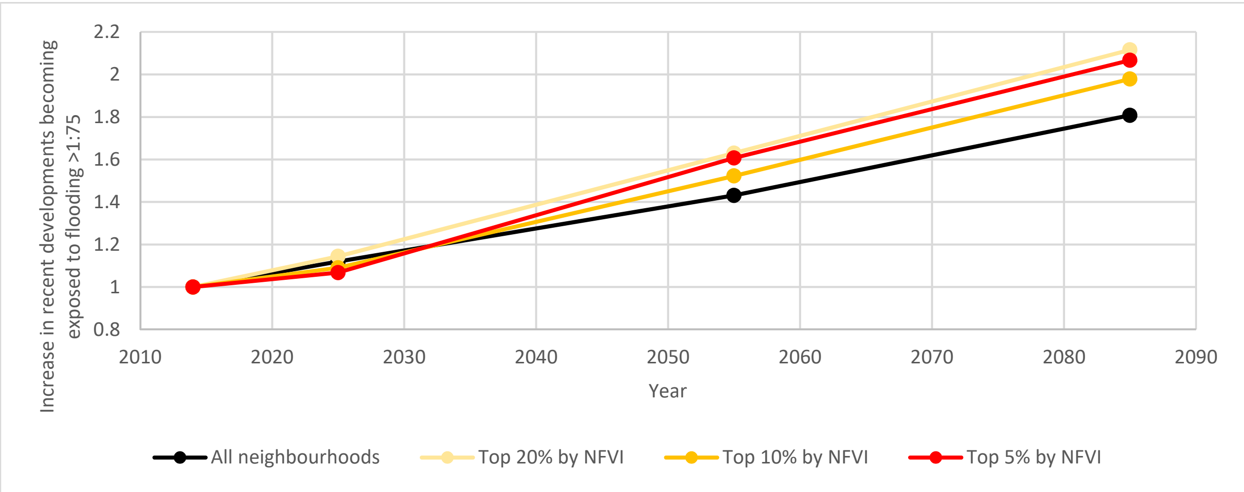
	Recent Developments (2008-14) - No. of Properties		
	All neighbourhoods	More vulnerable neighbourhoods (20% by NFVI)	
All developments	1,404,000	297,046	
Built on floodplain	11%	14%	
Residential developments only	1,198,656	224,195	
Built on floodplain	12%	13%	
Breakdown by source (within the 1:1000-year undefended floodplain)			
Coastal	71,313	22,241	31%
Fluvial	61,726	11,792	19%
Surface water	92,049	22,456	24%
Areas subject to very frequent flooding (1:30 years or more frequent)			
Coastal	3,653	974	27%
Fluvial	8,827	892	10%
Surface water	19,021	4,573	24%
Areas subject to frequent flooding (1:75 years or more frequent)			
Coastal	8,482	2,084	25%
Fluvial	18,665	2,378	13%
Surface water	34,842	8,576	25%

Future risks: By the 2080s all developments built between 2008-14 will experience a significant increase in their exposure to flooding (Figure 4-21). Across all sources of flooding the increase is greatest in those developments built in the most vulnerable neighbourhoods (primarily in London). The discrepancy in future changes in exposure between developments that have taken place in more and less vulnerable neighbourhoods is most significant at the coast. Of those developments built on the coastal floodplain, 25% are exposed to frequent flooding (more frequent than 1:75 years, on average). By the 2080s this increases to 40% (under both a +2°C and +4°C climate future).

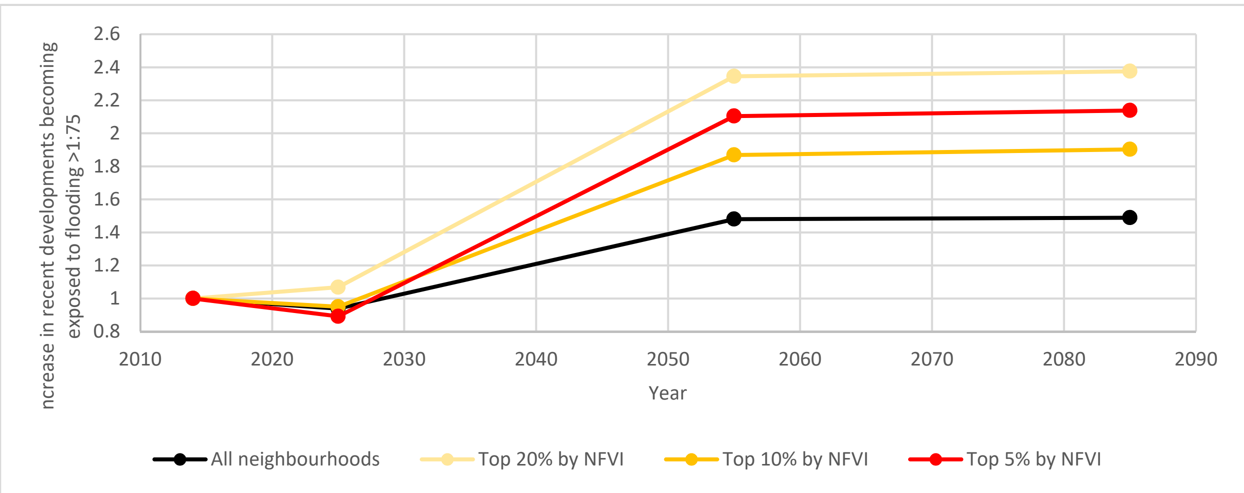
Note: There is no clear reason for the slight reduction in exposure by the 2020s (particularly noticeable for coastal). This may be due to adaptation measures, many of which make assumptions and approximations which could lead to a small reduction in risk when the climate change increase is small (*i.e.* not large enough yet to outpace adaptation).



2⁰C climate future, high population growth and a continuation of current adaptation: All flood sources



4⁰C climate future, high population growth and a continuation of current adaptation: All flood sources



4⁰C climate future, high population growth and a continuation of current adaptation: Coastal flood areas

Figure 4-21 Future risks: Growth in the number of recent developments (2008-14) exposed to flooding

4.8 Long-term investment in England: Evidence for greater investment in vulnerable neighbourhoods

Summary findings

- There is strong evidence to support improving the protection provided to the most vulnerable neighbourhoods in England.

Discussion

Within the Environment Agency's LTIS for England (that seeks to explore the long-term investment needs for FRM in England, as introduced earlier in Section 2.2), the investment scenario which maximises the Net Present Value over the 100-year period is referred to as the so-called *'optimised investment scenario'*. This provides a utilitarian investment appraisal and excludes consideration of funding sources (*e.g.* Partnership Funding does not influence the investment case). The analysis presented in the CCRA of the LTIS policy choices (a simplified set of policy options from 'do nothing' to 'improve +' with a time horizon stretching through to 2100, as described in Table 4-7) is extended here to explore the impact on risk in socially vulnerable neighbourhoods.

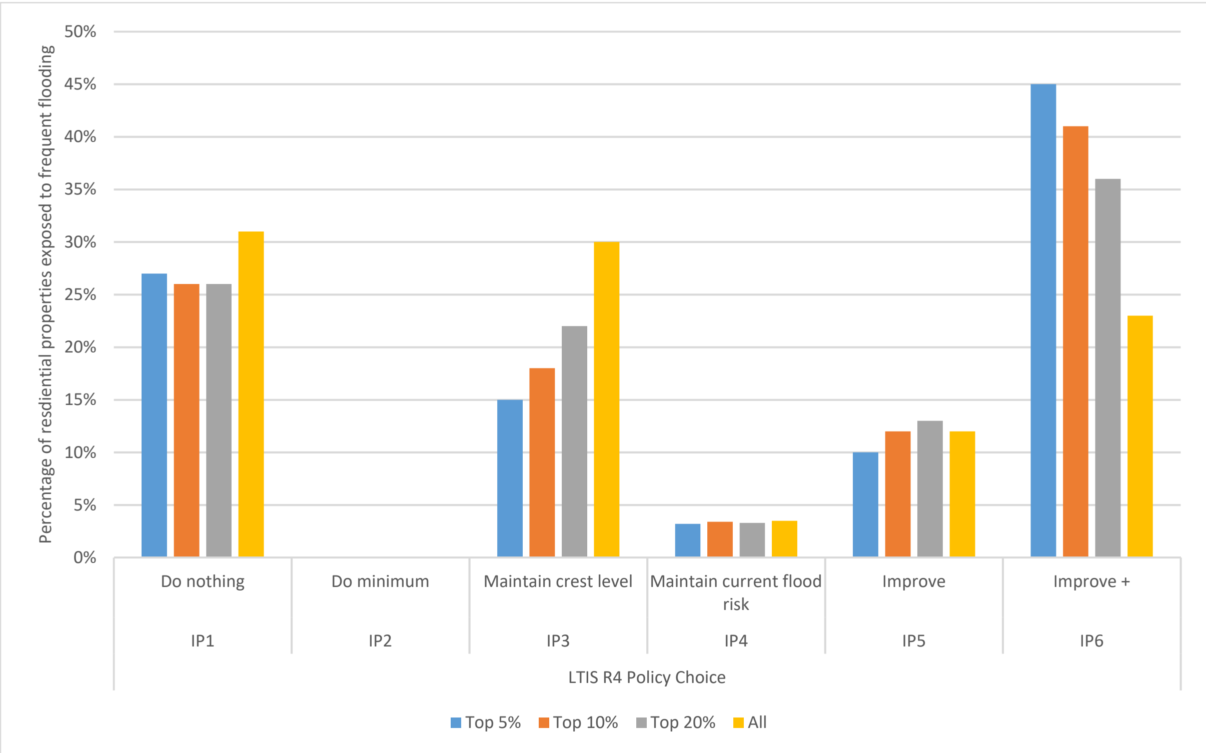
Table 4-7 The LTIS policy options

Policy Option	Influence on expenditure	Influence on risk
Do Nothing	Passive assets: no expenditure on maintenance or replacement of passive assets. Active assets: not included in expenditure.	Passive assets degrade and fail over a short period of time. The level of flood risk will increase quickly over time as assets fail. Non-operation of active assets increases risk in the very short term.
Maintain crest level	Maintain and replace current assets to their existing crest levels.	The level of flood risk will increase over time due to climate change.
Maintain current flood risk	Maintain current assets, replace with larger/longer/more robust structures. Build new assets.	The level of flood risk will remain static as the standard of protection provided keeps pace with climate change.
Improve	Maintain and replace current assets. Assets to be replaced with larger/longer/more robust structures. Build new assets.	The level of flood risk reduces as assets are replaced with ones that offer a better standard of protection.
Improve+	Maintain and replace current assets. Assets to be replaced with larger/longer/more robust structures. Build new assets.	The level of flood risk reduces as assets are replaced with ones that offer a better standard of protection.

Table 4-8 and Figure 4-22 show the percentage of residential properties exposed to frequent flooding (a return period of 1:75 years or less) that, under the optimised investment scenario, are assigned each LTIS policy option. The results suggest that there is a strong utilitarian case for improving the protection afforded to socially vulnerable neighbourhoods (with nearly 55% of properties in socially vulnerable neighbourhoods, defined by the top 5% by NFVI, assigned an *Improve* or *Improve+* policy option compared to c.35% on average). Residential properties in socially vulnerable neighbourhoods are also less likely to be assigned a '*do nothing*' or '*maintain crest*' policy choice - indicating possible deteriorating or no change in protection standards - when compared to residential properties on average (c.48% compared to 61%). Together these results suggest that there is a direct long-term economic case for greater investment in FRM in vulnerable neighbourhoods (although this is an inference which will need to be explored further in future research).

Table 4-8 The relationship of LTIS policy choices and neighbourhood vulnerability

Neighbourhood by NFVI	Percentage of Neighbourhoods assigned an LTIS Policy Choice (R4 Investment scenario)					
	IP1 Do nothing	IP2 Do minimum	IP3 Maintain crest level	IP4 Maintain current flood risk	IP5 Improve	IP6 Improve +
Top 5%	27%	0%	15%	3.2%	10%	45%
Top 10%	26%	0%	18%	3.4%	12%	41%
Top 20%	26%	0%	22%	3.3%	13%	36%
All	31%	0%	30%	3.5%	12%	23%



Frequent flooding: 1:75 years or more frequent: Note: IP2 is not considered in LTIS policy investment option selection

Figure 4-22 Percentage of residential properties in areas receiving each LTIS Policy choice

5.0 CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Reconfigure existing FRM metrics

#1: Introduce new metrics that better reflect the nature of flood vulnerability and the risks faced by vulnerable neighbourhoods.

The research presented here reinforces the need to reconfigure existing metrics of vulnerability and risk to better capture the differential nature of the risks faced in vulnerable communities.

To overcome the deficiencies in existing approaches, three new metrics should be used (alongside existing metrics) to provide a better understanding of flood risk and monitoring of FRM outcomes:

- **Neighbourhood Flood Vulnerability Index** (NFVI): The NFVI provides an improved expression of flood vulnerability, and is put forward as an alternative/replacement to the Index of Multiple Deprivation in FRM decision-making and as an evolution of previous vulnerability metrics.
- **Social Flood Risk Index** (SFRI): The SFRI is used to provide a combined expression of probability, exposure and vulnerability and provides a means of directly comparing risk in one area with another in a way that explicitly accounts for vulnerability and the potential loss in well-being of residents.
- **Relative Economic Pain** (REP): The REP considers the influence of lower income levels and flood insurance penetration to better reflect the experience of a given economic loss in more and less vulnerable neighbourhoods. The REP highlights the systemic flood disadvantage experienced by those living in vulnerable neighbourhoods, when income and insurance take up (a function of tenure, income and history of flooding) are considered. This highlights the significant role that income, tenure and insurance play in systemically disadvantaging the most flood vulnerable communities (regardless of other characteristics that make communities flood vulnerable).

The role of these new metrics within the appraisal process and definition of outcome measures are discussed further in the following recommendations.

5.2 Set clear social outcomes for FRM and measure success

#2 Reconfigure outcome measures to monitor flood disadvantage based upon a better understanding of flood vulnerability.

To some degree FRM policies across the UK promote the notion of targeting effort towards managing the risk for socially vulnerable populations (through formal processes such as the FDGiA in England and more informal consideration of social flood vulnerability as criteria for prioritisation in Scotland). However, there is no routine assessment of the extent to which policies achieve this (notwithstanding that in England outcomes for households in deprived areas are monitored through Outcome Measure 2c). A pre-requisite to delivering greater social justice in FRM is therefore to monitor performance more directly in this context.

This could include assessing levels of systemic flood disadvantage (by routinely recording a comparison of the risk faced by the more and less vulnerable) as well as geographic flood disadvantage (focusing, for example, on number of homes protected in socially vulnerable neighbourhoods defined by NFVI – top 5% and 20%ile - and ranking local authorities by the SFRI. These measures would be an alternative, for example, to outcomes based on the IMD.

5.3 Ensure FRM investment appropriately targets the socially vulnerable

#3 Embed positive discrimination in FRM investment decisions to target support to the most vulnerable communities.

Many policy documents across England, Wales, Scotland and Northern Ireland refer to reducing vulnerability. The only formal mechanism for targeting investment towards more vulnerable neighbourhoods however is in England through the Flood Defence Grant-in-Aid (FDGiA). Although FDGiA uses the IMD as the basis (see previous section), this is a good start and one that should be considered across the UK (although it is recognised that elsewhere informal prioritisation processes exist with the aim of helping the most vulnerable). This is not to say that the process in England is perfect (as evidenced through the continued flood disadvantage in England) and further work is needed to formalise approaches that target the most flood vulnerable within the investment planning process; a conclusion supported by the long-term economic case for improving the protection afforded to vulnerable neighbourhoods suggested by the LTIS.

The research presented here suggests that to develop a new approach that better manages risk in the socially vulnerable neighbourhoods it will be important to recognise that:

- **Economic efficiency (utilitarian) criteria may not, alone, be capable of adequately assisting particularly vulnerable areas (and delivering Rawlsian outcomes).** An approach based solely on economic efficiency is unlikely to significantly reduce disadvantage in dispersed rural communities, in some coastal floodplains or elsewhere where the costs of providing traditional schemes is relatively high compared to a narrow definition of economic damage.
- **Any requirement for local contributions (for example, as required in England) must ensure both residential properties and non-residential properties (*e.g.* small businesses) within vulnerable neighbourhoods are treated preferentially.** Without positive discrimination towards both residential and non-residential properties, it may be difficult for flood protection schemes in deprived areas of mixed land use to achieve the necessary national prioritisation.
- **In many locations, particularly in many rural neighbourhoods, a conventional flood defence scheme may simply not be feasible.** There is a need to better support the socially vulnerable neighbourhoods to develop community level solutions, installing appropriate property level protection and accessing insurance. This is equally applicable in many areas where low standard schemes are in place and significant residual risk persists.

Tackling these issues will require an acceptance that addressing flood risk in vulnerable communities is a complex endeavour and that FRM is only part of the solution and will need to be integrated with other policy endeavours to reduce or avoid exacerbating exposure to flooding and vulnerability.

5.4 Ensure FRM actively supports integrated solutions

#4 Ensure FRM actively supports inclusive growth, the delivery of multi-functional and resilient developments whilst continuing to deliver flood risk reduction benefits.

Low income and poor health, together with a lack of community capacity and social capital, are important drivers of social vulnerability to flooding. These are most directly influenced by agendas outside of FRM policy, including broader economic development and social policy that seek to support inclusive growth (to ensure that economic prosperity benefits all) as well as general welfare provision. The role of FRM policy in supporting these broader agendas (and vice versa) will be vital in delivering socially just FRM outcomes.

Planning (national and local), for example, has a central role to play in this process as good urban planning stimulates economic growth as well as promoting positive health and flood management outcomes (as recognised across the UK with Garden Cities firmly on the political agenda, TCPA, 2012). The evidence presented here, through the analysis of the NFVI and the *'relative economic pain'* (REP) metrics, reinforces the support for more integrated planning that links economic and social regeneration, blue-green planning principles (*e.g.* embedding Sustainable Urban Drainage Systems, SUDS, in local development plans), encouraging flood and broader climate resilience (through building regulation that support sustainable place making and resilient design) and ensuring new developments provide *'the right homes in the right places'* (DCLG, 2017).

One approach to encouraging this would be to reconsider the way in which FRM funding is geared by supporting multiple government and private sector funding streams, including regeneration and economic growth that encourages employment to be retained locally to promote higher incomes and hence reduced vulnerability. Such strategic action is not easy, requiring local authorities and the planning system to recognise the challenge, but if appropriately supported offers significant opportunity to reduce flood disadvantage.

The preferential weighting given to the protection of deprived households in England (through the FDGiA) could be developed further to better support regeneration not only in England but across the UK. In doing so, it will be important to recognise that, at present, the FDGiA process makes no distinction between small businesses operating in deprived areas and those in more affluent areas; in both cases businesses are expected to make a financial contribution to a scheme (through Partnership Funding). This is can be a significant barrier when flood defence schemes protect a mix of commercial and residential properties. In such settings, the economic income-generating infrastructure (*i.e.* businesses) in less affluent areas are treated in the same way as similar infrastructure in more affluent areas. The absence of preferential weighting given to businesses can be a significant barrier to securing flood defence funding in vulnerable urban areas requiring significant lengths of defence to protect a mix of residential and non-residential properties.

Reconfiguring the flood defence granting process will be an important step towards the goal of ensuring FRM funding processes align with, and complement, broader activities that in combination deliver multi-benefits (including health and well-being outcomes) as well as FRM outcomes.

5.5 Improve take-up of property level protection and community-level measures

#5 Improve take-up of appropriate property level measures and wider community level approaches in vulnerable neighbourhoods.

Although not a silver bullet, property level measures can provide a legitimate contribution to FRM. Evidence suggests however the take-up of government grants to support property level measures (*e.g.* when provided following a flood event) is significantly lower in vulnerable communities than in the population as whole. This reflects several difficulties that are characteristic of more vulnerable neighbourhoods, including rented tenure and low income as well as the need for collective action demanded by the nature of the housing stock (for example to provide flood resistance to terraced housing). This differential take-up is an important driver in systemic flood disadvantage, particularly in areas where conventional flood defence schemes may not be justified. The case studies undertaken in support of the analysis presented here highlight four issues that will need to be addressed to improve access to grants for property level improvements by:

- Streamlining access to subsidies and grants for the most vulnerable;
- Removing/reducing the need for the most vulnerable to provide supplementary funding;
- Raising awareness of both the flood risks faced and the availability of grants and reputable contractors and products – through both passive information provision and the use of intermediaries to support specific applicants and target vulnerable communities and support the on-going maintenance (*e.g.* drawing upon the National Flood Forum, local resilience fora, flood action groups and other local routes).
- Joint working between the insurance sector, government and community groups to offer grants and subsidies for protection level measures for the most vulnerable through an on-going process (rather than in reaction to flood events).

5.6 Improve access to affordable insurance

#6 Improve access to appropriate insurance for the most vulnerable by developing an insurance mechanism that bridges the gap in take-up between the more and less vulnerable.

When income and insurance penetration (a function of tenure and income) are considered, the REP associated with flooding is significantly higher in flood vulnerable neighbourhoods than elsewhere. This primarily reflects the lower levels of income and the associated lower levels of insurance take-up and highlights the role insurance plays in systemically disadvantaging the most vulnerable. The development of the Flood Re reinsurance scheme underlines the insurance industry's commitment to providing affordable insurance for all at highest risk (with premiums differentiated by council tax band as a crude proxy for income). Innovative 'collective instruments' are also used by some insurers to enable access by vulnerable groups (including insurance with rental schemes, although flood insurance may not be a priority in the social housing sector as it competes with other financial pressures and requirements to avoid rent increases).

Despite these initiatives, insurance take-up amongst those on lower incomes and in rented accommodation is much lower than elsewhere; a disparity that is likely to increase when actuarial (fully risk-reflective market) pricing is introduced in 2039 (when the Flood Re scheme ends). It is also the case that Flood Re excludes properties built after 2009; this is material given the analysis presented earlier suggests that those developments (built between 2008-14) in the most vulnerable neighbourhoods experience a significant increase in flood frequency in the future (more so than less vulnerable neighbourhoods).

Addressing the complex issues that exist in providing effective insurance in vulnerable neighbourhoods (including those associated with affordability, excesses, capability, awareness, and tenure) imply the solution does not lie with flood policy alone and a greater coherence between wider housing and welfare policy together with flood policy will be required.

5.7 Improve spatial planning and development control processes

#7 Better reflect the differential nature of the long-term flood risks faced in vulnerable neighbourhoods within national planning policy and local guidance.

Analysis presented here suggests that recent developments in vulnerable neighbourhoods are projected to experience a greater increase in risk than those constructed elsewhere. This suggests that:

- Current planning processes and the associated control of development in flood prone areas do not adequately account for future climate change ((TCPA, 2017)).
- Opportunities for embedding blue-green responses that reduce flood risk, and deliver multiple benefits opportunities, may be missed (TCPA, 2017) – although the analysis presented here assumes all new developments incorporate appropriate surface water management.
- There is a need to deliver flood resilient homes through appropriately enforced building regulations.
- The vulnerability of those who are likely to live in the homes provided may not be being adequately considered. For example, although consideration is given to safe access and egress, it is unclear if the differential impacts of flooding on the most vulnerable are influential in the planning choices, and the construction detailing of the homes built.

Taking the opportunity presented by the Housing White Paper (DCLG, 2017) to address these issues through a combination of national planning policy and spatial planning guidance for local planners will be important to avoid exacerbating flood disadvantage through inappropriate new development.

5.8 Maintain a socially just process

#8 Ensure flood events do not divert significant funds inappropriately from managing risk in more vulnerable areas and do not foreclose more sustainable longer-term options.

It is well known that funding, in part at least, responds to public ‘outrage’ (Sandman, 1987). This can lead to those with the ‘*loudest voice’* being prioritised over those with the greatest need. A socially just approach certainly includes responding to immediate emergency needs after a major flood event, but this must not undermine existing investment processes or divert FRM funds that have been committed elsewhere.

Such investment must also avoid foreclosing future choices. It is increasingly recognised that some floodplain communities, particularly at the coast, cannot be sustained in the long-term due to climate change. This is confirmed by analysis of future flood risk under extreme, but plausible, sea level rise assumptions that highlights significant lengths of existing coastal defences that will become increasing untenable to maintain (Sayers *et al.,* 2015) and the various Shoreline Management Plans that promote a ‘managed realignment’ policy option (ASC, 2012).

Across the UK, legislation and policy promote a proactive rather than reactive approach to FRM (as discussed in Appendix E). Understanding how to respond to emergencies whilst transitioning towards a more sustainable approach (that may require a transformative approach in the face of climate change) is a significant challenge. To do so in a socially just way will require a combination of community involvement and a policy imperative to establish objectives with communities and agree how these can be achieved to support a sustainable future (providing the procedural justice to ensure that those involved have their voice heard).

6.0 GLOSSARY, ACROYNMS AND REFERENCES

6.1 Glossary

The following definitions are drawn from a variety of sources and are interpreted in the context of this report. The primary sources used are Sayers *et al.* (2015), Lindley *et al.* (2011) and Twigger-Ross *et al.* (2014).

Adaptation	The on-going adjustment in natural, engineered or human systems in response to actual or expected changes in climate or other drivers of risk. Adaptation may be either autonomous (and achieved through self-motivated change) or planned (and achieved through purposeful adaptation planning).
Adaptive capacity	The general ability of institutions, management systems, infrastructure and individuals to adjust (or be adjusted) to future change to take advantage of opportunities that arise and appropriately manage additional risks that are present with minimum use of resources (social, financial and ecological).
Annual exceedance probability	Annual exceedance probability (AEP) describes the probability of an event (*e.g.* a flood of a given magnitude) occurring in any given year. AEP is approximately equivalent to the inverse of return period (in years). For example, 3.3% AEP refers to a return period of 1 in 30 years. This is not true for very frequent events (see Sayers *et al.,* 2015).
Capacity	The combination of all the strengths, attributes and resources available within a community, society or organisation that can be used to achieve agreed goals.
Climate Projection	A well-defined plausible climate future. Two climate change projections are considered here, namely a +2^{o}C and +4^{o}C change in Global Mean Temperature (GMT) by the 2080s.
Coastal flooding	Flooding from the sea arising when tidal surge, wave action or a combination of both overtop or overflow the shoreline boundary.
Data zones	Local areas containing around 500-1,000 residents with similar social characteristics. Data zones (DZ) are used by the Scottish Government for reporting social statistics, for example from the census.
Disadvantage (geographic)	Geographic Flood Disadvantage (GFD) provides an 'absolute' interpretation of disadvantage (as proposed by Lindley *et al.,* 2011) and enables those locations where high levels of social vulnerability combine with a large number of people exposed to flooding to be identified. GFD therefore identifies areas that are 'hot spots' of social flood risk.
Disadvantage (systemic)	Systemic Flood Disadvantage (SFD) provides a 'relative' interpretation of disadvantage and enables bias in the flood risk faced by the most vulnerable when compared to the average to be explored. As such, SFD measures the degree to which FRM policy (or its implementation in practice) can be considered to deliver a fair and socially just outcome.
Endogenous change	Purposeful adaptation to manage the probability of flooding, the exposure to floods and/or the vulnerability of those exposed.
Exogenous change	Changes that cannot be significantly influenced by FRM policy. Examples include climate change and population growth.
Exposure	Exposure is used here to refer to the number of people that may be flooded during a given flood event and thereby subject to potential loss of well-being.
Flood	The temporary covering by water of land not normally covered by water. Coastal, fluvial and surface water flood sources are considered here. *Note:* Groundwater flooding is not considered.
Floodplain	The area of land where water flows in time of flood (arising from any source of flooding, coastal, fluvial or surface water) or would flow but for the presence of structures and other flood controls. The limits of floodplain are notionally infinite, and are therefore defined by the maximum flood extent resulting from a given

	return period storm. Here, for practical reasons, the floodplain is defined by the 1:1000-year return period in the absence of any defences that may exist.
Flood prone area	An area of land that could be flooded by any source of flooding (used here interchangeable with floodplain).
Flood risk	A combination of the probability of a flood and the associated harmful consequences.
Fluvial flooding	Flooding from a watercourse when water from an established river or drainage channel spills onto the floodplain.
Groundwater flooding	Flooding from the ground caused by high groundwater levels in aquifers. *Note:* Groundwater flooding is not considered.
Household	'One person living alone, or a group of people (not necessarily related) living at the same address who share cooking facilities and share a living room or sitting room or dining area. This includes sheltered accommodation units in an establishment where 50 per cent or more have their own kitchens (irrespective of whether there are other communal facilities) and all people living in caravans on any type of site that is their usual residence (this will include anyone who has no other usual residence' elsewhere in the UK). (Census, 2011).
Index of Multiple Deprivations (IMD)	The official measure of relative deprivation for neighbourhoods in England.
Lower Super Output Area	Compact areas with around 1,000-3,000 residents with similar social characteristics. LSOAs are used in England and Wales for reporting social statistics, for example the census[11].
Neighbourhood	Defined here as a spatial unit covering Lower Super Output Areas (LSOAs) in England and Wales, Data Zone (DZs) in Scotland and Super Output Areas (SOAs) in Northern Ireland.
Neighbourhood Flood Vulnerability Index (NFVI)	Defined here based on a series of indicators that provide insight into the inherent social characteristics of a neighbourhood that make a community more or less vulnerable to a loss of well-being should a flood occur.
Receptor	The entity that may be harmed by a flood. For example, in the event of heavy rainfall (the source), flood water may propagate across the floodplain (the pathway) and inundate housing/householders (the receptor) that may suffer material damage (the harm or consequence).
Relative Economic Pain	A new metric proposed here that reflects the ratio of the uninsured loss to income. The REP is calculated as (1- insurance penetration) x Expected Annual Damages (direct residential) per household within the floodplain / Average Income per household within the neighbourhood.
Return period	A statistical measure denoting the average recurrence interval in time that an event (*e.g.* an in-river water level) of a given magnitude equalled or exceeded (when considered over an extended period). While it is true that a 1 in 10-year event will, on average, be exceeded once within any 10-year period, this does not imply that it will not reoccur for ten years. The chance of encountering or exceeding such an event in the next 10 years is approximately 65% - the so-called encounter probability (see for example Sayers, 2015).
Residential property	As defined by the national property datasets from England, Wales, Scotland and Northern Ireland and used here to establish the presence of a single household.

[11] http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/super-output-areas--soas-/index.html Accessed Oct 2016

Residual (flood) risk	The risk that remains after accounting for the performance of all FRM actions (*i.e.* measures to reduce the chance of flooding and those taken to reduce exposure or vulnerability).
Resilience	The ability of an individual, community, city or nation to resist, absorb or recover from a shock (*e.g.* an extreme flood), and/or successfully adapt to adversity or transform in response to changing conditions (*e.g.* climate change, economy turn down) in a timely and efficient manner to sustain functions and livelihoods. See Chapter 2 for further discussion.
Risk	The combination of the chance of an event (*e.g.* a flood), with the impact that the event would cause if it occurred. Risk therefore has two components - the chance (or probability) of an event occurring and the impact (or consequence) associated with that event.
Social Flood Risk Index (SFRI)	Defined here as the product of Neighbourhood Flood Vulnerability Index (defined previously) weighted by a measure of the flood exposure. See Chapter 3 for further discussion.
Social Flood Risk Index (SFRI): Individual	As the SFRI, but normalised by population.
Super Output Area (SOA)	Compact areas with similar social characteristics used in Northern Ireland for reporting social statistics, for example the census. These contain on average approximately 800 households and a population of 2,000.
Surface water flooding	Flooding directly from a rainfall event prior to the generated run-off reaching an established river or drainage channel (also called pluvial flooding).
Susceptibility (to loss of well-being)	A dimension of vulnerability which reflects the characteristics of an individual (namely age and health status), which increase the likelihood that a flood event will have a negative impact on well-being.
Vulnerability (social flood) / social vulnerability	In context of this study, the inherent characteristics of individuals and communities in which they live that influence the potential to experience loss of well-being when exposed to a flood and over which flood management policy has limited or no control (although other policies may be relevant *e.g.* housing or welfare policies)
Z-score	A statistical measurement of how an individual score relates to the mean (average value) in a group of scores. A Z-score of 0 means the score is the same as the mean (average value). A Z-score can be positive or negative, indicating whether it is above or below the mean and by how many standard deviations.

6.2 Abbreviations

AEP	Annual Exceedance Probability
ASC	Adaptation Sub-Committee
BCR	Benefit Cost Ratio
CA	Calculation Area
CCA	Census Calculation Area
CCC	Committee on Climate Change
CCRA	Climate Change Risk Assessment
CDF	Comparative Disadvantage Factor
CLA	Current Level of Adaptation
DCLG	Department for Communities and Local Government
Defra	Department of Food and Rural Affairs
DZ	Data Zone (census polygon used in Scotland)
EAD	Expected Annual Damages
EADi	Expected Annual Damages: Individual
EAP	Expected Annual number of People flooded
EAPi	Expected Annual number of People flooded: Individual
FDGiA	Flood Defence Grant-in-Aid (England)
FRM	Flood Risk Management
FFE	Future Flood Explorer (the analysis model used here)
GMT	Global Mean Temperature
GFD	Geographic Flood Disadvantage
iBCR	Incremental Benefit Cost Ratio
IMD	Index of Multiple Deprivation
JRF	Joseph Rowntree Foundation
LEP	Local Enterprise Partnerships
LSOA	Lower Super Output Area (census polygon used in England and Wales)
LTIS	Long Term Investment Scenarios
MSOA	Middle Layer Super Output Areas
NFVI	Neighbourhood Flood Vulnerability Index
ONS	Office of National Statistics
PEFf	Number of People Exposed to Frequent Flooding (1:75 years or more frequent, on average)
RBD	River Basin District
REP	Relative Economic Pain
SEPA	Scottish Environment Protection Agency
SFD	Systemic Flood Disadvantage
SFRI	Social Flood Risk Index
SOA	Super Output Area (census polygon used in Northern Ireland)
SoP	Standard of Protection
SPL	Sayers and Partners LLP
TCPA	Town and Country Planning Association

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7.0 APPENDICES

The following appendices (provided separately) accompany this report:

APPENDIX A: Data sources and resolution of the associated analysis

APPENDIX B: Neighbourhood flood vulnerability index

APPENDIX C: Exogenous change: Climate and population change

APPENDIX D: Endogenous change: Adaptation measures

APPENDIX E: Consultations Policy engagement and local case studies

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