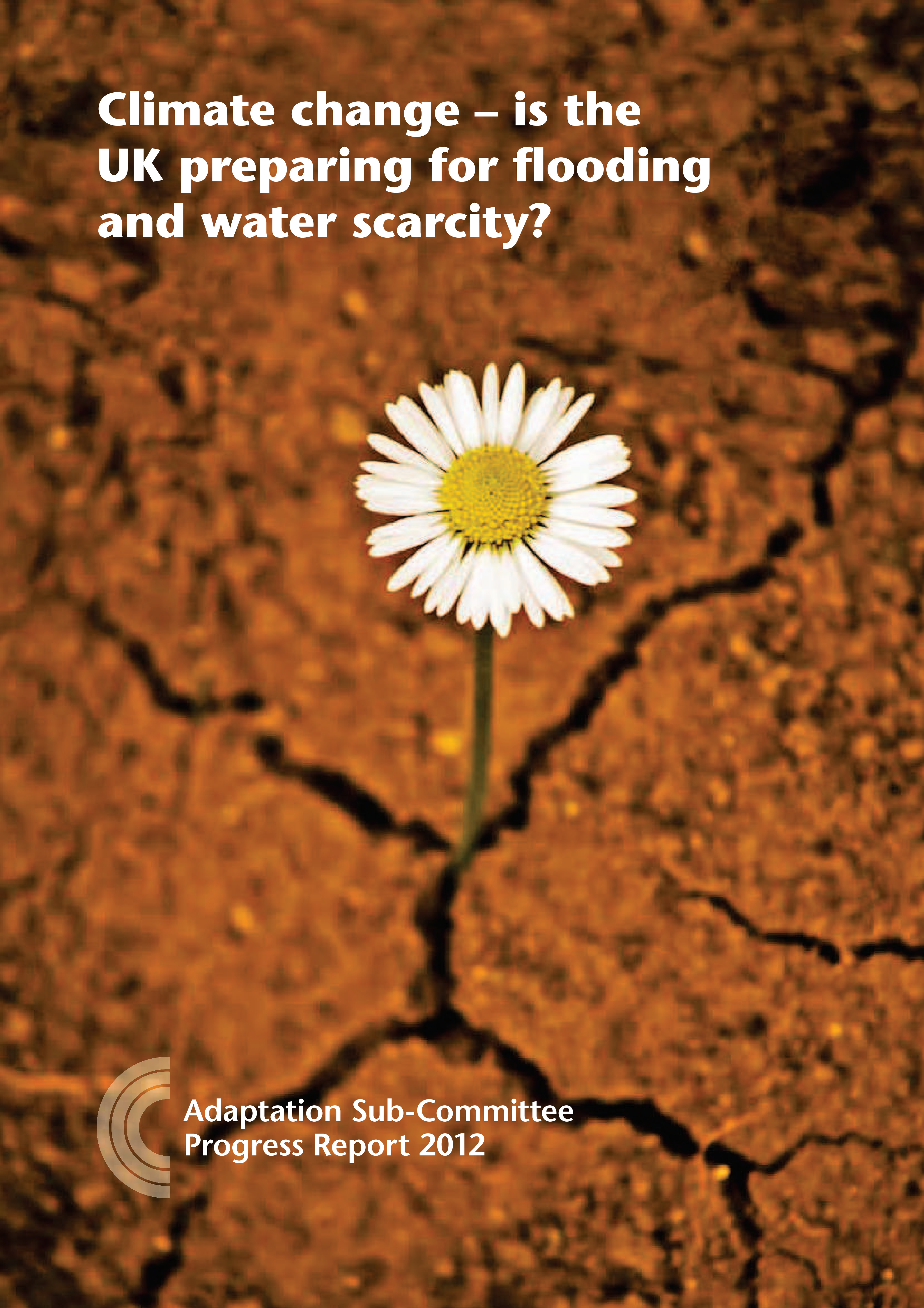
Climate change – is the UK preparing for flooding and water scarcity?



Adaptation Sub-Committee
Progress Report 2012

Contents

Foreword

During the first six months of 2012, the country suffered first from too little water, and then from too much water: drought followed by flooding. The year started with a second dry winter in a row. This together with an unusually hot and dry March caused drought conditions in many parts of England. Seven water companies imposed hose-pipe bans, affecting more than 20 million customers.

This was followed by the wettest spring (April – June) on record. Many parts of the country were affected by flash-flooding. Rivers burst their banks and roads turned to rivers as a result of surface runoff, after some areas saw a month's worth of rain in 24 hours. This led to serious flooding of at least 1,200 properties from Sussex in the south of the country to Cumbria, Lancashire and West Yorkshire further north. The news reports underlined the devastating impact of these floods on people's lives and livelihoods.

It is not possible to attribute current weather events to climate change. However, the latest climate models tell us that extremes of the kind seen this year are likely to become more common in the future. The Government's Climate Change Risk Assessment, published earlier this year, identified increasing frequency of floods and increased pressure on water resources as two of the most significant climate risks facing the country now and in the future.

The Adaptation Sub-Committee has analysed how well the country is preparing for these key climate risks. In this report we use national indicators to show that the country has become more exposed to future flood risk through continued development in the floodplain and paving over of front gardens. At the same time, climate change combined with population growth is likely to increase the risk of water scarcity.

The actions that the Environment Agency, water companies and local authorities are taking go some way to addressing these risks, for example through investment in flood defences and water supply infrastructure, and in the design of new development. Current efforts to manage flood risk, if they were to continue, would not keep pace with the combined effects of climate change and economic development in the future. Stronger policies may be required to sustain a continued, but necessary, reduction in household water use.

The Government's National Adaptation Programme provides an important step towards ensuring that the country is preparing well for climate change. The Programme can do this by encouraging greater action by households and businesses, for example through faster rollout of water meters to provide a clear incentive to save water. The Programme can also ensure that those making strategic decisions, such as local authority planners and water companies, build climate change into their long-term plans in a robust and transparent way.

John Krebs

Lord John Krebs Kt FRS

Acknowledgements

The Adaptation Sub-Committee would like to thank:

The core team that prepared the analysis for this report: this team was led by Sebastian Catovsky and included Emily Beynon, Kathryn Humphrey, Clare Pinder, Kiran Sura, David Thompson, Lola Vallejo and Adam Ward.

Other members of the secretariat that contributed to the report: Tara Barker, Sharon Gaisie, David Kennedy, Jo McMenamin and Laura McNaught.

Former members of the Adaptation Sub-Committee: Dr Andrew Dlugolecki and Prof Tim Palmer.

Organisations and individuals that carried out research for this report: AEA Technology, Arup, HR Wallingford, Paul Watkiss Associates, Royal Haskoning, Alistair Hunt and Prof Rob Wilby.

Funding partners in our research: Environment Agency.

Peer reviewers of our research and analysis: Peter Bide (Independent Consultant), Dr Jeremy Carter (University of Manchester), Ian Gilder (Environmental Resources Management), Prof Robert Gurney (University of Reading), Dr Sarah Lindley (University of Manchester), Heather McGray (World Resources Institute), Prof Jean Palutikof (National Climate Change Adaptation Research Facility, Australia), Prof Gary Pender (Heriot-Watt University), Dr Nicola Ranger (Grantham Research Institute on Climate Change and the Environment, London School of Economics), Prof Edmund Penning-Rowsell (University of Middlesex), Dr Mark Stafford Smith (CSIRO Climate Adaptation Flagship, Australia) and Dr Steven Wade (HR Wallingford).

Organisations that have provided feedback on our research and analysis: Anglian Water, Association of British Insurers, Atkins, House Builders Federation, Department for Communities and Local Government, Department of Energy and Climate Change, Department for the Environment, Food and Rural Affairs, Dwr Cymru, Environment Agency, Institute of Civil Engineers, Local Government Association, Met Office, Northumbrian Water, Ofwat, Planning Officers Society, Royal Society for Protection of Birds, Severn Trent Water, Thames Water, United Utilities, Waterwise, Wessex Water, WWF and Yorkshire Water.

The Adaptation Sub-Committee

Lord John Krebs, Chair

Professor Lord Krebs Kt FRS is currently Principal of Jesus College Oxford. Previously, he held posts at the University of British Columbia, the University of Wales, and Oxford, where he was lecturer in Zoology, 1976-88, and Royal Society Research Professor, 1988-2005. From 1994-1999, he was Chief Executive of the Natural Environment Research Council and, from 2000-2005, Chairman of the Food Standards Agency. He is a member of the U.S. National Academy of Sciences. He is chairman of the House of Lords Science & Technology Select Committee.

Professor Samuel Fankhauser

Professor Samuel Fankhauser is acting Co-Director of the Grantham Research Institute on Climate Change at the London School of Economics and a Director at Vivid Economics. He is a former Deputy Chief Economist of the European Bank for Reconstruction and Development.

Professor Jim Hall

Professor Jim Hall FREng is Director of the Environmental Change Institute at Oxford University where he is Professor of Climate and Environmental Risks. A chartered engineer by background, Prof Hall has pioneered the use of probabilistic methods in flood risk assessment and water resource systems. He is Associate Editor of the Journal of Flood Risk Management and Fellow of the Royal Statistical Society.

Professor Anne Johnson

Professor Anne Johnson is a public health doctor. She is Professor of Infectious Disease Epidemiology and Co-Director of the Institute for Global Health at University College London (UCL). She was a member of the UCL/Lancet Commission report on managing the health effects of climate change. She was previously Chair of the Medical Research Council Population Health Sciences Group. She became a Wellcome Trust governor in 2011.

Professor Martin Parry

Professor Martin Parry is a visiting Professor at Imperial College and was Co-Chair of Working of Group II (Impacts, Adaptation and Vulnerability) of the Intergovernmental Panel on Climate Change's (IPCC) 2007 Assessment Report. He was chairman of the UK Climate Change Impacts Review Group, and a coordinating lead author in the IPCC first, second and third assessments. He has worked at the Universities of Oxford, University College London, Birmingham and University of East Anglia.

Sir Graham Wynne

Sir Graham Wynne is a former Chief Executive and Director of Conservation of the RSPB. He is currently a Special Adviser to the Prince of Wales' International Sustainability Unit (ISU), Chair of the Harapan Rainforest Foundation in Indonesia, and a Trustee of Green Alliance. He was a member of the Policy Commission on the Future of Farming and Food, the Sustainable Development Commission, the Foresight Land Use Futures Group and England's Wildlife Network Review Panel. His early career was in urban planning and inner city regeneration.

Executive Summary

The Adaptation Sub-Committee (ASC) has a statutory duty to report regularly to Parliament on the UK Government's progress in delivering its adaptation programme. In our first two reports, we developed and piloted a toolkit to assess progress in preparing for climate change, including use of adaptation indicators.

In this report we apply the toolkit at a national level to two of the largest risks to emerge from the UK's first Climate Change Risk Assessment (CCRA): flooding and water scarcity.[1] Many of the effects of climate change in the UK will be felt through changes in the water cycle. Climate change is likely to increase the frequency and severity of floods and droughts. Without action to prepare, this could lead to increasing costs and unnecessary damage and disruption.

Key messages

- **Exposure to flooding.** The Government and local authorities should ensure more robust and transparent implementation of planning policy in relation to development in areas at risk of flooding.
  - Development in the floodplain grew at a faster rate than elsewhere in England over the past ten years.
  - While much of this development is well protected from flooding by the presence of community defences, one in five properties built in the floodplain were in areas of significant flood risk. Design features at the site level should have helped to make this development more resilient to flooding.
  - The current "build and protect" approach to floodplain development will leave a legacy of rising costs of protection and flood damage in the face of climate change. These long-term costs may outweigh the benefits of development in some locations.
- **Protecting existing properties from flooding.** The Government should support sustained and increased investment in flood defences from public or private sources; or in the absence of this identify ways to manage the social and economic consequences of more frequent flooding.
  - Current levels of investment in flood defences and uptake rates of protection measures for individual properties will not keep pace with the increasing risks of flooding. Climate change could almost double the number of properties at significant risk of flooding by 2035 unless there is additional action.

1 Our statutory remit under the UK Climate Change Act is to assess progress two years after publication of the UK Government's adaptation programme. Because this programme covers UK-wide issues for reserved matters and England only issues for devolved matters, such as floods and water policy, our assessment toolkit develops specific indicators for England on floods and water. The toolkit is being developed in such a way that it has UK-wide applicability and could be used for the adaptation programmes in the devolved administrations if so requested.

- By increasing investment in both flood defences and property protection measures, the number of properties at significant flood risk could be halved from current levels by 2035 accounting for climate change. The potential impact of climate change means that increased investment could lead to a four-fold reduction in risk when compared with a scenario of no additional action.

- **Future water scarcity.** The Government and water companies should take further steps to increase efficiency in water use, including through water metering and pricing. Increased uptake of meters will be particularly important in locations with current and future risks of supply-demand deficits.
  - More efficient use of water is a powerful way to cope with future deficits in water supply. Improving water efficiency has a triple benefit: (i) it saves consumers money on water and energy use; (ii) it defers the need for costly investments in new supply infrastructure; and (iii) it limits damage to the natural environment arising from over-abstraction of water.
  - On current trends average water consumption could be reduced from 145 litres per person per day to 130 litres or less per person per day by 2035.
  - This is readily achievable by uptake of household efficiency measures, wider use of water metering and raising awareness. Reducing average consumption by 15 litres per day goes further than current water company plans and could halve the projected deficit from climate change and population growth.

Flooding: assessing preparedness for a changing climate

Scale of flood risk today and in the future

- Around one in seven properties (3.6 million homes and businesses) currently face some form of flood risk. Under current standards of protection, insured losses from flooding and other severe weather are modest, on average costing around £1.5 billion or 0.1% of GDP each year. Such events also cause substantial personal stress and hardship for affected households.
- Total costs of individual weather events can be much higher through disruption of essential services (power, water, and ICT) and business supply chains. Around 10% of critical infrastructure (power stations, water treatment works) and emergency services (fire, police and ambulance stations) are currently located in the floodplain.

- Climate change could increase the number of properties in England with a significant chance of flooding[2] from rivers or the sea: from 330,000 now to between 630,000 and 1.2 million by the 2080s, according to the climate change scenarios used in the CCRA. The annual expected costs of flooding could increase from £1 billion now to between £1.8 billion and £5.6 billion (present day prices) over the same time period. These estimates assume no further action to prepare, no population growth and no change in the property stock.

New development and land use planning

- Indicators show that development in the floodplain in England increased by 12% over the past ten years compared with a 7% increase outside the floodplain. Around 21,000 homes and business premises (13% of all new development) have been built in the floodplain every year over this time period. Since 2008 there has been a relative decrease in the rate of development in coastal areas.
- Planning policy ensures that this development is generally well protected from flooding. The majority of floodplain development proceeded in line with Environment Agency advice, because the developer incorporated adaptation features, such as raised ground and floor levels or safe evacuation routes.
- However, our analysis raises some questions about implementation of the policy.
  - While over 80% of floodplain development took place in locations well protected from flooding with community defences, one in five properties built in the floodplain were in areas of significant flood risk under today's climate.
  - In addition, the approval process is not sufficiently transparent or accountable. The Environment Agency only knew whether or not their advice had been followed in 65% of planning applications where they had objected.
  - Development in the floodplain may be a rational decision in cases where the wider social and economic benefits outweigh the flood risk, even when accounting for climate change. However, from a review of 42 of the most up to date local development plans we found mixed evidence on whether or not local authorities were transparently:
    - assessing the potential for accommodating growth elsewhere before deciding to allocate land for development in the floodplain; or
    - accounting for the long-term costs of flooding with climate change, both in terms of the increasing costs of flood damage and any additional costs of flood protection.

2 Throughout this report, we use the Environment Agency categories of flood risk. Properties with a "significant" risk of flooding are those with a greater than 1 in 75 year likelihood of flooding in any given year.

Protecting the existing property stock

- If current investment plans for flood defence continue into the future, the country will be faced with an increasing risk of flooding from climate change. Greater investment in flood defences, either from public or private sources, would help to stem this increasing risk.
  - Investment in flood defences has helped to reduce flood risk to 182,000 homes in the last three years and improved the condition of some defences.
  - Planned yearly spend on flood defences is lower for the current period (2011/12 – 2014/15) after taking into account the effect of inflation. This remains the case even allowing for additional spend generated from Environment Agency efficiency savings and contributions secured to date from local authorities and businesses.
  - The Environment Agency estimates that investment needs to increase by £20 million above inflation every year to keep risk levels constant in the face of climate change and deterioration of flood defence assets.
- Property-level protection measures, such as door guards and air-brick covers, could benefit properties in locations of lower population density where flood defences may not be cost-effective. However, uptake of such measures is around 20 – 35 times lower than the rate required to reach all 200,000 – 330,000 properties that could benefit within a meaningful timeframe (25 years).
- By 2035, the combined effect of increased investment in flood defences (£20 million per year on top of inflation) and faster uptake of property-level measures could reduce the number of properties at significant risk by half from current levels accounting for climate change. The potential impact of climate change means that increased investment could lead to a four-fold reduction in risk when compared with a scenario of no additional action.
- Managing water at the catchment scale to attenuate flood flows also plays an important role in adaptation to flood risk. The Committee's next progress report will look at this in more detail.

Managing surface water flows

- Surface water flooding in urban areas is already increasing as a result of paving over green spaces in towns and cities. It may increase further with more intense rainfall due to climate change. Despite the scale of the risk, knowledge of the impacts of climate change on surface water flooding remains poor.
- Indicators show that in towns and cities the proportion of gardens that have been paved over increased from 28% of total garden area in 2001 to 48% in 2011. Total garden area in towns and cities has remained roughly constant at around 340,000 hectares of the 1.3 million hectares of total urban extent in England.

- Our analysis identifies scope for greater use of sustainable drainage in new developments to slow down surface water flows in urban areas. By itself this is unlikely to be sufficient to stem the growing risk from surface water flooding. Using roads and paths as emergency flood channels can help keep surface water away from vulnerable people and property during extreme downpours.

Water scarcity: assessing preparedness for a changing climate

Risks of water scarcity now and in the future

- Over recent decades England has been affected by a drought every seven years on average. Security of supply has improved through continued investment by water companies. As a result, significant interruptions to public water supply from drought, such as those requiring the use of standpipes, are rare. Restrictions such as hosepipe bans and constraining the level of abstraction are more common. Current levels of abstraction are putting undue stress on the natural environment.
- Climate change is likely to alter annual and seasonal rainfall patterns, but the extent and timing of changes remain uncertain. Water companies estimate that without action to prepare nearly half of water resource zones could be at risk of deficit during a drought by the 2020s due to the combined effect of climate change and population growth. The CCRA suggests that the supply-demand deficit in the 2020s could range from negligible to 3 billion litres per day, with a central estimate of 1.2 billion litres per day (7% of existing supply).[3]
- In their latest plans water companies proposed measures to deal with around 1.4 billion litres of deficit by 2035. Just over half of their effort focussed on measures to improve supply, with the remainder of their effort split between reducing consumer demand or limiting leakage.

Reducing water use and limiting leakage losses

- Our analysis identifies scope for greater action to manage demand in the face of the likely deficit from climate change combined with population growth. Low-regret actions, such as increased household water efficiency and basic rainwater harvesting, provide benefits today and against any future deficit. These should intensify given the lead-times required for altering household fixtures and fittings and behaviour change of consumers in relation to water use.

3 This is for England and Wales combined and includes the effects of population growth as well as climate change.

- Managing demand has other co-benefits:
  - saving consumers money on water and energy use;
  - deferring the need for costly investments in new supply infrastructure; and
  - reducing over-abstraction of water from the natural environment.
- Indicators show that household use of water per person has declined since 2000. However, average water consumption in England, at 145 litres per day per person, remains one of the highest in north-western Europe.
- If the current trend were to continue, water use would be reduced to 130 litres per day per person by 2035. This could save around 700 million litres of water per day, according to the CCRA, dealing with around half the deficit in the 2020s. In comparison, the latest water company plans deliver savings of 440 million litres of water per day by 2035 from reductions in water use.
- A faster pace of reduction in water use could be readily achievable through sustained rollout of water metering, uptake of water efficiency measures and information campaigns. Previous ASC analysis suggests that reducing consumption to 115 litres per day per person could be achieved in a cost-effective way through uptake of water efficiency measures.
- Leakage increased slightly to an average of 22% of public water supply in 2010, mainly due to cold winters causing increases in pipe bursts. Water company estimates suggest that leakage could be reduced to 20% of current total public water supply with further investment over the next 25 years, saving a further 240 million litres of water per day. Taking into account the effects of climate change on the long-run value of water would make further leakage reductions cost-effective.

Water metering

- In order to put in place an effective system to manage demand, the price of water should reflect its availability and how much is used. Water metering will be a necessary component of any effective strategy for demand management.
- The number of households with water meters has increased by 2% per year in recent years, with 40% of households in England and Wales currently metered. If current trends were to continue, metering could reach 85% of households by 2035. However, a stronger policy framework may be required to sustain even this rate of rollout.
- A greater prevalence of metering in locations with higher risks of supply-demand deficits from climate change would provide the right incentive for achieving such reductions. At present, climate change is not taken into account in designating areas of water stress. This is a barrier to timely uptake of metering to deal with risks from climate change.

Improving water supplies

- Reducing water use by households and tackling leakage is unlikely to deal with all of the deficit expected in the future – for example the mid-range deficit expected in the 2020s (1.2 billion litres per day) or any plausible deficit in the 2050s (2.1 to 8.2 billion litres per day).
- The degree of risk that water companies and regulators choose to plan for – and conversely how much risk to accept – should determine the scale and timing of supply-side measures required. For example, water sharing could contribute around 100 – 300 Ml/day to reducing the supply-demand deficit, according to the CCRA analysis. The water company price review in 2014 provides an important opportunity to factor in uncertainties in future climate transparently into long-term plans.

Abstraction reforms

- The Government's Water White Paper proposes reform of abstraction licensing by the 2020s to establish a stronger market framework to ensure efficient allocation of water between all users, including power stations, heavy industry and agriculture.
- In the meantime there is a risk that policy decisions that are sensitive to water availability (such as in energy and agriculture) do not take full account of future water availability or the underlying requirement to support the natural environment. Taking climate risks into account will avoid lock-in to development pathways that lead to unsustainable levels of abstraction in the future.

Advice on the UK Government's adaptation programme

- The National Adaptation Programme is an important step for the Government to outline its long-term approach to preparing for climate change. The programme should take a systematic and proportionate approach to addressing priority climate risks and assess existing and proposed policies against this. An important part of this will be to examine whether current and planned actions of public agencies, local authorities, businesses and households are sufficient to address the risks of climate change, or whether changes to the policy framework are required to enable and encourage action.
- The programme should set out tangible steps to remove outstanding barriers to adaptation action, in order to:
  - increase the uptake of low-regret adaptation measures, such as water efficient fixtures and fittings, sustainable drainage systems and property-level flood protection; and
  - ensure that those taking decisions with long-term or systemic consequences, such as local authorities and infrastructure providers, take account of climate change in a way that is transparent and acknowledges the uncertainties.

- Box ES.1 sets out some specific advice on tackling barriers to action based on the analysis set out in this report.
- The programme should establish an approach to monitoring the effectiveness of policies to address climate risks, and look to improve the evidence base on the impacts of climate change.

Box ES.1: ASC advice for the National Adaptation Programme in relation to flooding and water scarcity.

Flooding

- Ensure robust and transparent implementation of planning policy in flood risk areas, so that local authorities consistently and explicitly take into account the long-term risks of flooding when deciding the location of new development.
- Support sustained and increased investment in flood defences from public or private sources, given that current spending plans will not keep pace with increasing climate risk; or in the absence of this, identify ways to manage the social and economic consequences of more frequent flooding.
- Enable greater uptake of property-level measures to protect against floods and encourage greater use of sustainable drainage systems to manage surface water.

Water scarcity

- Take further steps to increase household efficiency in water use, including through water metering and pricing. This could include removing legal barriers to metering in areas with high risk of future deficit.
- Ensure that water companies are transparent about how the risks and uncertainties from climate change are factored into their long-term investment planning for future water resources.
- Ensure current policy decisions that affect future abstraction levels factor in the risks from climate change to avoid locking certain industries or regions of the country into unsustainable patterns of water abstraction.

Next steps

- Over the next two years, the ASC will apply its toolkit to other key climate risks and opportunities identified as priorities by the CCRA, including those affecting agriculture, forestry and the natural environment, impacts of heat and cold on human health and energy use, and changes to business supply chains and consumer demand. For each key risk or opportunity, we will aim to identify an appropriate set of indicators and use them to help assess how well each priority sector is preparing for climate change.
- This autumn we will also provide advice to inform early thinking on the second risk assessment, drawing on lessons from the first and from experience in other countries. This advice will also examine some of the important research gaps that need filling in the intervening years.

Chapter 1

Picture courtesy of Mike Page, Norfolk Skyview.

Chapter 1
Applying the ASC assessment toolkit

1.1 Aims of the report

This is the third report by the Adaptation Sub-Committee (ASC) to assess progress in adaptation to climate change in the UK. It follows publication of the UK Government's first Climate Change Risk Assessment (CCRA) in January 2012.[1] The CCRA identified some of the priority climate risks that the UK Government's forthcoming National Adaptation Programme needs to address. This report:

- applies the ASC toolkit to assess progress in adaptation for two of the major risks identified by the CCRA: flooding and water scarcity; and
- uses the findings of the ASC assessment to advise on the development of the UK National Adaptation Programme.

1.2 The ASC role

The ASC has a statutory role under the Climate Change Act to report to Parliament with an independent assessment of the UK Government's progress in implementing its National Adaptation Programme.[2] This programme should set out the Government's objectives and policies for adaptation, addressing the risks and opportunities identified by the CCRA.

In making an independent assessment of progress in its statutory report due in 2015, the Committee will have to consider whether or not:[3]

1. the objectives of the adaptation programme address the key climate change risks where further Government intervention is required;[4]
2. the policies set out meet the objectives of the programme by addressing outstanding barriers to adaptation and enabling action to prepare; and
3. the policies are being implemented.

1 HR Wallingford (2012a) for Defra.
2 UK National Adaptation Programme will cover England and reserved matters. The ASC also has a duty to report on progress in Wales, Scotland or Northern Ireland if requested to do so.
3 Under the Climate Change Act the Committee has a duty to report to Parliament on the Government's progress in delivering the programme in the second year after which it is published, and then every two years after that. The UK Government expects to publish its first National Adaptation Programme in 2013.
4 For some climate change risks identified in the CCRA, the Government may decide that existing policy mechanisms are sufficient or that they are likely to be addressed by the market (often described as 'autonomous adaptation'). Further policy intervention may not justified because the risks and their uncertainties are considered to be acceptable or the costs of addressing them considered to be too great.

1.3 The ASC assessment toolkit

Previous ASC reports identified the key components for assessing preparedness for climate change.[5] Drawing on this analysis and work by other countries on measuring progress, the ASC has developed an adaptation assessment toolkit.[6]

The ASC assessment toolkit has two main components (Figure 1.1):

1. **Monitoring changes in climate risks using indicators.** These fall into three broad categories:

   – **Indicators of risk**. These measure changes in society's exposure and vulnerability to weather events. They will be the result of changes in climate as well as in society, such as economic growth and demographic change.

   – **Indicators of adaptation action**. These aim to measure risk reduction rather than just the action itself, for example the reduction in household water consumption rather than the number of households that have installed water-efficient appliances.

   – **Indicators of climate impact.** These track the realised impacts of weather events on the economy, society and environment. The impacts are a net result of the risk factors and the effect of adaptation actions. Historic data on some climate impacts are already collected by certain organisations, but this monitoring is not in place across all sectors.[7]

Developing indicators requires locating appropriate and robust datasets that: (i) have a reliable time series, in order to distinguish long-term trends from year-to-year variability, and (ii) are spatially disaggregated, to identify hot-spots of risk and provide information relevant at the local, as well as the national, level. The ASC previously scoped the types of indicators and available data across the broad range of risks identified by the CCRA.[8]

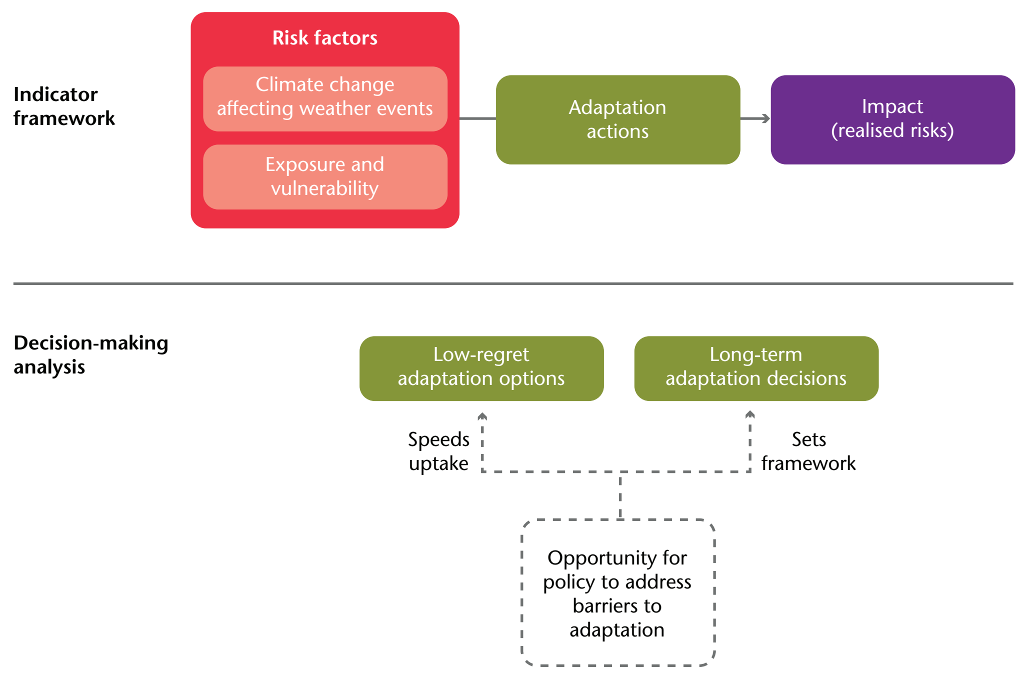
5 The ASC assessment toolkit is based around the concept of a 'preparedness ladder', introduced in ASC (2010), and built on in ASC (2011a). This characterises progress in adaptation, with the rungs of the ladder indicating increasing levels of adaptation activity.
6 AEA Technology (2012) for ASC.
7 For example, the Centre for Ecology and Hydrology and the Environment Agency already collect and publish indicators on climate impacts. The Environmental Agency is working with the Living With Environmental Change (LWEC) programme to develop climate change impacts 'scorecards' for water resources and terrestrial biodiversity.
8 AEA Technology (2011) for ASC.

2. **Evaluating preparedness for future climate**. This involves analysing decision-making to assess if the amount of adaptation occurring is sufficient to address climate risks, now and in the future. As acknowledged in previous ASC reports, early adaptation efforts to address priority climate risks should focus on the following:[9]

   – **Promote the uptake of low-regret adaptation options that deliver benefits whatever future climate unfolds.** Our analysis will identify low-regret adaptation options, estimate the current level of uptake and evaluate the potential scale of uptake that would be beneficial nationally given future climate risks. This report focuses on low-regret options for managing flooding and water scarcity, such as property-level flood protection and water efficiency measures.

   – **Ensure that decisions with long-lasting or systemic consequences take future climate change into account.** The benefits of these options depend more strongly on the future climate that unfolds. They involve managing large uncertainties and trade-offs between different objectives and over time. In these instances low-regret options are not always available. This report looks at how climate change is factored into strategic decisions such as the location and design of new development, or the long-term planning of water resources.

Figure 1.1: The ASC assessment toolkit



Notes: The definition of terms is set out in the Glossary, along with examples for the two climate risks examined in this report (flooding and water scarcity). The indicator framework was developed through work by AEA Technology (2011) for ASC and is aligned with the latest IPCC (2012) approach. The decision-making analysis component was developed through work by the Ranger et al. (2010) for ASC.

9 Based on the work of Ranger et al. (2010) for ASC.

In undertaking this analysis, the Committee will identify existing barriers to action, for example barriers that might be preventing households or businesses from installing low-regret measures, or preventing infrastructure providers from investing in adaptation. This analysis will highlight opportunities for Government policy to enable adaptation by key actors.

1.4 Applying the ASC assessment toolkit

The CCRA identified the major risks the UK faces from future climate change (Box 1.1). Over the next three years, the Committee will apply its toolkit to assess changes in exposure and vulnerability to each of the major climate risks and the uptake of actions to prepare. Doing this will help form a baseline against which progress in the implementation of the UK National Adaptation Programme can later be evaluated.[10] This report starts with two of the largest risks identified by the CCRA: flooding and water scarcity.

Chapter 2 applies the ASC toolkit to assess national progress in adaptation to flood risk in a changing climate, focussing on the impacts on properties and people. This builds on indicators we piloted last year for a sample of local authorities.

Chapter 3 updates the ASC's previous (2011) assessment of preparedness for water scarcity by reviewing the latest data on measures to address water supply and demand, and considering the impacts of new policy reforms over the last year.

Chapter 4 summarises the implications of the analysis for the development of the UK National Adaptation Programme. This chapter also sets out the Committee's future work to inform the preparation of the next CCRA and apply the assessment toolkit to the other main climate risks facing the UK.

10 This approach is in line with HM Treasury (2011) guidance for Government on policy evaluation (Magenta Book). To test the extent to which the policy was responsible for the change observed, it is necessary to first establish the 'counterfactual', namely what would have occurred in the absence of policy. This can then be compared with the realised outcome of the policy once implemented.

Box 1.1: UK Climate Change Risk Assessment 2012

The UK's first Climate Change Risk Assessment (CCRA) considered how climate change will affect important aspects of UK society, economy and the environment. It sets out projections of risk for over 100 threats and opportunities from climate change in the UK up to the end of the century. The CCRA allows comparison of a wide range of risks from across different sectors in a broadly consistent way.

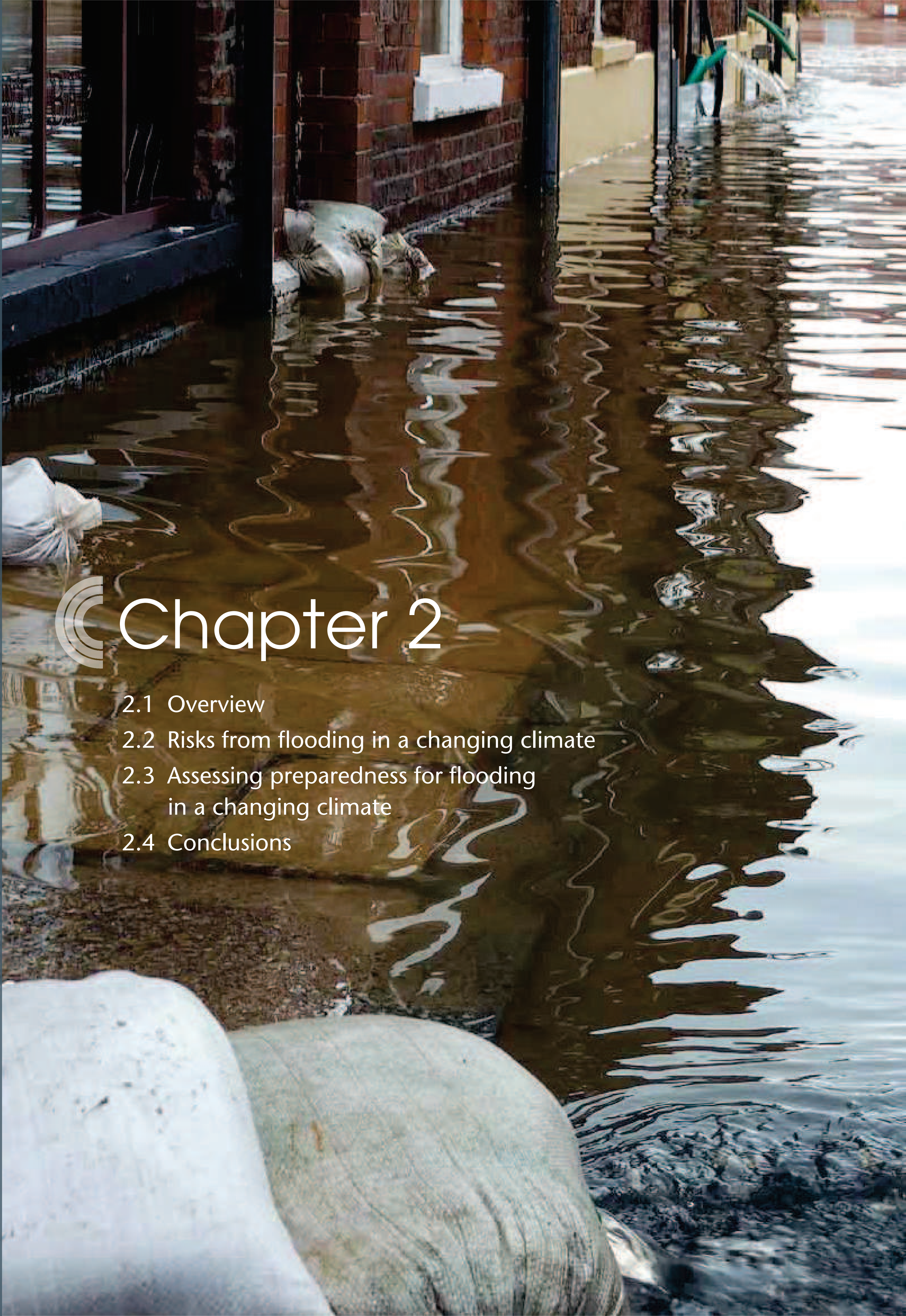
The CCRA assumed that no additional adaptation action is taken on top of current policies, in order to determine a baseline level of risk. As such, the projections consider the result of a 'do-nothing' scenario and are not predictions of actual future change. However, they highlight where additional action is likely to be required.

Some of the major findings from the CCRA:

- **Flood risk is projected to increase across the UK.** Expected annual damages increase from a current baseline of £1 billion to between £1.8 and £5.6 billion by the 2080s for England (not including the effects of projected population growth).
- **Risk of increased pressure on the country's water resources.** The current public water supply surplus of around 900 Ml/day on average is projected to turn into a water supply deficit of around 1250 Ml/day by the 2020s and 5500 Ml/day by the 2050s, with large regional variations.
- **Potential health risks related to hotter summer conditions, but potential benefits from milder winters.** There are projected to be between 580 to 5,900 additional premature deaths per year by the 2050s in hotter summer conditions. Conversely, between 3,900 and 24,000 premature deaths are projected to be avoided per year with milder winters by the 2050s.
- **Sensitive ecosystems that have already been degraded by human activity may be placed under increasing pressure due to climate change.** The main direct impacts relate to changes in the timing of life-cycle events, shifts in species distributions and ranges, and potential changes in hydrological conditions. While some species would benefit from these changes, many more would suffer.
- **Some climate changes projected for the UK provide opportunities to improve sustainable food and forestry production.** Some agri-businesses may be able to increase yields of certain types of crops and introduce new crops in some parts of the country, as long as pests and diseases are effectively controlled and sustainable supplies of water are available.

The UK is at risk of both water supply deficits (too little water) and greater risk of flooding (too much water). While this can seem counterintuitive, it arises due to changes in the timing and extent of when rain falls. Water supplies (groundwater and reservoirs) need sustained rainfall over a period of time, particularly in winter, to remain at required levels. The intense rain that can lead to flooding from rivers and surface water does not necessarily replenish these large stores, as the water may flow rapidly downstream before it is captured, and not fall in sufficient quantity over a prolonged period.

The CCRA focussed on risks and opportunities from climate change experienced in the UK, and did not attempt to quantify the risks to the UK from the impacts of climate change overseas. The Government's Foresight Group identified a number of additional risks to the UK at the international scale, including on investment flows, international supply chains and global health. A lack of evidence meant that these risks could not be quantified in the same way as the CCRA analysis, and this remains a key evidence gap. In Chapter 4, we point to some additional work to scope out approaches to filling some of these gaps in coverage in future risk assessments.



Chapter 2

2.1 Overview

2.2 Risks from flooding in a changing climate

2.3 Assessing preparedness for flooding in a changing climate

2.4 Conclusions

Chapter 2
Flooding: assessing preparedness for a changing climate

2.1 Overview

This chapter applies the ASC assessment toolkit to evaluate preparedness for the impacts of flooding on homes, businesses and people in England.[1] It also provides some evidence on the risks of coastal erosion. Flooding was one of the largest risks to emerge from the UK's first Climate Change Risk Assessment (CCRA).

In line with the ASC's approach set out in Chapter 1, this chapter:

- summarises the current scale of risk England faces from flooding and coastal erosion;
- summarises the future risk of flooding with climate change, based on the latest evidence from the CCRA;
- uses indicators to identify how exposure and vulnerability to flooding have changed in recent years and the amount of adaptation taking place;
- evaluates the decision-making of key organisations, such as local authorities and the Environment Agency; and
- reviews potential barriers to adaptation to flooding.

This analysis, along with the analysis on preparedness for water scarcity in Chapter 3, forms the basis for the Committee's advice on the preparation of the UK Government's National Adaptation Programme in Chapter 4.

1 The chapter focuses on flooding in England, in line with the ASC's statutory duty to report on progress of the UK Government's adaptation programme, which applies to England only for devolved issues like flood management.

2.2 Risks from flooding in a changing climate

Flooding is one of the largest current risks identified in the UK Government's National Risk Register, alongside pandemic human disease and terrorist attacks.[2] One in seven homes and businesses, which equates to 3.6 million properties, face some form of flood risk in England. Of these, 330,000 are located in areas that have a significant chance of river or coastal flooding, after accounting for the presence of flood defences. Box 2.1 defines the different categories of flood risk used in this report.

Flooding can cause loss of life and injury, damage to properties and infrastructure, and interruptions to essential services and business supply chains. Under current standards of flood protection, insured losses from flooding and other severe weather amount to around £1.5 billion on average each year (0.1% of national GDP).[3] Total costs can be much higher. For example, in 2007 widespread flooding in England affected 55,000 homes, killed 13 people as well as costing the economy £3.2 billion (2007 prices).[4] Such events also cause substantial personal stress and hardship for affected households, particularly for the more vulnerable in society. There is evidence that flooding can have a long-term impact on people's health and well-being.[5] Disruptions to the economy are also felt through interruptions to critical infrastructure (power stations, water treatment works) and emergency services (such as fire, police and ambulance stations). Around 10% of such critical infrastructure and emergency services are currently located in the floodplain (see page 51).

Climate change is likely to increase the chance of flooding and the rate of coastal erosion, although large uncertainties in the potential scale of the impact remain (Table 2.1). Current evidence suggests that increases in rainfall intensity and the frequency of high river flows are likely under a changing climate, leading to an increased risk of surface water and river flooding in the UK.[6] There is greater certainty that sea levels will rise, leading to an increased risk of coastal flooding and erosion. There remains considerable uncertainty on how climate change may affect storminess in the future, because it is difficult to predict the position and intensity of storm tracks.

2 Cabinet Office (2010).

3 Data from Association of British Insurers http://www.abi.org.uk [accessed June 2012]. The financial cost of a coastal tidal surge is estimated to be between £2.5 billion and £6.2 billion (Association of British Insurers 2006).

4 Environment Agency (2009b).

5 The CCRA refers to studies that have found the effects of flooding on the mental health of some victims can be enduring and long-term, and that this burden adds significantly to the strain on medical services, as well as potentially undermining the capacity of health care systems to respond to emergencies. The CCRA estimates that currently in the region of 3,500 – 4,500 people in England and Wales suffer a mental health effect due to flooding each year.

6 The CCRA found that changes in peak flow varied from 'no change' to increases of 48% for the 2050s under a Medium emissions scenario and increases from 7% to 60% for the 2080s under the full range of emissions scenarios. These results were based on research by the Centre for Ecology and Hydrology (CEH) which used UKCP09 to estimate change in flood peaks with a return period of 2, 10, 20 and 50 years for one river catchment in each of the nine river basin districts in England and Wales. The CCRA translated the CEH peak flow results to changes in average flood frequency for each river basin district. The CCRA caveats that changes in individual catchments may be larger or smaller than the average for a river basin district, but that the approach taken was appropriate for a national-level risk assessment. If peak flow increases, floods of a given severity will become more frequent. For example flood frequency would increase to approximately twice its current level in the Thames river basin for the 2080s Medium emissions scenario.

Flood damages are expected to increase across the UK, according to the CCRA. The number of properties with a significant chance of river and coastal flooding in England is expected to increase from around 330,000 today to between 630,000 million and 1.2 million by the 2080s as a result of climate change alone. Damage costs are projected to follow a similar pattern, increasing from current levels of £1 billion per year to £1.8 – £5.6 billion per year (today's prices) by the 2080s.[7] The CCRA did not examine the implications of climate change for surface water flood risk in the future.[8] Other studies have estimated that flood damage from surface run-off could increase by between 60% and 220% over the next 50 years as a result of different rainfall patterns from climate change and continued urbanisation.[9]

Climate change is not the only factor changing the risk of flooding in the future. Risk can change either if the probability of an event occurring changes, or if the consequences of an event alter. Continuing to locate vulnerable assets in areas that are exposed to flooding will increase the consequences when a flood occurs, in terms of damages to people and property. Some studies have found that these social and economic factors could have a greater impact on flood risk than climate change over the coming decades.[10] The next section of this chapter explores the effect of both climate change and socio-economic factors on future flood risk, and efforts to manage this risk.

Box 2.1: Definitions of flood and coastal erosion risk

River and coastal flood risk. The Environment Agency's National Flood Risk Assessment (NaFRA) identifies land at risk from river and coastal flooding, when considering the presence and condition of flood defences. The data are expressed in terms of likelihood of the onset of inundation and are presented in three categories:

- **Significant:** greater than 1 in 75 chance in any given year.
- **Moderate:** 1 in 200 to 1 in 75 chance in any given year.
- **Low:** 1 in 1,000 to 1 in 200 chance in any given year.

Surface water flood risk. The Environment Agency has modelled areas that are susceptible to flooding from surface water under two storm likelihoods; 1 in 30 and 1 in 200 chance of occurring in any year.

Sewer flood risk. Ofwat identifies three risk categories for sewer flooding: 2 in 10 chance, 1 in 10 chance and 1 in 20 chance in any given year.

Coastal erosion risk. The National Coastal Erosion Risk Mapping data, published by the Environment Agency, estimate zones of land that may be subjected to coastal erosion between the present day, the 2020s, 2050s and 2100s. The data are expressed probabilistically, via upper bound, lower bound and best estimates. The data provide the rates for all erodible coastline for a theoretically undefended situation known as 'no active intervention' and for the shoreline management plan policy that is expected to be in place at the time of the future predicted rate.

7 These figures do not include population growth or any additional adaptation action. The range represents low and high climate scenarios from UKCP09.
8 This is highlighted as major evidence gap in the CCRA, which recommends that there is an urgent need to develop projections of future surface water flood risk for the next assessment in 2017.
9 Reviewed in Department for Environment Food and Rural Affairs (2012a).
10 For example, Houston et al. (2011) for Joseph Rowntree Foundation, Ofwat (2011a) and Eigenbrod et al. (2011).

Table 2.1: Comparison of the scale of a range of severe weather risks and the effects of climate change in England

	Current risk			Future risk		
Climate Hazard	**Number of properties at risk**	**Expected annual damages to properties**[11]	**Average insured losses to properties (all UK)**[12]	**Climate change effect**	**Level of confidence**	**Impact of climate change**
River flooding	1.2 million (5% of stock in England) Significant risk: 230,000[13]	£690 million	£350 million (all flooding types)	Increase in peak river flows (7 – 60% by 2080s)	Medium	Increase in properties at significant risk, from 230,000 today to between 320,000 and 580,000 in 2080s purely due to climate change. With population growth this could increase to between 350,000 and 1,100,000.[14] Increase in expected annual damages from £0.7 billion today to between £0.9 billion and £6.9 billion by 2080s (2011 prices).
Coastal flooding	1 million (4% of stock in England) Significant risk: 100,000[15]	£310 million		Sea level rise (13 – 76cm by 2080s) Storm surges	High Low	Increase in properties at significant risk, from 100,000 today to between 310,000 and 570,000 in 2080s purely due to climate change. With population growth this could increase to between 330,000 and 840,000. [16] Increase in expected annual damages from £0.3 billion today to between £1 billion and £3.7 billion by 2080s (2011 prices).
Surface water flooding	1.9 million[17] (8% of stock in England) Of these, 50,000 are at 1 in 30 annual chance or greater	£320 million[18]		Increase in rainfall intensity (15 – 30% in annual maximum daily rainfall by 2080s)	Medium-High	Not estimated by CCRA. Defra estimate increase in expected annual damages from £320 million to between £510 million and £1 billion over the next 50 years.[19]
Sewer flooding	4,700 at 1 in 10 annual chance (<0.1% of stock in England)	£16 million[20]		Increase in rainfall intensity	Medium-High	Not estimated by CCRA. Ofwat estimate properties at 1 in 10 annual chance could increase from 4,700 today to between 4,700 and 8,100 the 2040s purely due to climate change. With population growth and urban creep, this could increase to between 5,500 and 8,900.[21]

Table 2.1: Comparison of the scale of a range of severe weather risks and the effects of climate change in England

	Current risk			Future risk		
Climate Hazard	Number of properties at risk	Expected annual damages to properties[11]	Average insured losses to properties (all UK)[12]	Climate change effect	Level of confidence	Impact of climate change
Coastal erosion	61,000[22] (0.3% of stock in England)	£17 million[23]	Insurers do not cover coastal erosion	Sea level rise Storm surges	High Low	Not estimated by the CCRA. Foresight estimate expected annual damages could increase from £17 million to between £55 million and £150 million by 2080 depending on the social scenario.[24]
Storms and gales	All properties are potentially at risk	Not estimated	£460 million	Change in number and severity of storms	Low	Not estimated by the CCRA.
Subsidence	30,000 properties per year at risk	Not estimated	£290 million	Shrink-swell in clay soils	Medium	Increase in properties at significant risk, from 30,000 today to between 28,000 and 40,000 in 2080s purely due to climate change.[25]

11 Expected annual damages are the estimated average economic cost per year of damage from the weather hazard. The costs will not be evenly distributed over years.
12 Figures are averages of UK-wide insured damages 2000 – 2011 in 2011 prices. For household claims, Association of British Insurers report separate categories for 'flood' and 'storm', although damages categorised as 'storm' can include damages from flooding following a storm event. Commercial claims are not split by peril, so have been apportioned between flood and storm in the same proportion as households. Commercial claims also include costs of business interruption.
13 HR Wallingford (2012d) for ASC. Note that the CCRA reports a higher figure of 340,000 properties. The data that underpin the CCRA (the Environment Agency's National Receptor Database) includes 5 million more commercial properties than the dataset used in our assessment (Ordnance Survey's MasterMap Property Layer 2). The National Receptor Database includes `properties' such as residential outbuildings that are unlikely to suffer substantial damages from flooding, which Property Layer 2 excludes.
14 Climate change figures taken from HR Wallingford (2012b) for Department for Environment, Food and Rural Affairs, and apportioned according to results of HR Wallingford (2012d) for ASC. See Footnote 13 for details.
15 HR Wallingford (2012d) for ASC. Note that the CCRA has a higher figure of 146,000 properties (explained in Footnote 13).
16 Climate change figures taken from HR Wallingford (2012b) for Department for Environment, Food and Rural Affairs, and apportioned according to results of HR Wallingford (2012d) for ASC. See Footnote 13 for details.
17 HR Wallingford (2012d) for ASC. Note that the CCRA has a higher figure of 4.2 million (explained in Footnote 13). Defined as a 1 in 200 annual chance 'shallow' (>0.1m depth) flood event. Of this total, 278,000 are also located within the river or coastal floodplain.
18 Evans, E., et al. (2004), updated for 2011 prices.
19 Reviewed in Department for Environment Food and Rural Affairs (2012a). Defra report a potential increase of 60% to 220%. We have applied this to the baseline of £320 million set out in Evans et al. (2004) (updated for 2011 prices).
20 Figures based on Evans, E., et al. (2004) updated to account for the reduction in the number of properties at risk since 2004, and in 2011 prices.
21 Ofwat (2011a).
22 Defined as houses located on erodible coastlines that are predicted to be at risk within the next 100 years under a central scenario.
23 Figures from Evans et al. (2004) updated for 2011 prices.
24 Figures from Evans et al. (2004) updated for 2011 prices.
25 HR Wallingford (2012b) for Department for Environment Food and Rural Affairs.

2.3 Assessing preparedness for flooding in a changing climate

This section uses indicators to identify how exposure and vulnerability to flooding have changed in recent years and the amount of adaptation occurring. It then evaluates the decision-making of key organisations, such as local authorities and the Environment Agency, with respect to adaptation.

The analysis focuses on a number of key adaptation measures to manage long-term flood risk in a changing climate, namely:

- the location and design of new development;
- actions to protect existing properties from flooding;
- measures for managing surface water flow in urban areas; and
- emergency planning and response measures.

The Committee's next progress report in 2013 will assess the contribution of non-structural, catchment-scale approaches to managing flood risk.[26]

The full set of indicators used is set out in the Annex to this report and in more detail in the accompanying technical report.[27]

Location and design of new development

Decisions concerning the location and design of new development are important for adaptation to flood risk. Land use planning decisions can reduce exposure to current and future flood risk by avoiding inappropriate development within the floodplain and other areas at risk from flooding and coastal erosion. Where development in flood prone areas is considered necessary, the land use planning system can potentially reduce risk by requiring it to be designed in a way that minimises damages should flooding occur, and does not increase risk elsewhere. This is, in essence, the Government's policy on flood risk and development, as set out in the National Planning Policy Framework.[28]

This section starts by using indicators to monitor the amount and type of development in areas of likely flooding and coastal erosion over the past ten years and the uptake of measures to protect this development from flood risk.[29] It then evaluates preparedness for future climate by assessing how local authorities take account of flood risk when making strategic decisions on new development and the engagement of the Environment Agency in advising on flood risk.

26 Including measures such as working with natural processes, providing upstream storage and managing water flow.
27 HR Wallingford (2012d) for ASC.
28 Department of Communities and Local Government (2012). Planning policy requires local authorities to apply a sequential, risk-based approach to the location of development to avoid where possible flood risk to people and property and manage any residual risk, taking account of the impacts of climate change. The aim of the sequential test is to steer new development to areas with the lowest probability of flooding. Development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower probability of flooding.
29 Our analysis has focussed on the development of new properties rather than new infrastructure due to data limitations.

Identifying trends in exposure: rate of development in flood risk areas

The river and coastal floodplain[30] has been populated for centuries. The floodplain makes up 12% of England's total land area and contains 8% of all properties, including many of England's major cities, ports and towns.

Development in the floodplain has continued over the last ten years. While the majority (87%) of all new development in England occurs outside the floodplain,[31] the rate of development in the floodplain between 2001 and 2011 was higher (12%) than outside the floodplain (7%) (Figure 2.1). There have been some changes in the annual rate of development since 2008:

- the rate has declined slightly in the river floodplain, in line with the national fall in the rate of development due to the recession;
- the decline in the rate has been more rapid in the coastal floodplain, although it still remains above the national average (0.8% per year versus 0.6% per year); and
- there has been a noticeable decrease in the rate of development behind eroding coastlines, which is now well below the national average.

Most floodplain development has been within built-up areas that are already protected by flood defences. Just over 80% of development in the floodplain since 2001 has been in locations where the current chance of flooding is low or moderate, either due to the presence of existing flood defences or because of floodplain topography (Figure 2.2). In our sample of 42 local authority development plans, 70% of allocations in the floodplain were on previously developed ('brownfield') land within existing built-up areas.[32]

Continued development in protected parts of the floodplain increases the total value of the assets located behind the defences. This in turn makes it more cost-beneficial to invest in flood defences.[33] However, this can act to increase the consequences of flooding (in terms of loss of life and costs from damages and disruption) in the event of these defences being over-topped or breached. Such activity also locks in a long-term commitment to flood defence, meaning that higher and stronger defences will be required when existing defences reach the end of their functional life. This phenomenon has been recognised for a number of years as the 'escalator effect'.[34]

Just under a fifth (19%) of floodplain development has been in areas that are exposed to a significant chance of flooding. These are areas of the floodplain that have a low level of flood protection, or do not have any defences at all. The area at significant chance of flooding is likely to increase further with climate change.

30 Defined as the area that would naturally be affected by flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas, taking no account of existing flood defences. This area could be flooded from the sea by a flood that has a 1 in 200 or greater chance of happening in any given year, or from a river by a flood that has a 1 in 100 or greater chance of happening in any given year. The Environment Agency's Flood Map also shows the additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to 1 in 1000 chance of occurring in any given year.

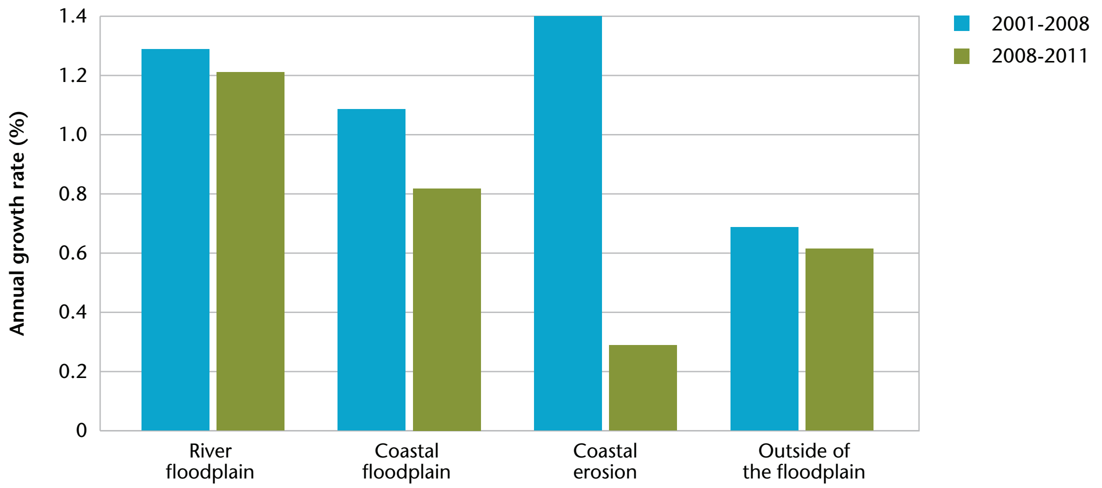
31 On average, 21,000 properties were built each year in the floodplain between 2001 and 2011. This equates to 13% of annual development in England. A further 11,000 properties per year were built in areas at risk of surface water flooding and 500 properties in areas at risk of coastal erosion.

32 Arup (2012) for ASC.

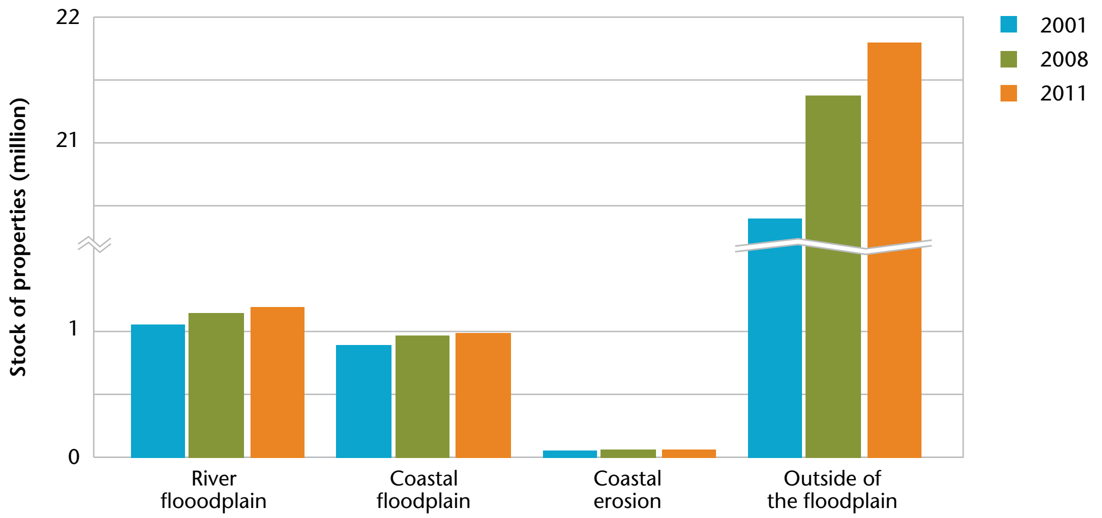
33 Under Defra's Partnership Funding formula introduced in May 2011, the amount of national funding provided towards projects does not take account of new development after January 2012, in order to avoid a possible incentive to develop in the floodplain to boost local flood defence funding levels.

34 See Parker (1995) and Hallegate (2011).

Figure 2.1: Development in the river and coastal floodplain and in areas at risk from coastal erosion, compared with all development in England outside the floodplain, shown as:
(a) annual growth rate for two time periods (2001-2008 and 2008-2011)

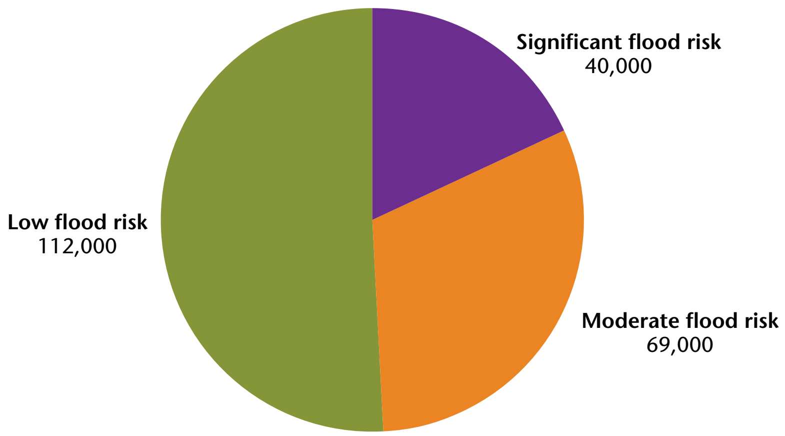


(b) stock of properties in each category (2001, 2008 and 2011)



Source: HR Wallingford (2012d) for ASC.
Notes: GIS mapping was used to identify the number of properties in three time periods (2001, 2008 and 2011) for all England and within the river and coastal floodplain (not accounting for the presence of flood defences) and within areas of eroding coastline. The datasets used were Ordnance Survey MasterMap Address Layer, Environment Agency's Flood Map, and the National Coastal Erosion Risk Map. OS MasterMap is updated every six weeks and ground-truthed through aerial photography and site visits. The Address Layer gives the grid reference, type, address and other parameters for around 27 million properties in Great Britain (but not Northern Ireland). The data include residential and non-residential properties and buildings without postal addresses, such as factories, halls and churches. The data include upper floor addresses, therefore a proportion of the observed development in flood risk areas will include properties such as high-rise flats and apartments that would not be at risk of damage from a flood event (although they would still suffer disruption). It was not possible to estimate the proportion of upper floor property in the above data. However, according to the National Receptor Database, there are around 25,000 registered upper floor residential properties in England.

Figure 2.2: Number of properties built in the floodplain over ten years (2001 to 2011), by flood risk category (defined in Box 2.1), accounting for the presence of flood defences



Source: HR Wallingford (2012d) for ASC.
Notes: GIS mapping was used to identify the number of properties in three time periods (2001, 2008 and 2011) in significant, moderate and low flood risk categories, accounting for the presence and condition of flood defences in 2011. This provides a slightly conservative estimate because, for example, a property built in a significant risk area that was subsequently protected by a defence and moved into the moderate risk category would be recorded as being built in a moderate risk area. These areas are identified by the Environment Agency's National Flood Risk Assessment (NaFRA) dataset.

Uptake of actions: minimising flood risk to and from new development

This section examines whether or not the development occurring in the floodplain is being designed in a way that will make it safe and resilient to flooding. Although there is some evidence of local authorities requiring safety and resilience measures for floodplain development (Box 2.2), there is no national dataset available to assess uptake. In our last report, we reviewed flood mitigation measures in a sample of development applications.[35] For this report, we assessed the outcomes of all planning applications that the Environment Agency advised on in relation to flood risk from 2005/06 to 2010/11.[36]

35 ASC (2011a).. We sampled major applications in areas of flood risk within two local authorities.
36 In future reports we may also be able to assess the outcomes of applications for Nationally Significant Infrastructure Projects (such as power stations, major transport projects and wind farms) that have been considered by the Planning Inspectorate to understand how they have accounted for climate change and incorporated resilience measures. To date only around 20 schemes have been through the application process.

Box 2.2: Two examples of managing flood risk in the re-development of the urban waterfront: Leeds and Southampton

The waterfronts in the cities of Leeds and Southampton have a long history of development and both City Councils have long-term aspirations for the regeneration of these areas.

As part of its regeneration scheme along the River Aire, Leeds City Council has delivered a number of developments with resilient design features, including requiring that the lowest floors are used as garages or other unoccupied use. The City Council is also taking forward a major Flood Alleviation Scheme for new and existing properties at risk of flooding along an 18km length of the waterfront.

Southampton City Council requires the incorporation of a suite of measures for development along the waterfront, such as appropriate resistance and resilience measures within buildings, raised floor levels in residential developments above the projected flood level over the lifetime of the development, and completion of a Site Flood Plan detailing how users of the site can avoid being placed in danger from flood hazards.

The City Council's long-term approach to the regeneration of the waterfront is to raise land along much of the lower lying areas of the tidal frontage, rather than rely on traditional flood defences, which could be unsustainable in the long-term if the projected sea level rise is realised. The Council aims to take a long-term managed adaptive approach to reducing tidal flood risk without creating an unsustainable legacy of development behind ever-increasing defences.

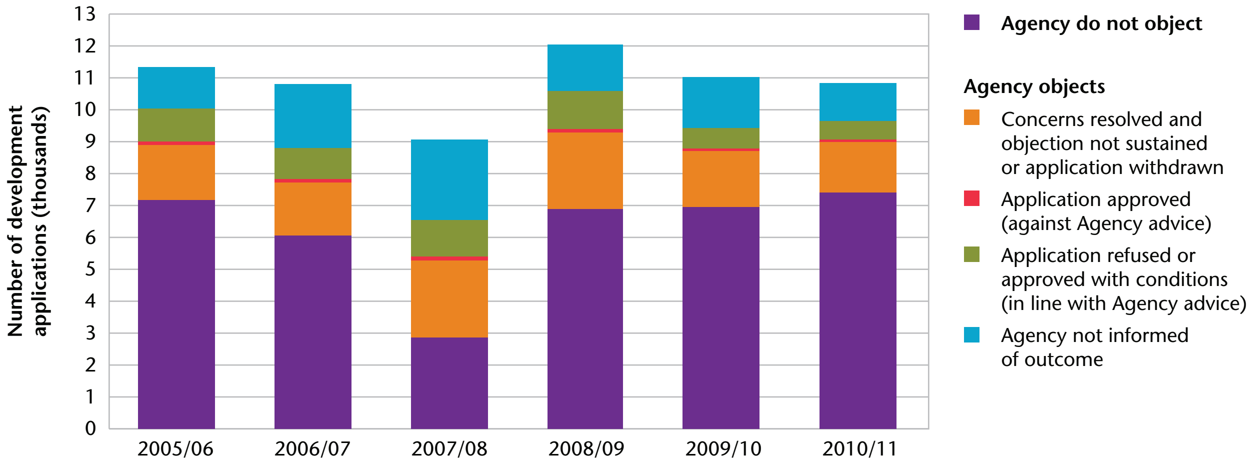
Source: Leeds City Council, Southampton City Council

Where the outcome is known, we found that only a very small number of planning applications had been approved in the face of a sustained objection from the Environment Agency (Figure 2.3). Between 2005/06 and 2010/11, the Environment Agency advised on around 11,000 planning applications per year on flood risk grounds. In more than half of these applications the Agency raised no objection (around 6,000 per year on average). The Agency objected and were notified of the outcome for around 3,000 applications per year.[37] For these:

- 65% of applications were either withdrawn by the developer, or were resolved through negotiations between the Agency and the developer.
- 31% of applications were either refused by the local authority, or approved with conditions that mitigated the Agency's concerns.
- 4% of applications (around 100 per year on average) were approved by the local authority contrary to the Agency's sustained objection.

37 The Agency will generally object if the applicant has not properly assessed flood risk, or has not proposed sufficient flood mitigation measures. The Agency is more likely to object to development that has vulnerable users (such as housing) and where flood damage is likely to occur in a 1 in 100 annual chance flood event.

Figure 2.3: Outcomes of Environment Agency advice on planning applications on flood risk grounds (2005/06 to 2010/11)



Source: Environment Agency (2011a).
Notes: In some cases there may be a time-lag between an Agency objection and the outcome of the application being decided, and so the outcome may not be reported in the same year as the original objection. The Agency do not separately record the number of applications refused and applications approved with conditions, and so this is displayed as one category in the chart. Similarly, it reports objection not sustained and application withdrawn as one category. The 2010/11 Annual Monitoring Report provides a breakdown of the outcomes of Agency objections (where notified) for 2010/11, which was as follows:
– Applications refused: 18%.
– Applications approved with conditions: 8%.
– Applications withdrawn by developer: 23%.
– Objection not sustained by Agency following negotiations with developer: 48%.
– Applications approved contrary to sustained Agency objection: 3%.
The Annual Monitoring Report notes that where an application is withdrawn, the developer will often re-submit the proposal at a later date with revised designs.

The low level of planning applications proceeding against a sustained Agency objection suggests that the majority of development in areas of flood risk has been designed in ways that:[38]

- ensure human safety in the event of a flood, for example by including evacuation routes that do not flood (so-called 'dry routes');
- minimise damages from a flood event, for example by raising floor levels;
- manage surface water run-off, for example by requiring sustainable drainage systems; and
- allow for sufficient water flow during a flood event so as not increase risk downstream, for example by incorporating compensatory flood water storage areas**.**

However, this development will still be subject to residual risk and will require on-going investment in flood protection.

38 National planning policy requires local authorities to demonstrate that development in flood risk areas will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

Some floodplain development may not be designed to the standards required by the Agency. Between 2005/06 and 2010/11, the Agency were only notified of the final decision for around two-thirds (65%) of their objections, despite the Government's good practice guidance encouraging local authorities to inform them.[39] Where the Agency was not notified of the outcome, it is possible that applications may have been permitted that were contrary to the Agency's advice.[40]

Evaluating preparedness: local authority decision-making

The evidence indicates that in general, local authorities are implementing national planning policy by continuing to build with protection in the floodplain. Local authorities are generally allowing development in the floodplain, but ensuring either that the development is well protected by flood defences or that it is being designed in ways that will minimise the impact of flooding to individual properties and the surrounding area. To understand better whether local authorities were proactively choosing this model for floodplain development in the face of climate change, we examined the most up-to-date development plans available (Box 2.3).

Box 2.3: Approach taken to evaluate local authority decision-making

We assessed how local authorities had applied national planning policy on flood risk, including how they assessed the implications of climate change on future flood risk. We focused on assessing strategic allocations of land for development, rather than decisions on individual planning applications. To do this, we undertook a high-level review of the publicly available evidence base informing 42 local authority development plans:[41]

- We assessed the 18 Site Allocations Development Plan Documents that have been adopted to date in England and a further 9 that are currently going through the examination stage. We also identified 2 additional plans that included strategic allocations in a slightly different format. Most of these 29 plans were from local authorities in the South-East and London.
- We assessed a further 13 plans produced in a slightly older format, but which included site allocations (Unitary Development Plans that were adopted in 2006 and 2007) for other parts of the country. This was to ensure that our analysis covered a wide geographical range.
- In addition, we explored the Sustainability Appraisals of 12 of the 42 authorities to assess how they had weighed up flood risk in a changing climate against the range of wider objectives that influence strategic decisions on the growth of the locality when preparing their development plans.

See Arup (2012) for ASC for a map of the location of these local authorities, a description of their characteristics, and further details on the approach taken.

The local authorities studied had developed a good understanding of current flood risks and had started to explore the implications of climate change. Of the 42 development plans assessed, 10 were adopted without having a Strategic Flood Risk

39 The Environment Agency (2011a) notes that Decision Notices are being increasingly posted on-line and not formally submitted to the Agency by local authorities.
40 Environment Agency (2011a) points to unpublished research that shows no significant difference in outcome between cases where they are notified and cases where they are not. The Agency have informed us that they have recently commissioned further research to better quantify this.
41 Evidence reviewed by Arup (2012) for ASC included any Strategic Flood Risk Assessments, the Core Strategy, development plan policies and the corresponding narrative in the Inspectors report (where relevant).

Assessment.[42] These were all older plans produced between 2005 and 2007. The flood risk assessments of the remaining 32 local authorities were informed by a variety of data, including Catchment Flood Management Plans and historic flood maps, generally with the support and advice of the Environment Agency. All of the Strategic Flood Risk Assessments included contingency allowances to account for expected increases in sea level rise, rainfall intensity and river flow as a result of climate change.[43] Some local authorities have taken more innovative approaches to accounting for future flood risk.[44]

There was mixed evidence that local authorities were using their improved understanding of flood risk to inform development plans. A key component of planning policy is the requirement that local authorities should strategically assess whether some or all of their growth needs can be accommodated outside the floodplain before deciding to allow floodplain development (known as the 'sequential test').

- **Less than a quarter of the development plans studied (10 out of the 42) had a clear audit trail setting out how they had applied the sequential test** (Table 2.2a).[45] One-third of the authorities (14 of the 42) referred to the sequential test in other documents, such as the Strategic Flood Risk Assessment, but did not explicitly demonstrate its application. The remaining 18 authorities did not document how, or whether, they had applied the sequential test in their development plan.[46] We did not find evidence of the Environment Agency objecting to any of these plans on the grounds of the sequential test not being applied robustly.

- **For some authorities (6 out of 42), the sequential test is unlikely to have resulted in the identification of alternative locations**. These authorities either had limited land outside the floodplain or had other constraints, such as green belt, nature designations or high-grade agricultural land, potentially reducing the amount of 'reasonably available' land for development.[47]

- **The majority of flood risk management policies in the plans reviewed focussed on making floodplain development safe once the strategic decision to allocate land in the floodplain has been made.** (Table 2.2b).

42 National planning policy requires that Strategic Flood Risk Assessments (SFRAs) should refine information on the probability of flooding, taking other sources of flooding and the impacts of climate change into account. They provide the basis for applying the sequential test. Where, following application of the sequential test, an authority concludes that development in the floodplain is necessary, they should carry out a Level II SFRA to consider the impact of flood defences on the frequency, impact, speed of onset, depth and velocity of flooding. The SFRA should be prepared in consultation with the Environment Agency and, where appropriate, internal drainage boards.

43 Strategic Flood Risk Assessments should use contingency allowances for the rates of relative sea level rise and national precautionary sensitivity ranges for peak rainfall, peak river flows, offshore wind speeds and wave heights. These are set out in the Technical Guidance to the National Planning Policy Framework. The guidance also notes that sensitivity testing of the Flood Map using the 20% peak flow allowance suggests that changes in the extent of inundation are negligible in well-defined floodplains, but can be dramatic in areas of flat topography. This means that a site currently located within a lower risk zone could in future be re-classified within a higher risk zone.

44 For example, Bristol City Council's Strategic Flood Risk Assessment redefined the extent of flood zones to account for the predicted impact of climate change (with advice from the Environment Agency). The Environment Agency further advised Bristol City Council that both the current and future areas of flood zones must be accounted for when making strategic development allocations, to ensure protection from flood risk over the development's lifetime, in accordance with national policy. The Core Strategy included supporting text specifically stating that no development within future Flood Zone 3 would be necessary to facilitate the delivery of the local authority's housing target.

45 These authorities produced a separate technical paper setting out how they applied the sequential test. Different approaches were applied which ranged from filtering out constrained land (such as green belt, open space and nature conservation designations) to directly comparing sites within and outside the floodplain.

46 10 of the 18 plans were adopted in 2006 and 2007 and so would have been prepared before the publication of PPS25 in 2006, and therefore may not have been expected to explicitly document their application of the sequential test. However, previous planning policy on flood risk (Planning Policy Guidance 25, published in 2001) also expected that local authorities should apply a risk-based approach through a sequential test.

47 Defined in planning policy good practice guidance as sites that are 'developable' and 'deliverable'.

Table 2.2: Results of review of local authority development plans in relation to flood risk

(a) Demonstration of application of sequential test in the 42 plans assessed	Number of plans
Separate technical paper documenting application of sequential test	10
Sequential test is referred to in other development plan documents (Strategic Flood Risk Assessment or Sustainability Appraisal), but not explicitly applied	14
Not explicitly documented	18

(b) Types of policies to manage flood risk in the 32 plans that were informed by a Strategic Flood Risk Assessment	Number of policies
Avoid development in strategically identified areas of flood risk	2
Within a development, locate vulnerable uses in areas of lower flood risk	17
Require flood resilience measures in new dwellings	24
Require developer contributions for flood defences	5
Require compensatory flood storage areas to reduce risk down stream	1

Source: Arup (2012) for ASC
Note: Some plans had more than one policy. There were a total of 49 separate flood risk policies in the 32 development plans that had been informed by a Strategic Flood Risk Assessment.

A key question when assessing preparedness for climate change is whether a 'build and protect' approach is the most rational adaptation response, given climate change. Continuing to develop and protect some parts of the floodplain is likely to be rational because of the scale of social and economic benefits that result, even after accounting for climate change. Avoiding development altogether in these areas may not be a proportionate adaptation response. Equally, however, continuing to develop in other parts of the floodplain may not be sensible where the costs associated with future flood events and the ongoing costs of flood protection outweigh the benefits. This will particularly be the case if infrastructure assets, or even whole communities, have to be relocated at some point in the future. If these long-term implications are not taken into account, some development decisions will inadvertently increase the costs of adaptation in the future.

There was limited evidence of the local authorities studied transparently accounting for the long-term costs of floodplain development. In a well-preparing society, we would expect to see local authorities explicitly assessing the long-term costs and benefits of developing in the floodplain and weighing up the need to manage flood risk against other objectives when planning the future growth of their communities. Local authorities are required to set out and consider such trade-offs when preparing their development plan through the Sustainability Appraisal process.[48] None of the Sustainability Appraisals studied had attempted to estimate the long-term costs from development in the floodplain in a quantified way.[49]

48 The purpose of the sustainability appraisal process is to appraise the social, environmental and economic effects of a development plan from the outset. The sustainability appraisal is integral to the plan making process. It should perform a key role in providing a sound evidence base for the plan by evaluating alternative options for development and help demonstrate that the plan is the most appropriate given the reasonable alternatives.
49 See Arup (2012) for ASC for further details on the approach taken to review the 12 Sustainability Appraisals.

We have explored an approach that could help planners understand the costs of developing in the floodplain when explicitly accounting for climate change across a range of scenarios (Box 2.4). If local authorities were to undertake this type of assessment as part of their Sustainability Appraisal, then we would have more confidence that appropriate decisions are being made which balance the long-term costs of flooding against the short-term benefits of development.

Box 2.4: Assessing the costs of developing in the floodplain

Our approach considers the long-term costs of developing in the floodplain, such as costs of property-level flood protection, maintenance of existing community flood defences and potential damage costs in the event of a flood.

For example:

- **One-off costs to make the development safe and resilient, for example £3,250 for property-level protection measures in areas where there is a greater than a 1 in 100 chance of flooding in any given year.** In other areas, site design could be used to achieve the same effect, for example raising floor or ground levels.
- **Ongoing flood risk costs include the residual damage should a flood occur weighted by the chance that it occurs. These costs will be determined by the standard of protection of the flood defence and its condition, and also the scale and intensity of climate change.** For example, annual average flood damages for a property built behind a 1 in 50 annual chance flood defence are £180 today, rising to £220 with climate change by the 2050s (under the medium emissions scenario). For a property built behind a 1 in 200 annual chance flood defence, annual average damages are £50 today, rising to £65 with climate change by the 2050s (under the medium emissions scenario).
- **Ongoing flood protection costs include the annual contribution to community flood defence, and the annual maintenance and replacement of property-level protection measures,** estimated to be approximately £300 per property.

See Arup (2012) for ASC for further detail on the approach taken and the results from the analysis.

In summary, the findings of our analysis in relation to the location and design of new development are as follows:

- Development in the floodplain grew at a faster rate than elsewhere in England over the past ten years, although the rate has declined in coastal areas.
- Most floodplain development has been in areas that are already protected by flood defences, but around a fifth has been in locations that currently face a significant chance of flooding, which is likely to increase further with climate change.
- Although development in the floodplain generally appears to be well protected from flooding, it will leave a legacy of rising costs of protection and residual flood damage in the face of climate change.
- The local authorities studied generally assume that the benefits of continuing to develop in the floodplain outweigh the costs rather than looking at alternative locations first.
- These long-term costs may outweigh the short-term benefits of development in some locations. This means that some development decisions being taken today are likely to be inadvertently increasing the costs of adaptation in the future.

Protecting existing properties from flooding

Climate change is expected to increase the costs of flooding to the existing property stock. 3.6 million properties (17% of the building stock in England) are located in areas at risk of all sources of flooding. With no additional action beyond maintaining existing defences, flood risk to this stock is likely to increase due to the effects of climate change, as set out in Section 2.2.

This section assesses the uptake of measures to manage the risk of flooding to existing properties from rivers and the sea. The focus of the analysis is on the provision of structural flood defences and on the uptake of property-level protection measures. We analyse how the number of properties at risk of flooding in the future could be reduced by investment in flood defences, when accounting for climate change.

Investment in structural flood defences

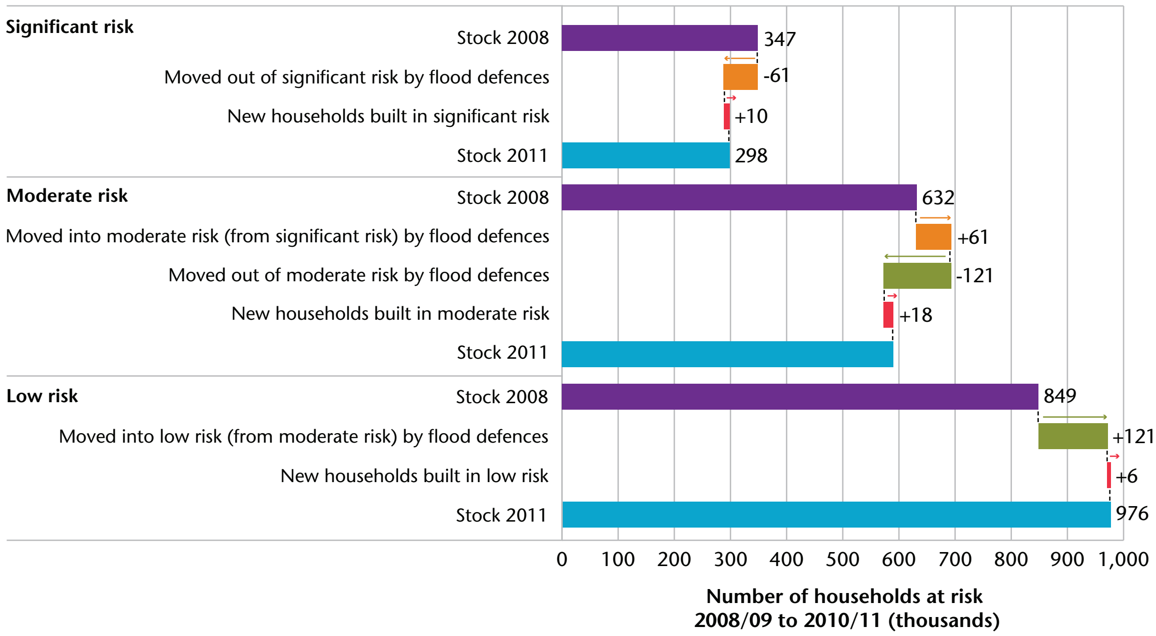
Over the period of the last spending review (2008/09 to 2010/11), investment in new flood defences reduced the chance of river and coastal flooding for 182,000 households, 21% of the housing stock at significant or moderate risk.[50] Capital investment of £1 billion in new or enhanced defences during the period resulted in 61,000 households moving from having a significant to a moderate chance of flooding, and a further 121,000 households moving from a moderate to a low chance. This reduction in the number of properties with a significant or moderate risk has been greater than the number of properties added to these categories as a result of new development (Figure 2.4).[51]

Over the same period, there has been investment in maintaining the condition of existing flood defence infrastructure. The Environment Agency invested £780 million on maintenance of flood defences and flood warnings over the period of the last spending review. As a result, only 6% of the Environment Agency's structural defences are currently classified as being in a poor condition.[52]

The Environment Agency, under the direction of Defra, has taken a more strategic approach to how funding is allocated, targeting investment towards communities at greater flood risk and with the highest social vulnerability. Over the last spending review period, investment in new flood defences achieved an average benefit-cost ratio of 8:1, that is every £1 spent on flood defences is expected to reduce the long-term cost of flood damages by around £8 on average.[53] This compares well with the return on most other types of public-private infrastructure investment, for example the benefit-cost ratio of Cross Rail is estimated as 2:1.[54]

50 The Environment Agency and Defra only measure change in risk from the capital investment programme to households, not all properties.
51 The number of households in each risk category are from HR Wallingford (2012d) for ASC. The numbers differ from those reported by the Environment Agency's. For an explanation, please see Footnote 13.
52 The Environment Agency are only responsible for around half of England's structural flood defence infrastructure, with the remainder being the responsibility of local authorities, internal drainage boards, water companies and private individuals. There is no single register or database that records the condition of these defences. See HR Wallingford (2012d) for ASC for more information.
53 The impact of climate change on future flood risk is accounted for when assessing different options of potential flood defence schemes.
54 Department for Transport (2005).

Figure 2.4: Change in number of households in each flood risk category due to investment in new flood defences and new development (2008/09 to 2010/11)



Source: Environment Agency (2011a), HR Wallingford (2012d) for ASC.
Notes: Chart presents stock of households in 2008 and 2011 in significant, moderate and low flood risk categories (purple and blue bars). Households moved down a flood risk category between 2008/09 and 20010/11 due to flood defences are shown by the orange and green bars. Environment Agency reports the number of households that moved out of significant risk, and it reports total number of households moved down a risk category. The Agency does not report the impacts on commercial properties. We have assumed that the households either move from significant to moderate, or from moderate to low risk on the basis that it is unlikely that the return would be sufficient to justify Environment Agency spending on projects that move households from low to very low likelihood. Red bars show increase in each flood risk category due to new development (HR Wallingford (2012d) for ASC).

The funding allocated for flood defences in the current spending review period (2011/12 to 2014/15) has fallen by one fifth compared with the past four years when accounting for inflation (in real terms).[55] This is due to the constraints on public finances. Capital funding for new flood defence schemes and improvements to existing defences has fallen from £300 million to £260 million per year on average, a reduction of 22% in real terms. Revenue funding for flood defence maintenance, emergency response, and mapping/modelling flood risk has reduced from £260 million to £240 million per year on average, a reduction of 14% in real terms. In addition to this funding:

- The Environment Agency has committed to deliver 15% efficiency savings on its capital investment programme,[56] which would equate to around an additional £54 million over the four year period.
- Defra's new policy to draw in contributions from local communities and the private sector has secured £72 million to date (most of which has come from local authorities that have been flooded in recent years). More may be achieved over the spending review period. This compares with £13 million secured during the last spending review, of which £3 million was from the private sector.

55 Inflation adjustments have been made using the GDP Deflator series.
56 A 15% efficiency saving is planned for the capital funding allocated for flood defence grant in-aid which goes towards building new and improved defences. Total capital spend is £260 million for each year of the current spending review period, and of this, grant in aid is planned to be £160 million in 2011/12, £170 million in 2012/13, £140 million in 2013/14, and £130 million in 2014/15.

Here we compare this level of investment with two scenarios of investment produced by the Environment Agency.[57]

- **Investment Scenario A is closest to the current spending level.**[58] This scenario holds the 2008/09 cash spending level constant out to 2035. If this spend level were to continue over the next 25 years, the Environment Agency estimate that properties in significant risk would increase from 330,000 today to 570,000 in 2035.[59]
- **Investment Scenario B delivers the greatest net benefits to society.** This scenario increases investment in flood defence investment by £20 million year-on-year on top of inflation out to 2035. This spend would keep the number of properties at significant risk broadly in line with the number today. The additional spending above inflation would prevent deterioration of existing assets and provide better protection to properties whose risk is increasing from climate change.

The gap between these scenarios will grow over the course of the spending review period. The combination of efficiency savings and external contributions already secured would only cover a small proportion of the gap (Figure 2.5). The Government could address the shortfall in several ways:

- **Use external contributions to fill the gap.** Third-party contributions would need to increase from the £72 million already secured to £230 million over the period to prevent total effective spend falling below the 2008/09 level in cash terms (Investment Scenario A).[60] External contributions would need to increase substantially– to £860 million – to keep spend in line with the increase required to keep pace with climate change (Investment Scenario B).[61] Innovative ways of partnership working between the Environment Agency and local authorities could help (Box 2.5).
- **Increase spending in future years to make up the shortfall.** Even if additional public funding could be secured when fiscal constraints eventually ease, it could be challenging to ramp up the Environment Agency's capital programme fast enough to make up the shortfall. This is because most capital schemes span across multiple years from approval to completion. If spending drops off for a period, it takes time and resource to build up a portfolio of capital schemes again.
- **Accept an increase in frequency of flooding and shift emphasis to manage the social and economic consequences, such as property-level measures and better emergency planning** (see next sections).

57 Environment Agency (2009a) have developed five Long Term Investment Strategy (LTIS) scenarios that set out the effect of flood defence investment on the number of properties at significant and moderate risk in 2035. Investment scenarios A and B in this report correspond to LTIS scenarios 1 and 4 respectively. These scenarios do not account for any increase in number of properties at risk as a result of new development. LTIS is currently being updated by the Environment Agency in light of new information, including the CCRA.

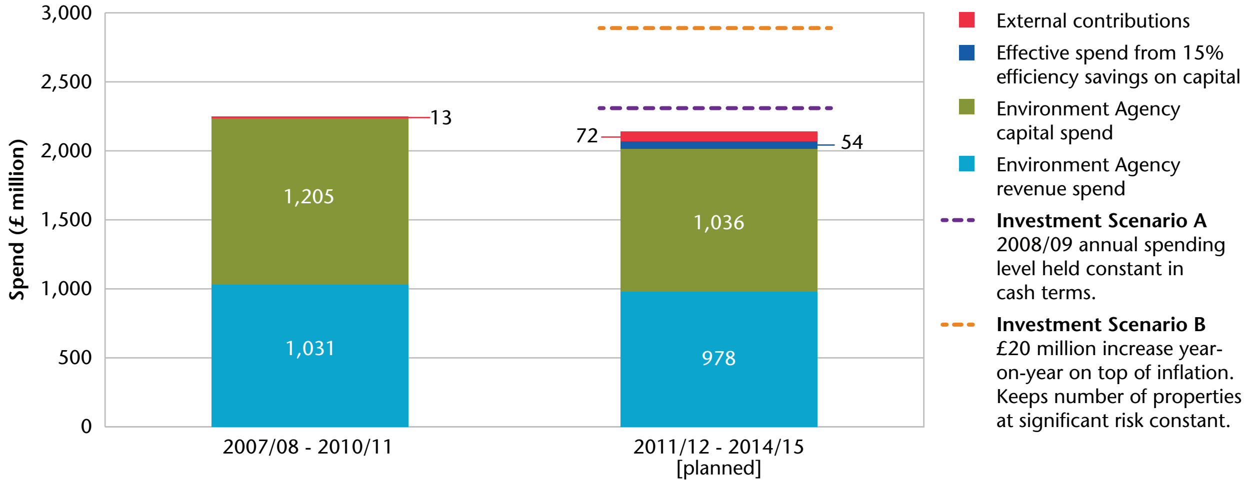
58 Current spending level refers to both the last spending review period (2008/09 to 2010/11), and the current spending review period (2011/12 to 2014/15). This accounts for the net effect of having had higher spend in the last period and lower spend in the current period.

59 Taken from Environment Agency (2009a) and apportioned according to results of HR Wallingford (2012d) for ASC. See Footnote 13 for explanation of differences in numbers.

60 Effective spend refers to the effect of purchasing 15% more with the same capital funding through the 15% efficiency savings.

61 The £230 million or £860 million external contributions needed to meet the shortfall includes the net effect of having had higher spend in the last period and lower spend in the current period.

Figure 2.5: Investment in flood defences for past and current spending periods compared to two long-term investment scenarios



Source: National Audit Office (2011), Environment Agency (2009a), calculations by ASC.
Notes: This chart presents outturn 2007/08 to 2010/11 and planned spend 2011/12 to 2014/15 on flood defences, when compared with two of the five Long-term Investment Strategy (LTIS) Scenarios modelled by the Environment Agency. The bar on the left shows capital, revenue and external contributions over the last spending review (2008/09 to 2010/11) and the previous year (2007/08). The bar on the right shows analogous information for the current four year spending review, but also includes the effective spend of 15% efficiency savings on flood defence grant in aid capital spend. LTIS scenarios assume 2% efficiency savings each year and 2.7% inflation. LTIS is currently being updated with a new long-term funding needs assessment, and is due to be published later this year by the Environment Agency.

Box 2.5: Delivering a partnership approach to funding new flood defences in Woking, Surrey

The town of Woking in Surrey has a history of flooding, with around 70 homes damaged in a flood event in 2000. Furthermore, some parts of the floodplain within the town were historically used for waste disposal resulting in contaminated land.

Woking Borough Council and the Environment Agency worked in partnership to develop the Hoe Valley Scheme, a £40 million regeneration project. This included a £11 million upgrade of the existing flood defences, comprising a series of flood walls, embankments, storage areas and the replacement of three bridges that restricted the river's capacity.

The project has:

- reduced flood risk to 198 existing properties, two schools and community buildings;
- set back defences to make space for water and re-connect people with the river environment, providing 27 acres of new parkland; and
- reclaimed land from a former landfill site for 100 new houses, so removing contaminated land from the floodplain.

Having gained planning permission, the Environment Agency entered into a legal partnership with Woking Borough Council. This included a £3.7 million contribution towards flood defence elements of the scheme provided through the Regional Flood and Coastal Committee Local Levy. The Borough Council funded the remainder of the scheme, in part through requiring developer contributions from the new housing.

The scheme incorporated a 'managed adaptive' approach, whereby the defences can be raised by 300mm without any additional strengthening and 500mm with minor strengthening work if it is found to be necessary as a result of future climate change.

Source: Environment Agency, Woking Borough Council

Uptake of property-level protection

Property-level protection can work alongside structural flood defences to help manage the risks from flooding. Structural flood defences provide protection to entire communities and in general offer a better return on investment than property-level protection. This is particularly true in densely populated areas where a flood defence systems protect a range of assets, including homes, businesses and infrastructure.

However, in rural, less populated locations, structural defences may be a more costly solution than property-level protection, as each flood defence system protects fewer properties. In addition, structural flood defences do little to protect properties at risk from surface water flooding. However, individual property-level protection is only effective against relatively shallow flooding, not extreme events that will overtop the door guards and cause structural damage to the property.

The current uptake of property-level protection is low. Around 1,100 households were retrofitted with property-level measures as part of a Government grant scheme between 2008 and 2011.[62] An estimated 50 additional properties (mostly commercial) have been retrofitted outside of the scheme over the same period, based on a survey of suppliers.[63] There may be a range of policy barriers preventing or discouraging the uptake of property-level measures. This is discussed further in Section 2.4.

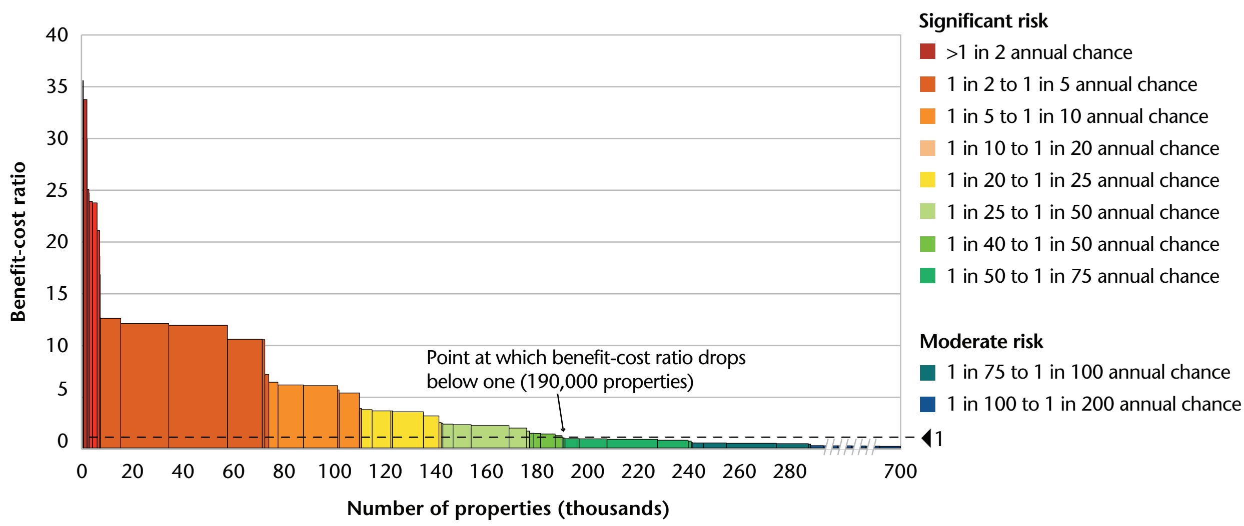
Our analysis has identified packages of low-cost measures (around £4,000 per property) that could reduce flood damages to properties with a greater than 1 in 50 chance of flooding in any given year across England (Figure 2.6).[64] This builds on our pilot analysis for one catchment last year.[65] These packages include measures such as door guards, airbrick and vent covers, non-return valves on sewer pipes, re-pointing of external walls with water-resistant mortar, silicone gel sealant around cables passing through external walls, and pumps to remove water.

Around 190,000 properties with a greater than 1 in 50 chance of flooding in any given year of flooding stand to benefit from property-level protection under the current climate and given existing flood defences (Figure 2.6**).** The number of properties that could benefit in the future from property-level protection will vary with the level of investment in structural flood defences.

- In a scenario where investment in flood defence remains constrained (Investment Scenario A), property-level measures could benefit around 330,000 properties by 2035 (Figure 2.7a). Uptake rates would need to increase 35-fold to 14,000 properties per year to achieve this.

62 See HR Wallingford (2012d) for ASC for the location of these 1,100 properties.
63 HR Wallingford (2012d) for ASC.
64 This refers to 'manual' measures, requiring physical deployment ahead of each flooding event, which are currently more cost-beneficial than 'automatic' measures. However, they are less reliable and do not provide residents with the same piece of mind. Manual measures may not be appropriate in areas at risk of flash floods where there is little advance warning of where the flood will hit (unlike river flooding). Packages of £4,000 per property include capital cost of around £3,000 plus maintenance over 20 years (discounted) of around £1,000.
65 Davis Langdon (2011) for ASC.

Figure 2.6: Cost curve to show potential for uptake of property-level flood protection in England



Source: Royal Haskoning (2012a) for ASC.
Notes: Chart plots benefit-cost ratio of installing the manual package against number of properties. Each coloured block represents a different level of flood risk, and each bar within the block represents a different property type (of which there are four residential and two commercial). The width of each bar corresponds to the number of properties of a particular type and at a particular level of flood risk. It is cost-beneficial to install property-level protection for properties that face at least a benefit-cost ratio of one (above the dashed line).

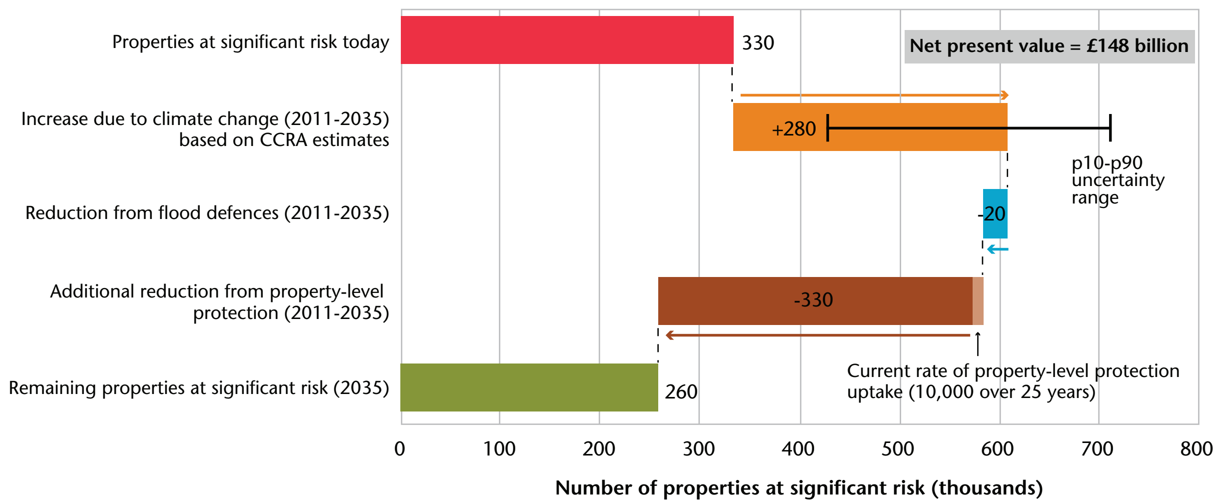
- Property-level protection still has a role even in a scenario where spend on structural flood defences has increased faster than inflation to keep pace with climate change (Investment Scenario B, Figure 2.7b). Together structural flood defences and property-level protection reduce the number of properties at significant risk by one-half by 2035 (from 330,000 to 160,000) and deliver net benefits of £193 billion. Uptake rates would need to increase 20-fold to 9,000 properties per year to protect all those properties over that timeframe.

The balance between structural flood defences and property-level protection could affect the distribution of costs between the public purse and private beneficiaries.

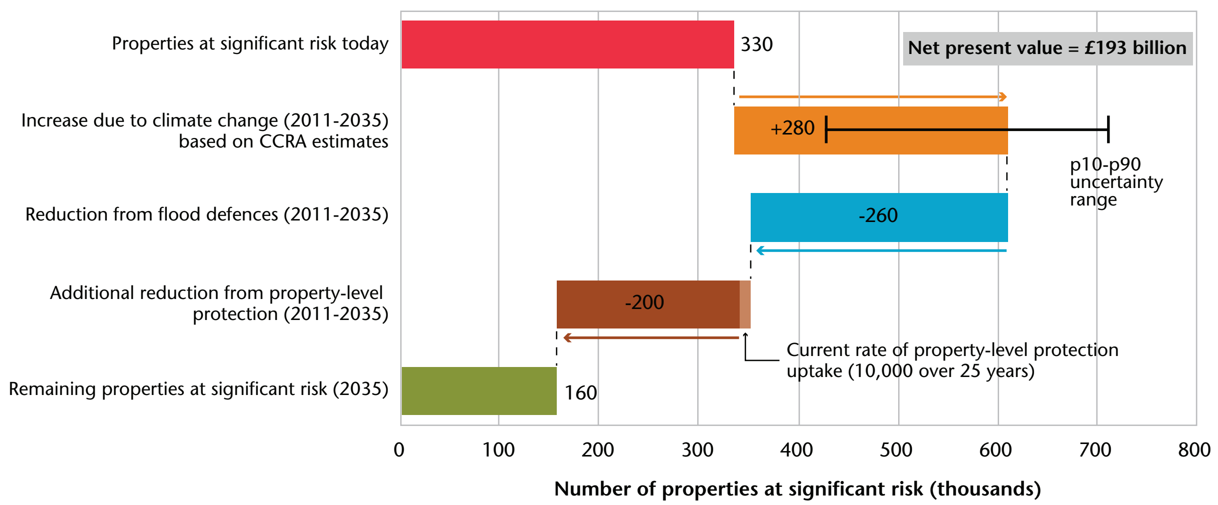
- Historically flood defences have largely been funded by government spending because of the wider benefits that accrue to society. The Government's new partnership funding arrangements seek to increase contributions from local beneficiaries.

- In principle individual households and businesses should be willing to cover the costs of property-level flood protection because they receive the benefits. However, the upfront costs and uncertain benefits mean that households and businesses may not be willing to invest in these measures on a significant scale. The Government has recently provided a limited number of grants for households to contribute to the costs, in order to encourage further uptake. The Government's new partnership funding could provide households with additional financial assistance.

Figure 2.7: Combined effect of climate change, varying levels of flood defence investment and take-up of property-level protection by all properties where it is cost-beneficial to do so on the number of properties in the significant risk category in 2035.
(a) Flood defence spending constrained to 2008/09 cash level (Investment Scenario A)



(b) Flood defence spending increased by £20 million year-on-year, over and above inflation, for greatest net benefits (Investment Scenario B)



Source: Environment Agency (2009a), HR Wallingford (2012b) for Department for Environment Food and Rural Affairs, HR Wallingford (2012d) for ASC, Royal Haskoning (2012a) for ASC.
Notes: Properties at risk today is taken from HR Wallingford (2012d) for ASC. All subsequent numbers have been apportioned for the results of HR Wallingford (2012d) for ASC. Please see Footnote 13 for an explanation of different data. Increase in risk due to climate change (CCRA mid emissions p50 scenario with error bar for p10 and p90) does not account for asset deterioration, new defences or new development. Reduction in risk from flood defence investment is based on Scenario 1 (Figure 2.7a) and Scenario 4 (Figure 2.7b) in Environment Agency (2009a). Additional reduction in risk from potential property-level protection is taken from Royal Haskoning (2012a) for ASC.

In summary, the key findings of the analysis in relation to the protection of existing properties are as follows:

- Current levels of investment in flood defences and uptake rates of protection measures for individual properties will not keep pace with the increasing risks of flooding. Climate change could almost double the number of properties at significant risk of flooding by 2035 unless there is additional action.
- By increasing investment in both flood defences and property protection measures, the number of properties at significant flood risk could be halved from current levels by 2035 accounting for climate change. The potential impact of climate change means that increased investment could lead to a four-fold reduction in risk when compared with a scenario of no additional action.

Managing surface water flows in urban areas

In towns and cities, urban design can play a critical role in managing the flow of surface water and the risk of surface water flooding. Every millimetre of rainfall deposits a litre of water on a square metre of land. A day of even modest rainfall can deposit several million litres of water on a town or city.[66] Managing the resulting surface water run-off will be increasingly important as climate change is likely to increase the frequency of intense rainstorm events. Key measures include:

- **Minimising urban creep**. The paving over of permeable green space within existing developed areas results in an expansion of hard impermeable surfacing.[67] Urban creep can increase the risk of surface water flooding[68] by exacerbating the impacts of intense rainstorms.[69] Hard surfacing can also intensify the urban heat island effect, potentially magnifying the effects of heatwaves, with harmful consequences for the health and well-being of vulnerable people, particularly the elderly.[70]
- **Managing surface water at source or above ground, and keeping rainwater out of sewers.** This can involve using sustainable drainage systems (SuDS) to slow down surface water flows and store water above ground. This will reduce loads on existing sewerage systems and control peak rates and volumes of run-off on site, so reducing the risk to properties downstream. Using roads and paths as emergency flood channels and designating low value land for temporary flood storage can keep surface water away from people and property.
- **Maintaining or upgrading conventional sewers** to help deal with some of the most persistent cases of sewer flooding caused when surface water overwhelms urban drains. This can provide a remedy for some sewer flooding. However sewers have fixed capacity, meaning they still overflow when the intensity of rainfall exceeds this capacity.

66 Ofwat (2011a).
67 This is different from 'urban development', which is the creation of urban areas from previously rural areas.
68 As well as increase the risk of river flooding, particularly in rapid response catchments where there is less infiltration and run-off attenuation.
69 Houston D et al. (2011) for Joseph Rowntree Foundation, Ofwat (2011a) and Eigenbrod et al. (2011).
70 HR Wallingford (2012b) for Department for Environment Food and Rural Affairs.

In addition, wider flood risk management measures will also provide some benefits for managing surface water, such as:

- **Avoiding new development in areas prone to surface water flooding.** Our indicators show that the annual rate of development in these areas has increased since 2008 from 0.5% to 0.7% per year.
- **Use of property-level flood protection measures.** These can help to minimise the damages from surface water flooding to both new and existing properties. There can be difficulties in deploying manual protection measures given the lack of warning associated with surface water flooding. Structural flood defences have minimal effect on protecting from surface water flooding and in some circumstances can even exacerbate the problem by constraining the natural surface water flow.
- **Emergency planning and response.** This can help reduce loss of life and the costs of damages when floods occur. It is usually more difficult to predict surface water flood events compared to river and coastal flooding.

In this section, indicators are used to identify trends that may be increasing exposure to surface water flooding in urban areas and the uptake of adaptation actions.

Identifying trends in exposure: changes in surfacing

Our indicators show that the area of hard surfacing has increased in England's towns and cities over the last ten years. The increase has primarily been in areas that contain a mixture of hard and soft surfaces (defined as 'multiple' in the data), such as domestic gardens and road verges. The proportion of this area that was paved over increased from 28% of total 'multiple' area in 2001 to 48% in 2011. Total 'multiple' area in towns and cities has remained roughly constant at around a quarter (340,000 hectares) of the 1.3 million hectares of total urban extent (Figure 2.8).[71] This trend is consistent with other studies of land cover change in a particular number of towns and cities across the country.[72]

A small proportion of the hard surfacing installed since 2001 will have been permeable.[73] The use of permeable paving has increased in recent years, with sales accounting for roughly 2.5% of the total UK block paving market in 2011 compared to less than 1% in 2001.[74] This equates to around 370 hectares of permeable surfacing, out of the 70,000 hectares of gardens and verges that have been paved over since 2001. This level of uptake is significantly lower than in some other countries.[75]

71 This is consistent with other studies of urban land cover. For example, the National Ecosystem Assessment (2011) notes that domestic gardens make up 24% and 29% of the total land area of London and Birmingham respectively.

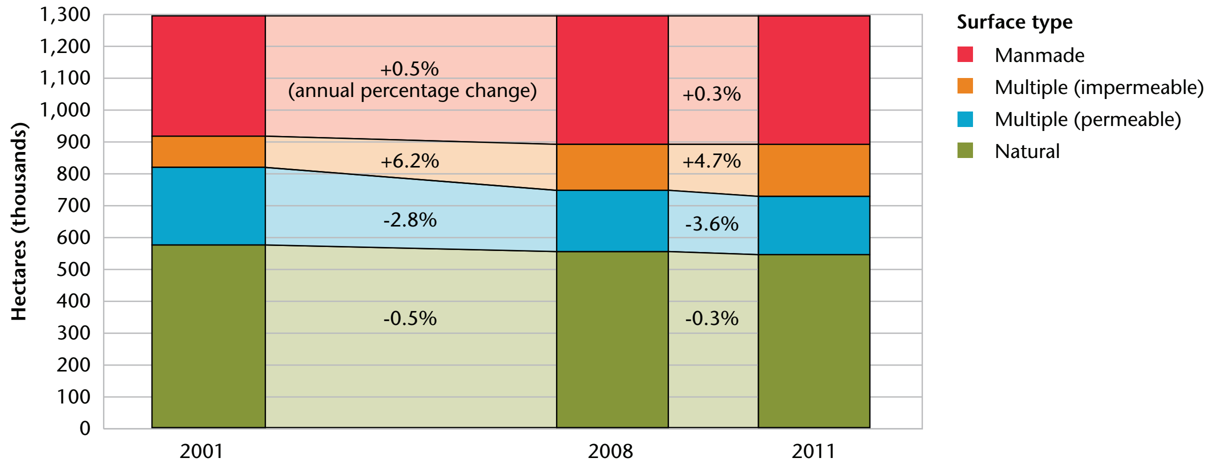
72 Details and references in HR Wallingford (2012d) for ASC. An example of another study with similar findings is Brent, north London. They found that more than half of properties have converted front gardens into driveways. A study in a suburban area of Leeds found that impermeable surfaces increased by 13% between 1971 and 2004 due to the paving of residential front gardens. A UKWIR study in 2010 of five urban areas in England using remote sensing technology identified that impermeable surfacing increased at a rate of 0.38 to 1.09 m^2 per house per year between 1999 and 2006. A study of three residential areas of Edinburgh observed that 61% of properties had increased the area of hard standing in front gardens since initial construction (circa 1970) with 56% making the surface completely impermeable. The National Ecosystem Assessment (2011) refers to a 2005 study which found that an estimated 3,200 hectares of front gardens in London have been covered in surfacing other than vegetation.

73 Permeable paving can be installed on private driveways as well as in larger areas such as car parks. It provides functional hard standing through which run-off can infiltrate. Surface water can then be stored and treated below the surface.

74 Survey of block paving manufacturers by HR Wallingford (2012d) for ASC.

75 For example, 2000 hectares of permeable paving were installed in Germany in 2011. See HR Wallingford (2012d) for ASC for further details.

Figure 2.8: Change in area of permeable and impermeable surfaces for urban areas in England (2001 to 2011)



Source: HR Wallingford (2012d) for ASC.
Notes: GIS mapping was used to assess change in the area of permeable and impermeable land within all urban areas in England. For the purposes of this study, 'urban' was defined as those 1km grid cells that had with a property density of >500 properties per km² in 2011. The analysis does not pick up land use change outside existing urban areas, for example from out-of-town greenfield development. The approach was validated by cross-checking the data against the Ordnance Survey 1:10,000 Raster Map for a sample of urban areas. The dataset used to assess change in surfacing was the OS MasterMap Topography Layer. This has three broad categories of land:
- **Natural** – features that are not man-made but possibly man altered, for example parkland, areas of water and uncultivated/cultivated vegetation.
- **Manmade** – features that have been constructed, for example, areas of tarmac or concrete including roads, paths and buildings.
- **Multiple** – features that contain a mixture of surfaces but are not depicted separately within the data, for example, residential gardens and road verges.

For the purposes of this study, it was assumed that 'natural' surfaces are permeable and 'man-made' are impermeable. These were measured directly via analysis of the MasterMap Topography Layer. The permeable area of the multiple category was more difficult to determine quantitatively since the MasterMap data does not sub-categorise the proportion which is paved. There is a considerable amount of variation in the proportion of impermeable surfaces within the multiple category, ranging from approximately 90% in densely urban areas to 40% in the suburbs. A methodology was developed that estimated the impermeable fraction of multiple land for low, medium and high density development and the rate of change of permeability ('urban creep') in this fraction, based on the results of a number of studies in different parts of the country that have used aerial photography and site surveys. The analysis has not directly accounted for the uptake of permeable surfacing measures. As such, a proportion of the observed increase in hard surfacing in the man-made and multiple land categories will have been permeable. However, our survey of paving manufacturers suggests this is likely to be low.

Uptake of actions: sustainable drainage systems (SuDS) and above-ground flow routes

Sustainable drainage systems (SuDS) moderate surface water run-off at source, store water above ground and limit flows into sewers, naturally filtering the run-off further downstream.[76] SuDS reduce the flow of polluted water, mitigating the risk of flooding and its consequences on the natural environment.

Urban design and land use planning often provide the best options for implementing such solutions. The focus in this report is on the uptake of SuDS in new development as an indicator of action on managing surface water. In the future, we may look to indicators of action at a more strategic scale, for example through analysis of local authority Surface Water Management Plans.

76 Examples of source control measures include permeable surfaces, rain water butts, swales and ponds.

Currently 40 – 50% of new development incorporates some form of SuDS.[77] Planning policy requires local authorities and developers to give priority to the use of SuDS in new development.[78] However, it is difficult to assess the effectiveness of this policy given the absence of any comprehensive national, regional or local datasets tracking the uptake of SuDS.

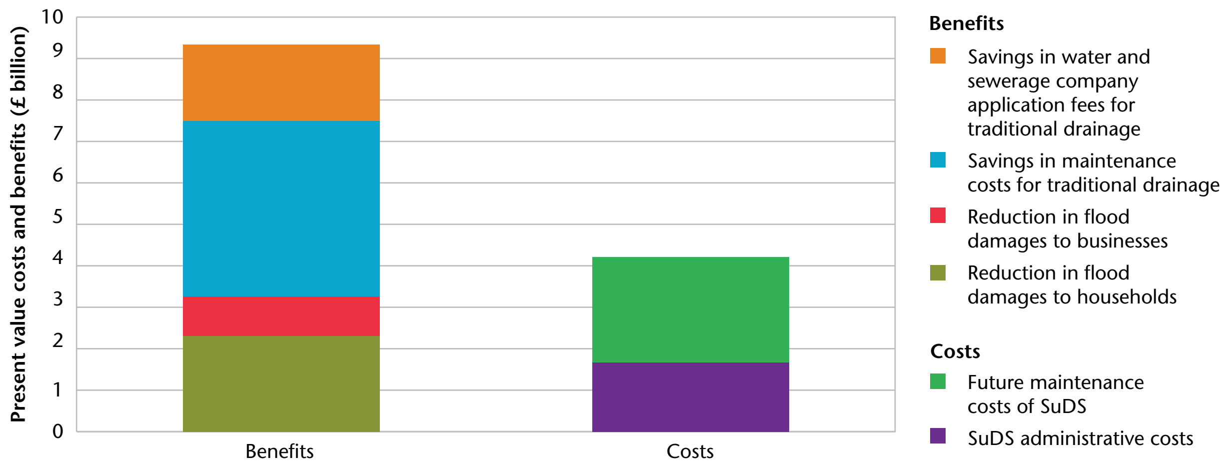
The question for adaptation is whether or not this level of uptake is sufficient to manage the rising risks from surface water flooding. To understand better the potential for using SuDS to manage the risk of surface water flooding, we reviewed studies that compare the capital and maintenance costs of SuDS (net of conventional drainage costs) with the flood damages avoided in different locations.[79]

- **The studies reviewed found that SuDS were cost-effective for most new developments, with the benefits around three times the costs over the lifetime of the scheme.** Studies have been patchy in their attempts to value the costs and benefits of SuDS. But in general they show that both capital and maintenance costs for SuDS are similar on average to those for conventional drainage, although more variable given the different types of SuDS available (Figure 2.9).[80]
- **Most studies do not consider the cost of land used for SuDS.** An initial assessment suggests that any additional space for SuDS can usually be accommodated within existing open space requirements, resulting in no additional land cost to the developer.[81] SuDS such as ponds and infiltration basins sit above ground and use space that might otherwise have been developed. Based on a case study site in Scotland,[82] SuDS are estimated to take between 2.5% to 8% of a medium density development site. Land take will be minimised if included in design at an early stage.

There is scope for greater use of sustainable drainage in new developments in urban areas. The available evidence suggests that the costs of SuDS are rarely greater than conventional drainage costs, even when accounting for land take. Greater use of SuDS in new development would help to offset some of the increase in flood risk from paving over green space and increased intensity of rainfall from climate change. But given that new development only comprises around 1% of land use change within the urban areas each year, there is also likely to be a need for some retrofitting of SuDS within the existing building stock (see Box 2.6). Strategic approaches to managing surface water above-ground across local authority catchments will also be required.

77 Department for Environment Food and Rural Affairs (2012a).
78 Department for Communities and Local Government (2012). Following publication of the Floods and Water Management Act, the automatic right for developers to connect to the existing surface water sewers has been removed. Local authorities have been given responsibility for leading the co-ordination of flood risk management in their areas.
79 Department for Environment Food and Rural Affairs (2012a).
80 Each SuDS is highly site-specific and varies considerably in its components. This makes it difficult to identify 'typical' cost ranges of systems and corresponding reduction of surface water run-off. Department for Environment Food and Rural Affairs (2012a) estimates that capital costs of SuDS are between -30% and +5% of that of conventional drainage systems if constructed to the same standard.
81 Royal Haskoning (2012b) for ASC.
82 Royal Haskoning (2012b) for ASC.

Figure 2.9: Total costs and benefits of incorporating SuDS schemes for all new developments across England



Source: Department for Environment Food and Rural Affairs (2012a).
Notes: The Impact Assessment monetises costs and benefits over 50 year period. Here we present the scenario that all new major and minor developments install SuDS, in line with the current policy. The benefit and cost numbers show the total values for England based on assumptions of flood damage reduction. The assessment assumes capital costs are the same for SuDS and conventional drainage which is why those costs are not presented here.

Box 2.6: Retrofitting sustainable drainage systems in built-up areas in Counters Creek, west London

Counters Creek is a drainage area covering seven west London boroughs. Most of the area was originally a low-lying, marshy floodplain, drained by several rivers. Since the late 1800s the watercourses have been incorporated into the sewerage system. Continued development and urban creep has resulted in an increase in impermeable areas. The loss of natural rivers and permeable areas means that the sewers are now the only means of drainage in the area. As such they can overflow during storms.

The Counters Creek area has a large number of inhabited basements, with cellars in new and extended properties commonly below the level of the sewers. Around 2,000 properties have been confirmed to have suffered basement flooding in recent years and up to 7,000 are modelled to be at risk of flooding.

Part of the solution will involve increasing the capacity of the sewer system, by building tunnels and pumping stations. Thames Water are also seeking ways to address the problem by reducing both the amount of rainwater that runs off the area and the speed that it enters the sewers. A range of measures could help to achieve this, for instance: replacing concrete and tarmac with permeable paving; increasing the amount of vegetation; installing rainwater butts; and constructing storage basins in public places.

There are few examples of SuDS being retrofitted in a dense urban environment such as Counters Creek. To explore the feasibility and effectiveness of the approach, Thames Water are conducting a series of pilot trials in which they will retrofit SuDS to selected streets and monitor their impact on flows into the sewers. As well as testing effectiveness, the trials will also identify the challenges involved in delivering SuDS and the attitudes of the public and other stakeholders towards them. This is particularly important because the SuDS will be highly visible and in many cases installed on customers properties, therefore the support of the community is essential to the success of the project.

Source: Thames Water

Developers need the right incentives to act. SuDS maintenance costs can fall to either the developer or the local authority, whereas maintenance for conventional drainage is paid for by the water company. As benefits such as reduced flood risk will accrue to those downstream and not always to the developer, developers may opt to connect to existing drainage systems rather than provide SuDS. These barriers are discussed in more detail in Table 2.3.

Uptake of actions: maintaining or upgrading sewers

The existing drainage system will continue to have an important role in helping manage surface water flood risk in the face of climate change. England's towns and cities have a complex network of underground sewerage and drainage infrastructure that has evolved over time. These systems, many of which were built in the Victorian era, can often reach full capacity in times of heavy rainfall, leading to sewer flooding.

Maintaining and refurbishing conventional drainage infrastructure is necessary, but can be expensive and often does not produce a particularly high return. Water and sewerage companies have invested £150 million each year on enhancing the existing drainage system since 2000, reducing the risk of sewer flooding to more than 15,000 properties, where the benefits outweigh the costs. These endeavours should continue, in order to deal with the most persistent cases of sewer flooding in towns and cities across the country. In practice, a combination of investment in conventional drainage along with retrofitting above ground SuDS will deliver the greatest benefits.

In summary, the key findings of the analysis in relation to the protection of existing properties are as follows:

- Surface water flooding in urban areas is increasing a result of paving over green spaces in towns and cities, and may increase further from more intense rainfall due to climate change. We found that the area of gardens that has been paved over increased from 28% of total garden area in 2001 to 48% in 2011.
- We have identified scope for greater use of sustainable drainage in new developments in urban areas, but this by itself is unlikely to be sufficient to stem the growing risk from surface water flooding. Better urban design to manage more surface water above-ground will also be required.
- Despite the scale of the risk, knowledge of the impacts of climate change on surface water flooding or appropriate responses remains very poor.

Emergency planning and response

Extreme weather events are likely to become more frequent and severe under a changing climate, increasing the chance of flood defences being overtopped or breached. Continued development in areas already protected by flood defences drives higher levels of investment in flood protection (the 'escalator effect'), as described earlier in the chapter. This increases the potential scale of damage from flooding if the defences are overtopped or breached. Emergency planning and response have an important role in reducing loss of life and the costs of damages when floods occur.

A single statutory framework for civil protection in the UK has been in place since 2004. It includes planning for and responding to flood emergencies (Box 2.7**).** Key measures to prepare for, respond to and recover from flood events include:

- **Forecasting and early warning systems,** including flood forecasting and warnings, disseminating information via the media, and auto-dialling warnings.
- **Raising public awareness of how to proceed in the event of a flood,** for example through publicity campaigns and community groups.
- **Managing the flood event,** including assisted evacuation of vulnerable members of the community and maintaining the provision of critical services during a flood event. Planning for the mass evacuation of vulnerable people can be challenging, especially when there is minimal warning of a flood event. The majority of fatalities from Hurricane Katrina in 2005 and the Japanese tsunami in 2011 were aged over 60. 30% of recovered victims in New Orleans were located in medical centres, hospitals or nursing homes.[83] Schools can also be very vulnerable if a flood event occurs when they are occupied, as was also seen in Japan.[84]
- **Post-event recovery**, including through the provision of affordable insurance.

Box 2.7: Statutory framework for emergency planning and response

The Civil Contingency Act (2004) established roles and responsibilities for those involved in emergency preparation and response at the local level, including the emergency services, local authorities, NHS bodies and utility companies. The Act emphasised the importance of co-operation by creating Local Resilience Forums, generally based on local police areas. These forums bring together all the organisations who have a duty to co-operate. They are required to publish and maintain a Community Risk Register that reflects the unique characteristics of each local area, including risks from natural hazards such as flooding.

The Government published the National Flood Emergency Framework in 2010. The framework aims to provide a strategic approach for all those involved in the planning for and response to flood events. The need for such a strategy was one of the recommendations of the Pitt Review following the 2007 floods. The framework encourages Local Resilience Forums to develop Multi-Agency Flood Plans for their areas to complement more generic Major Incident Plans. The Pitt Review also recommended the setting up of a national flood response exercise. This was delivered in March 2011 with Exercise Watermark, which tested all aspects of severe wide area flooding across England and Wales, making it the biggest civil emergency exercise to take place at national level.

Source: Cabinet Office, Department for Environment Food and Rural Affairs

83 Records of the Japanese tsunami show that over 65% of victims were aged over 60. Similarly, over 50% of victims from Hurricane Katrina were aged over 75 years. See HR Wallingford (2012d) for ASC for further details.
84 For example, 70% of pupils lost their lives in a single elementary school.

Vulnerability to flooding is high in some communities and locations, so emergency planning will continue to be an important part of managing flood risk in the future.

- **National critical infrastructure.** The temporary loss of critical and emergency services due to flooding can have far-reaching consequences, as was seen during the 2007 floods (see Box 2.8). A proportion of nationally important infrastructure is located in areas with a significant or moderate chance of flooding in England, including around 18,000 electricity infrastructure assets (7% of the national total), 1,400 sewage assets (25% of the total), 119 ambulance stations (10% of total) and 192 fire stations (9% of total).[85] Since 2009, the Government has been producing Sector Resilience Plans on an annual basis for the different categories of critical national infrastructure.
- **Deprived communities.** 650 of the 3,500 properties built in areas of significant flood risk between 2008 and 2011 were located in the 20% most deprived communities in England.[86] These communities generally have a lower capacity to prepare, respond and recover from flood events.[87]
- **Vulnerable groups – care homes and schools.** There are over 1,000 care homes (6% of the total in England) and 1,600 schools (7% of national total) located within the floodplain in 2011. Together some 30,000 care home residents and 500,000 school pupils occupy these buildings.
- **Flood warnings.** Less than one-quarter of all properties in the floodplain have registered for the Environment Agency's Flood Warning Direct service. The figure has increased from 18% in 2008. This service automatically telephones homes when a flood is forecast.[88] Take-up of the warning service is particularly low (less than 20% of properties) in many built-up parts of the floodplain, including London, Hull and Newcastle-upon-Tyne. This may reflect a lower awareness of flood risk amongst urban populations. The Agency is in the process of changing its approach to flood warnings. In 2008 the Extended Direct Warnings service was introduced. The Agency obtains the contact telephone numbers of properties at risk directly from the emergency services, giving occupants the opportunity to opt-out.[89]
- **Insurance.** Around 90% of owner-occupied houses have buildings and contents insurance, which includes cover for flood damage. The availability of flood insurance is covered by an agreement between the Government and the insurance industry. However, this agreement will end in June 2013, and the Government and industry have yet to agree how they will proceed after this time. The insurance industry estimates that up to 200,000 homes could face problems when seeking insurance cover after the agreement ends.

85 See HR Wallingford (2012d) for ASC for further details.
86 Based on the Multiple Index of Deprivation. See HR Wallingford (2012d) for ASC for further details.
87 Lindley (2011) for Joseph Rowntree Foundation.
88 Note that uptake may be higher within those areas of the floodplain at significant and moderate risk, but the Environment Agency does not provide a breakdown.
89 Only 1% have opted out to date. See HR Wallingford (2012d) for ASC for more details.

Box 2.8: Learning the lessons from 2007 in Gloucestershire

Much of Gloucestershire was adversely affected by the 2007 summer flooding, including major towns such as Tewksbury and Cheltenham. The flooding caused significant disruption to critical services, with 140,000 properties without a piped water supply over a two week period.[90] The emergency services were under major pressure, with the possibility of mass evacuations being seriously considered.

Since then, the Gloucestershire Local Resilience Forum, made up of key emergency responders, has published the Gloucestershire Community Risk Register, which includes planning for flood events. Gloucestershire County Council has also created a Civil Protection Team, which is embedded within the Fire and Rescue Service and co-ordinates the County Council's response to emergencies.

The County Council is working to improve understanding and resilience to the impacts of climate change, which is identified as a corporate Strategic Risk. For example, data on projected sea-level rise from the Shoreline Management Plan have been used to identify local critical infrastructure likely to be affected by flooding within the Severn Estuary in order to prioritise resilience planning.

Source: Gloucestershire County Council

2.4 Conclusions

This chapter has applied the ASC toolkit to assess progress in preparedness for flood risk in England in a changing climate by:

- Using indicators to identify how exposure and vulnerability to flood risk have changed in recent years and establish the current level of adaptation action underway in England.
- Evaluating preparedness for future flood risk by assessing how key decision-makers are accounting for climate change, and whether or not their decisions are leading to adaptation action that is proportionate to the scale of risk.

Indicators show a number of socio-economic trends increasing exposure and vulnerability to flooding. At the same time adaptation actions are being implemented that could be offsetting the risk.

- **Development in the floodplain is continuing and at a faster rate than that for development elsewhere.** However, the reduction in the development rate in the coastal floodplain and in areas at risk from coastal erosion could be evidence that decision-makers are starting to site new development away from higher-risk areas in some parts of the country.
- **The majority of floodplain development is in areas that are already well-protected by flood defences**. Investment in new or enhanced flood defences has reduced the net number of households at significant risk since 2008, even after accounting for new development in these areas. However, continued development in the floodplain is locking in a commitment to long-term investment in flood protection. Furthermore, if these defences fail, the consequences of a flood event will be increasingly severe.

90 Severn Trent Water (2007).

- **One fifth of floodplain development is in unprotected or poorly protected areas.** Here the probability of flooding is already high and is likely to get even higher with climate change. Development in these areas may have incorporated resilient design features, although property-level measures are not likely to be effective in the case of major flood incidents. Some of the country's most vulnerable communities are located in areas with a significant chance of flooding, and so are at disproportionate risk. This could have an impact on the affordability of flood insurance.
- **The majority of floodplain development is likely to be safe and not increasing flood risk downstream.** The Environment Agency's advice appears to be influencing decisions on individual development applications, although the outcome is not known in more than a third of the cases where they raise an objection.
- **Hard surfacing is continuing to replace permeable greenspace in urban areas, mainly through the paving over of gardens**. This will increase the risk of surface water flooding. Continued development in areas at risk of surface water amplifies the consequences of these types of floods, which cannot be predicted and planned for in the same way as river and coastal flooding.
- **The current deployment of sustainable drainage systems is unlikely to be sufficient to reduce the increasing risk from surface water flooding.** Around half of all new development includes SuDS and there has been on-going investment in the conventional drainage network. But given new development only comprises around 1% of the urban environment each year. This by itself is unlikely to mitigate the risk from continued urban creep.

Adaptation action to reduce the consequences of flooding can moderate some of the effects of increasing exposure and vulnerability on risk. However, these actions each have their own set of strategic challenges.

- **Trade-offs with other objectives.** The floodplain is generally still seen as a desirable location for development, in part because established and productive communities are already located there. The costs of relocating to areas of lower risk are seen as prohibitive or undesirable for other reasons. Local authorities and the Environment Agency mostly interpret policy to mean that development in the floodplain should continue, but in a way that minimises damages. As a result, relatively little effort is taken to strategically identify alternative locations at lower risk. Continuing to build in the floodplain will leave a legacy of rising costs of protection and flood damage in the face of climate change. These long-term costs may outweigh the benefits of development in some locations.

- **Adaptation action commensurate with the scale of risk.** Flood management in England was one of the first sectors to embed an understanding of climate change into its policies. However, given the latest evidence from the CCRA on the scale of future flood risk and its uncertainty, our analysis raises questions about whether sufficient action is underway to manage the risks from flooding. We observed:
  - **Low uptake of some sensible low-regret measures**, such as property-level flood protection, sustainable drainage systems and flood warnings. There are likely to be a number of market, institutional and behavioural barriers could be preventing uptake (summarised in Table 2.3).
  - **Current investment in flood defences will not keep pace with the increasing risk of flooding.** Climate change could almost double the number of properties at significant risk of flooding by 2035 unless there is additional action. The Government should either support increased investment in flood defences from public or private sources, or identify ways to manage the social and economic consequences of more frequent flooding.

Chapter 4 explores these findings further in the context of the UK Government's National Adaptation Programme.

Table 2.3: Assessment of barriers to uptake of SuDS and Property Level Protection Measures, taken from ASC (2011a) and Department for Environment Food and Rural Affairs (2011a).

	Property-Level Protection	Sustainable Drainage Systems (SuDS)
Insufficient information and externalities	**Consumers feel they do not have information about the best products.** Consumer awareness of products is still very varied. In addition, consumers often do not know the severity of the flood risk that their property faces. Acquiring and processing information incurs a hidden cost in terms of time and money spent finding the right product, sourcing reputable providers, costs of disruption, and differences in quality of the product and service. **In new builds and rented accommodation, there is a misalignment of incentives between developers/owners and occupiers.** It is the occupiers who may bear most of the cost of flood damage and so developers/landlords are not motivated to invest in property-level measures. Similarly, homeowners are unlikely to remain in the same home throughout the lifetime of the products. This means they will not accrue the full benefits of measures, although they incur the full cost (assuming that the benefits are not reflected in the property value).	**There is a lack of consistent standards for developers to identify affordable drainage that is fit-for-purpose.** The perception that SuDS are expensive persists. **The benefits of SuDS usually accrue downstream**, rather than to the individual making the upfront investment. This leads to little incentive for an individual to retro-fit.
Misaligned policies and institutional arrangements	**Households will be more likely to take action early if there are clear financial incentives to do so,** for example if they face a reduction in the costs of insurance or if they avoid uninsured and non-monetary losses (such as distress). Insurers may reduce the excess for properties that install flood-resistant products, but rarely the premium, in part because the measures have not yet been tested in real floods.	**There is a lack of a coherent policy framework to address ownership and ongoing maintenance arrangements.** Currently, developers or local authorities have to finance maintenance throughout the lifetime of the SuDS, whereas the maintenance cost is picked up by the water company for conventional drainage.

Table 2.3: Assessment of barriers to uptake of SuDS and Property Level Protection Measures, taken from ASC (2011a) and Department for Environment Food and Rural Affairs (2011a).

	Property-Level Protection	Sustainable Drainage Systems (SuDS)
Behavioural barriers	**Many residents and business owners feel that managing flood risk is not their responsibility.** Householders may not invest in property-level flood protection measures if they are already protected by structural flood defences, or believe the Government will provide such protection in the future. Flooded households are much more likely to take flood management steps than non-flooded households (27% and 6% respectively). **Residents often express concerns about impacts on the appearance and resulting saleability of the property and not wishing to be reminded of flood risk.** Community engagement for the Defra Grant Scheme was found to be key.	**There is evidence of behavioural inertia among developers.** Surface run-off has traditionally been drained into sewers, which means that foul water and surface run-off are often viewed as one problem and SuDS are not seriously considered.
Lack of adaptive capacity	**Many residents and business owners find the upfront cost of protection is too high and outweigh the uncertain benefits.** Many lack the funds to afford the capital cost of fitting their home with a full package of property-level measures. More vulnerable people located in areas of flood risk are less able to afford protection.	**Developers are faced with the whole-life cost of SuDS (where ongoing financing is not possible) a disincentive to the use of SuDS compared to conventional drainage**, for where maintenance is automatically taken on by water companies. In some cases, the lack of maintenance arrangements has given rise to 'orphan' SuDS.

Chapter 3

Chapter 3
Water scarcity: assessing preparedness for a changing climate

3.1 Overview

This chapter updates the ASC's 2011 assessment of progress in preparing for climate change in the water sector. The focus is on England, although the lessons may be relevant to other parts of the UK.[1] Together with risks from flooding, water supply-demand deficits driven by the combined effects of climate change and population growth were identified as a significant risk in the Climate Change Risk Assessment (CCRA).[2] They were also highlighted as significant in the Environment Agency's Case for Change report.[3] There have been important developments in water policy since the ASC's last report in 2011, including the publication of Defra's Water White Paper.[4]

In line with our analytical framework (Chapter 1), this chapter:

- summarises vulnerability of the public water supply system to the current climate;
- summarises future risks of supply-demand deficits from climate change, based on the latest evidence from the CCRA and Environment Agency analysis;
- compares the scale of risk outlined by the CCRA with current water company plans for addressing future water scarcity;
- examines further adaptation action that could be important for dealing with a range of plausible future deficits, focussing on indicators for water efficiency, uptake of metering and losses from leakage; and
- considers the latest evidence on future demand from water users outside of the public water supply system (such as power stations, heavy industry and agriculture) and the implications for the natural environment.

In Chapter 4, we draw on this evidence and analysis to provide advice on where the UK Government's National Adaptation Programme could enable further action.

1 In most cases, data have been provided for England and Wales together as it is difficult to separate out.
2 HR Wallingford (2012a), for the Department for Environment, Food and Rural Affairs.
3 Environment Agency (2011b).
4 Department for Environment, Food and Rural Affairs (2011a).

Box 3.1: Management of water supply (England and Wales)

Water resources management in England and Wales is governed by a number of different regimes:

Public water supply is managed through private water companies, and regulated by Ofwat (economic regulation), the Environment Agency (environmental regulation), and the Drinking Water Inspectorate (drinking water quality). Climate change must be taken into account in Water Resources Management Plans, which are produced by each water company every 5 years and look 25 years ahead. Some water companies have opted to do longer term planning (for example as part of the Adaptation Reporting Power process). Companies also have to produce business plans, which are used by Ofwat to set water prices in 5-year blocks. The next Periodic Review due in 2014 will dictate how much companies can invest in supply and demand-side measures over the coming 5 years (see section 3.4). Water companies have in the past also reported annually to Ofwat on numerous metrics related to their business operations through the June Returns process. From 2012 this has changed to a shorter set of Key Performance Indicators.[5]

Other abstractors outside of the public water supply system (such as power stations, irrigation, and fish farms) are subject to the abstraction licensing regime operated by the Environment Agency. The current system was designed in the 1960s. The Water White Paper included proposals for reforms to ensure that the system is flexible enough to deal with the future challenges of water scarcity, particularly from climate change. More details are given in section 3.6.

Natural environment issues are covered largely under the EU's Water Framework Directive. They are implemented through River Basin Management Plans, for which the current cycle ends in 2015. The Government reports annually on the environmental status of freshwater bodies through a number of environmental and chemical status indicators.

For a more detailed description of the policy landscape, see the CCRA Water Sector Report (2012).[6]

3.2 Vulnerability to current climate

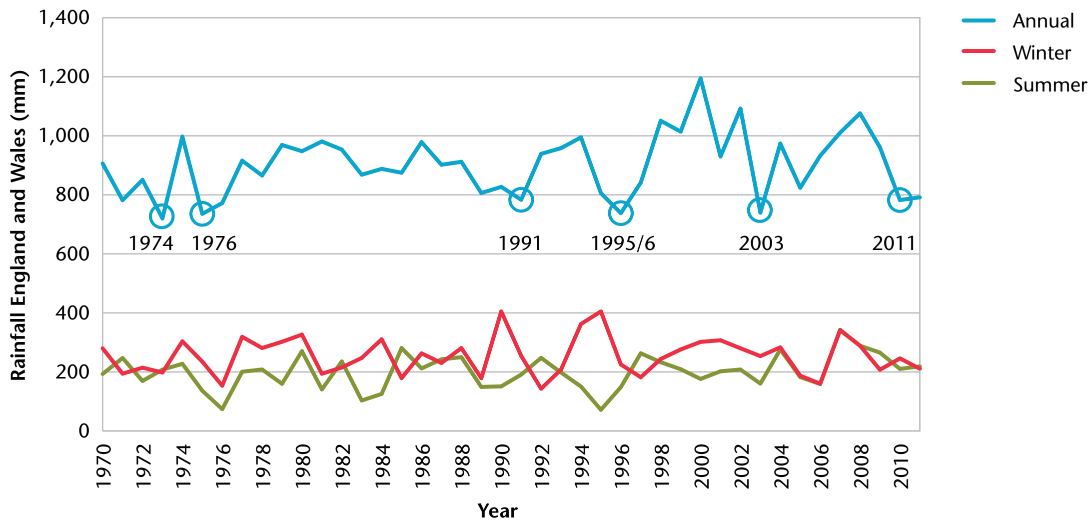
There are multiple demands on the total water supply available in the UK. Demand from people (household and business water supply, agriculture, and industry) needs to be balanced against the underlying requirement to maintain a healthy natural environment. Finding the right balance is not straightforward, and current levels of abstraction are putting undue pressure on the natural environment in some catchments.[7]

Drought events[8] currently occur every 7 years on average in England and Wales.[9] In recent years, drought conditions have tended to coincide with annual rainfall totals under 800mm, as shown in Figure 3.1.

Standpipes have not been required to a significant extent since 1976. Less restrictive measures such as hosepipe bans and drought orders have been implemented more frequently, including in this year's drought (Box 3.2).

5 http://www.ofwat.gov.uk/regulating/prs_web201203regcompliance
6 HR Wallingford (2012c) for the Department for Environment, Food and Rural Affairs.
7 Environment Agency (2010).
8 "Drought" and "water scarcity" have different meanings. Droughts occur where there is a temporary decrease in water availability due to low rainfall over a given period. Water scarcity occurs where there is insufficient water to meet demand, and can be influenced by the prevalence of drought conditions, but also other factors such as high population density. Water scarcity is quantified in terms of the supply-demand balance. A comparison of the two terms is available here http://ec.europa.eu/environment/water/quantity/about.htm.
9 There have been no significant trends in rainfall over the observed record, unlike for temperature, and it is not possible to attribute the 2012 or other droughts to climate change. See Jenkins et al (2008).

Figure 3.1: Annual, plus summer and winter observed precipitation for England and Wales (1970-2011)



Source: Met Office.
Notes: Recent drought years (1976, 1991, 1995/6, 2003, 2011/12) are characterised by annual rainfall of less than 800mm (circled years).

The risk of more serious problems increases when winter rainfall is low for more than one year in a row, as this prevents reservoirs and aquifers from being replenished. While the impacts of the 2012 drought have been relatively modest due to spring rain, water companies, the Environment Agency and the Government are concerned that a third dry winter could bring increased pressure on water resources, including public water supply, in some areas.[10]

There is a lack of systematic data on the costs to businesses, agriculture and the natural environment from droughts, though studies have been conducted on individual events. For example:

- In the drought of 1976, standpipes had to be introduced as demand increased up to 140% above average levels. This was coupled with vastly reduced supply.[11]
- The drought and associated heat wave of 1995 resulted in estimated economic losses worth £180 million for agriculture, £96 million for water supply and £380 million for the retail sector.[12]
- Economic impacts from the 2012 drought included reduced farm incomes due to changes in cropping practice. Some small businesses suffered in the horticulture, swimming pool and domestic cleaning sectors due to temporary use restrictions introduced in some areas. No discernible impacts on GDP, prices or inflation have so far been detected.[13]

10 http://www.environment-agency.gov.uk/news/138916.aspx
11 Rodda and Marsh (2011).
12 Palutikof et al. (1997).
13 Department for Environment, Food and Rural Affairs, upcoming report on the economic impacts of the 2012 drought.

As well as potential restrictions on water use for customers, the natural environment can be severely affected during drought events. Water scarcity has impacts on the availability of food and habitats for certain species, both through reducing water availability and water quality.[14] The Environment Agency and Natural England undertake continuous monitoring to assess the adequacy of measures in place to limit the impacts of droughts on the natural environment.[15]

Box 3.2: Examples of reported impacts on the environment, people and businesses from the 2012 drought

- Seven companies imposed hosepipe bans on customers in spring 2012. This is roughly in line with the number of restrictions imposed in previous droughts.
- Dry winter conditions meant that many winter storage reservoirs on farms were only partially filled, causing farmers in some locations to apply to the Environment Agency for additional abstraction allowances to increase their water supplies for crops and livestock.
- "Hands Off Flows" abstraction license restrictions were also put in place for some farmers in the Midlands, East Anglia and the South-East.
- Reports of watercourses drying up were received from locations in Herefordshire, Gloucestershire, Oxfordshire and Yorkshire.
- Severn Trent and Anglian Water are discussing the option to transport water, if required, from the Birmingham groundwater sources to help ease water shortages in the Anglian Water region. This system could transport up to 30 million litres per day (Ml/day).
- Drought permits were granted to several water companies. This included measures to help Southern Water refill Bewl Reservoir, which was down to 40% capacity in early March, using water from the Medway.
- There were a series of reports on adverse impacts on wildlife from the drought conditions.[16] The Environment Agency undertook several exercises to move fish in distress in Derbyshire, Hertfordshire and North Yorkshire.

Source: Environment Agency Drought Management Briefings.

16

3.3 Future risks to the supply-demand balance in public water supply

The Climate Change Risk Assessment (CCRA) identified a high level of uncertainty associated with risks to future water availability, but with some risk of a deficit in most regions in the near-term.[17]

The projected supply-demand deficits in the CCRA for England and Wales range from -15 to -3100 million litres per day (Ml/day) for the period 2010 – 2039 (characterised as the "2020s").[18] There are regional variations, with the largest deficits in the Thames and Humber river basins (Table 3.1). These calculations use the probabilistic information in the UK Climate Projections (UKCP09), which gives a much more detailed treatment of uncertainty than previous projections used in water resources planning.[19]

14 http://www.rspb.org.uk/news/306161-drought-warning-for-wildlife
15 Environment Agency (2012).
16 http://www.environment-agency.gov.uk/news/138161.aspx
17 It should be noted that like other climate modelling studies the CCRA does not quantify all possible uncertainties, and therefore the projections themselves are uncertain. The supply-demand deficit projections in the CCRA were assigned a medium confidence rating in the final Evidence Report. There is more confidence in projections of future changes in average supply-demand deficits than in future changes in drought frequency and intensity, so this is the focus of our analysis looking into the future.
18 These baseline projections assume no additional adaptation, including no water sharing, and are based on an average consumption per person of 150 l/day. Population growth is included in the projections, using a principal population growth projection from the Office for National Statistics. The CCRA river basin areas are different to those areas used in water company plans.
19 http://ukclimateprojections.defra.gov.uk/

Table 3.1: CCRA regional projections of supply-demand deficit (Ml/day) for England and Wales

UKCP09 river basin region	Surplus (positive values) or Deficit (negative values) in Ml/day			
	Baseline (2009/10)	CCRA low projection 2010-2039	CCRA mid-projection 2010-2039	CCRA high projection 2010-2039
Anglian	96	-13	-212	-429
Dee	8	no deficit	-4	-24
Humber	105	-2	-305	-643
Northumbria	212	no deficit	no deficit	no deficit
North West England	63	no deficit	-95	-461
Severn	106	no deficit	-138	-357
South East England	162	no deficit	no deficit	-26
South West England	68	no deficit	-13	-75
Thames	59	no deficit	-478	-1040
Western Wales	50	no deficit	no deficit	-27
Total (England and Wales)	**No Deficit**	**-15**	**-1245**	**-3082**

surplus or no deficit

deficit = -1 to -499 Ml/day

deficit = -500 and over Ml/day

Source: HR Wallingford (2012c) for the Department for Environment, Food and Rural Affairs.
Notes: These projections assume:
- no sharing of water, meaning surpluses in some regions do not cancel out deficits in others,
- average consumption per person of 150 l/day, and
- total population size of 61 million for England and Wales. For the 2020s, the effects of population growth contribute to around 70% of the deficit for the mid projection, but only 30% for the high projection (with climate change contributing to the remainder).

All results for the period 2010-2039 ("the 2020s") use a medium greenhouse gas emissions scenario only, as there is no difference between different emissions scenarios for this time period. For the 2050s, the total deficit increases to between -2100 Ml/day (low projection under a low emissions scenario) to -8200 Ml/day (high projection under a high emissions scenario).

The high levels of uncertainty in predicting the impact of future climate change on water availability present a challenge for adaptation planning (Box 3.3).[20] This is particularly problematic because water infrastructure is very long-lived, and therefore decisions made now have consequences far into the future.[21]

20 Climate change is not always the largest source of future uncertainty for water companies, but is generally amongst the top five key sources of uncertainty.
21 Ranger et al. (2010).

Box 3.3: Uncertainties in projections of rainfall

The latest set of climate projections for the UK (UKCP09) show increases in winter precipitation and decreases in summer rainfall on the whole. UKCP09 goes much further than the previous set of scenarios (UKCIP02) in quantifying uncertainties in these results. There are four important caveats to interpreting the outputs:

1 the projections for summer rainfall show modest probabilities of increases, alongside the much larger probabilities for decreases. This means there is uncertainty around the sign of change;

2 there is a very large range for both summer and winter rainfall as shown below;

3 the effects of short-term climate variability are not taken into account, as all of the results are thirty-year averages; and

4 the projections are likely to underestimate the effects of processes not well simulated in the models, such as the effects of the stratospheric circulation on surface climate, and the impacts of possible changes in the frequency of multi-year droughts or blocking episodes. Therefore, not all uncertainties are quantified.

Water resources planners have to bear in mind that the actual future climate could fall outside of these projections, and therefore even planning for this full range does not entirely cover every eventuality. In addition, transferring climate projections into impacts models for processes such as groundwater and river flows introduces further uncertainties.

The Met Office plan to assess the reliability of the UKCP09 projections in the light of more recent climate model projections run for the IPCC Fifth Assessment Report in 2013.

Source: Met Office.

3.4 Current action to prepare for future supply-demand deficits

The latest water company plans from 2009 calculated a baseline supply-demand deficit for England and Wales of about 1300 Ml/day in 2035 (about 7% of total public water supply for 2010), which is roughly equivalent to the CCRA mid-range scenario.[22] The analysis suggested that around half of water resource zones would have a supply-demand deficit in 2035 if no action was taken to reduce the risk, with the largest deficits in the Thames and Severn Trent regions.[23] (In 2012, water companies calculated that around 13% of water resource zones were at risk of supply-demand deficits).[24]

Water companies also put forward proposals to deal with the deficit in their regions. Collectively, these increase supply by around 720 Ml/day, reduce demand by around 440 Ml/day, and decrease leakage by around 240 Ml/day across England and Wales by 2035. These potential measures are sufficient to cancel out both the low and medium CCRA deficit projections at the national scale, though not the high-end estimate of risk (Figure 3.2).

The next round of Water Resource Management Plans, due in 2014, provides an opportunity to review the proposals in light of UKCP09, which was used in the CCRA.[25]

22 These deficits, and those described for the CCRA, are for public water supply only (and do not include other types of abstraction). They assume no additional action to reduce the deficits over and above the situation in 2009. The projections include the effects of population growth. The supply-demand balance is taken to be the difference between water available for use, and demand in a dry year (with head room built in which estimates, among other things, uncertainties in future climate change).

23 Data taken from 2009 Water Resources Management Plans. Baseline per capita consumption levels for 2035 varied across companies from 128 to 166l/d. The climate information used was based largely on the UKCIP02 climate scenarios.

24 Data taken from 2009 Water Resource Management Plans.

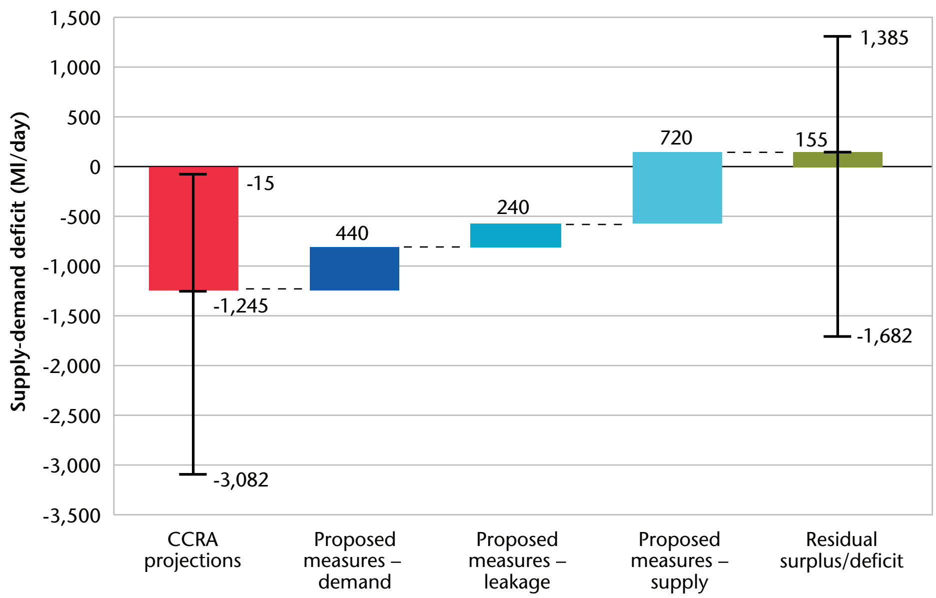
25 The CCRA projections themselves are not intended to be used in the place of the more detailed models used in water resources planning. They give an indication of the scale of uncertainty that will be present in the updated climate information which water companies will use in the next round of water company plans in 2014.

Generally speaking, water companies are being directed to consider a mid-range climate scenario out to 2040, or a high-end scenario for those more vulnerable to future deficits.

Ofwat must decide what proportion of the proposals put forward by water companies should be funded in each 5-year Price Review. This presents a difficult balancing act, as much of the cost for new measures has to be recouped from customer water bills. In the last Price Review in 2009, Ofwat allowed water companies to invest in supply and demand measures (including leakage) worth £1.8 billion between 2010 and 2015. This is equivalent to around 320 Ml/day, or 23% of the total proposals put forward for 2035.[26] The allowance did not include specific measures to address the risks from climate change, as the UK Climate Projections (UKCP09) had only just been published in 2009, and water companies had not had time to analyse the new information.

Both the CCRA and Environment Agency's Case for Change analysis show a marked intensification of supply-demand deficit risk for the 2050s and 2080s (see notes under Table 3.1). Considering long-term climate change is important for ensuring that plans are put in place early enough to respond adequately to the range of risks that may materialise in the 2050s and beyond. Although there is no legal requirement to look beyond 25 years in their plans, some water companies have opted to undertake longer term planning (for example as part of the Adaptation Reporting Power process).

Figure 3.2: Comparison of CCRA projected supply-demand deficit risk (left) with water company proposals out to 2035 for supply and demand measures to reduce the deficit (middle three columns).



Source: HR Wallingford (2012c) for the Department for Environment, Food and Rural Affairs; and 2009 Water Resources Management Plans.
Notes: The far left box plot shows the mid-range CCRA deficit projection for the 2020s (2010-2039) in red, with the error bar showing the range of deficit from the low to the high projection. The blue boxes show the total effect in Ml/day of proposals to reduce demand and leakage, and increase supply from the 2009 Water Resource Management Plans (these do not include the effects of autonomous adaptation). The residual surplus/deficit under each of the three CCRA projections, having applied the combined water company proposals for England and Wales, is shown on the right in green. Population growth estimates for England and Wales for the 2020s are included in the CCRA estimates. They give an increase in population to 61.3 million in the 2020s compared to 55 million in 2010.

26 Ofwat (2009).

Scenario planning for a high impact, low probability scenario would also be useful in order to identify when in the future decisions should be made on whether more extensive adaptation measures are needed, and to compare the robustness of long-term plans against uncertainties.[27]

3.5 Using indicators to assess the potential for further adaptation

Managing demand for water is about both reducing unnecessary consumption, and making consumption more responsive to changes in supply. Demand management is a low-regret strategy to take in the face of large uncertainties regarding future water availability.[28]

Demand measures such as low-flow showers or taps, basic rainwater harvesting and dual-flush WCs are classed as a low-regret adaptation option as they:

- provide benefits today and against any future deficit;
- defer the need for costly investments in new supply infrastructure which is more vulnerable to future uncertainties in climate change and population growth;[29] and
- provide co-benefits by reducing costs of water supply to metered households, reducing the amount of energy required to heat water in the home,[30] [31] and decreasing pressure on freshwater habitats from abstraction.

Supply-side measures such as the amount of water shared between water companies are also useful to monitor, as demand measures are unlikely to be sufficient on their own to address the risks from climate change. In future, the ASC plans to collect more data for indicators for supply measures, including total reservoir capacity and extent of water sharing.

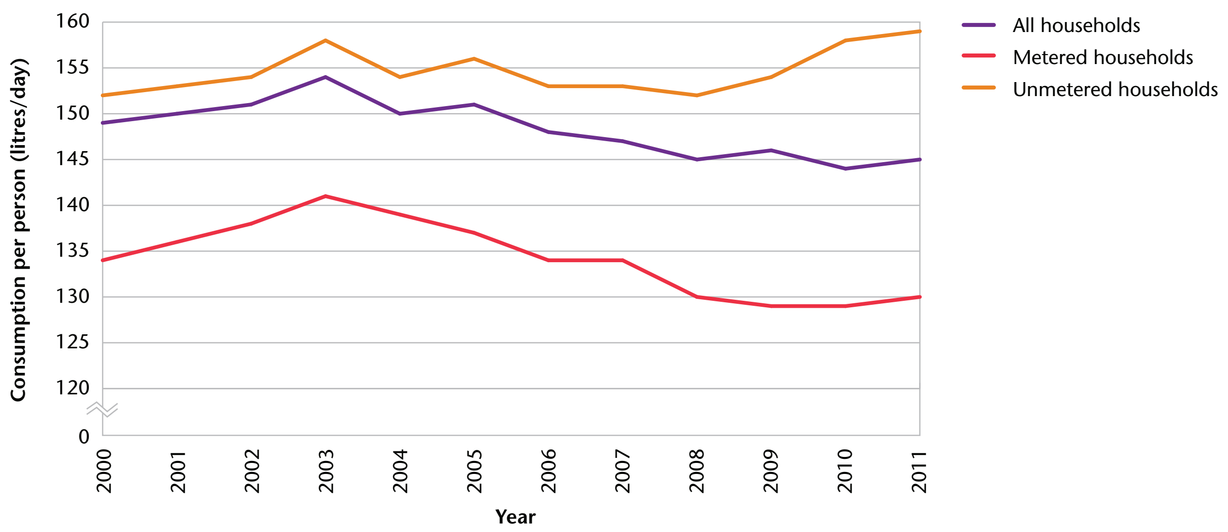
A summary of the latest trends is presented here, followed by a discussion on implications.

Water consumption per person

Current consumption per person[32] **in England is around 145 l/day on average (Figure 3.3). It has fallen from around 150 l/day in 2000.** There was a slight increase in overall consumption in 2011 compared to 2010. While metered consumption is lower than the average and is generally falling, unmetered consumption appears to have risen to its highest level for the last 11 years.[33] Regional averages vary significantly from around 110 to 185 l/day.[34]

27 Research is underway more widely to look at how the water resources system might react to more extreme climate change through research programmes such as the EPSRC's Adaptation and Resilience to a Changing Climate programme.
28 ASC (2011a). A case study with Thames Water showed that understanding the full range of climate change uncertainty builds the case for low-regret measures such as increasing water efficiency by households.
29 Ranger et al. (2010).
30 There is work going forward through the Green Deal, and by the Bathroom Manufacturers Association, to incentivise these win-win benefits of reducing water consumption.
31 Three Regions Climate Change Group (2008).
32 Consumption per person (per capita consumption) is the average amount of water consumed per person in their household from e.g. washing, drinking, cooking and gardening. It does not include water consumed outside of the household supply, or the water consumed which is embedded in products such as food.
33 This may be due to a flow of population with lower average consumption moving from the unmetered group to the metered group, which would drive up the average; but it could also be due to an actual rise in consumption.
34 This range is the lowest metered regional average to the highest unmetered regional average.

Figure 3.3: Trends in consumption per person – England (2000-2011)



Source: Ofwat.
Notes: Metered consumption is measured; unmetered consumption is estimated based on measurements of deployable output, metered consumption and leakage. Those households that choose to fit a meter tend to be those who have lower consumption. As there is a flow of population from the unmetered to the metered category, the average consumption of the unmetered category can increase as the more efficient customers move into the metered category, without changing overall consumption (purple line). It is not known if the rise in unmetered consumption is due to those with lower consumption moving to the unmetered category, or an actual increase overall.

If the trend seen since 2000 continues, consumption would fall to 130 l/day by 2035. This is both realistic and desirable as outlined by the three points below.

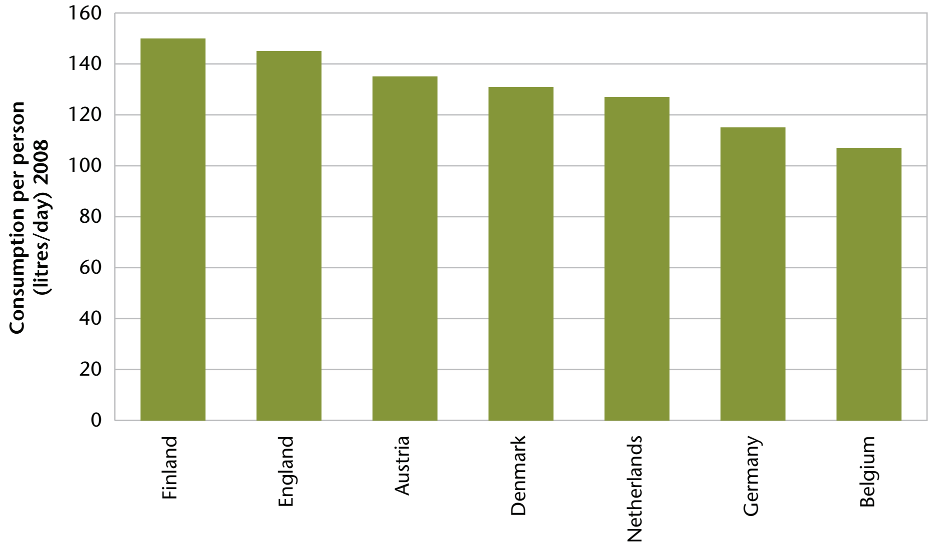
1. Reducing average consumption per person by 15 l/day or more appears readily achievable through uptake of water efficiency measures. ASC analysis from 2011 suggested that uptake of cost-effective water-efficiency measures, such as low flow showers and dual flush WCs, could reduce consumption to 115l/day from a baseline of 160l/day (which is higher than current average consumption). Empirical trials[35] suggest that water efficiency measures can reduce household consumption by an average of 20-40 litres, which roughly equates to 9 to 17 l/day per person.

2. Other north-west European countries tend to have lower consumption levels (Figure 3.4), suggesting there is scope for further efficiency improvements in England. Variations in socio-economic conditions, infrastructure systems and policy frameworks may explain this difference. All countries shown in Figure 3.4 with the exception of England have universal metering.

3. According to the CCRA, reducing average consumption per person by 13 l/day (from 150 l/day to 137 l/day)[36] in the 2020s could reduce the deficit by around 700 Ml/day; half of the deficit in a mid-range climate scenario, and around one quarter in a high climate scenario (Figure 3.5). This level of reduction is higher than current water company proposals for demand reduction measures of 440 Ml/day (see Section 3.4).

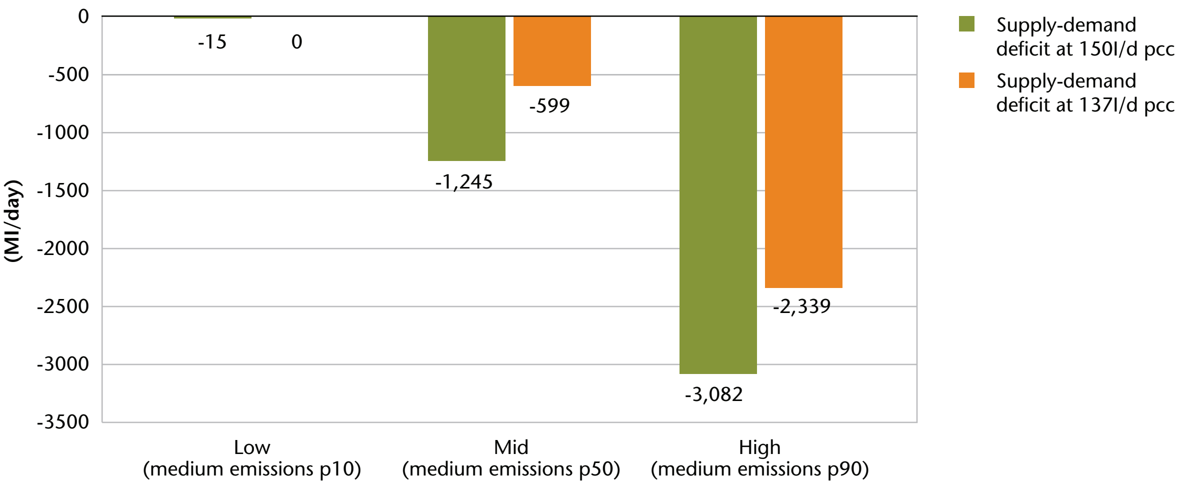
35 Waterwise (2010).
36 This is roughly equivalent to reducing consumption per person from today's average of 145 l/day to 130 l/day (i.e. a reduction of 15 l/day).

Figure 3.4: Comparison of consumption per person in England with other North-Western European Countries (2008)



Source: Environment Agency (2008).
Notes: The climate of the countries chosen for comparison by the Environment Agency are relatively similar to England, but differences in water management policies, infrastructure systems and socio-economic conditions makes it difficult to make direct comparisons.

Figure 3.5: The effects on supply-demand deficit of a reduction in per capita consumption (pcc) from 150l/d to 137l/d for England and Wales (2010-2039)



Source: Source: HR Wallingford (2012c) for the Department for Environment, Food and Rural Affairs; and 2009 Water Resources Management Plans.
Notes: These projections assume no additional adaptation over and above today's levels. Projections show the range across a Medium (IPCC A1B) emissions scenario. Population growth estimates for England and Wales are 61.3million in the 2020s compared to 55 million in 2010, which are included in the CCRA estimates.

Trends in water metering

Having a price for water that reflects the volume used provides a foundation for effective demand management. Metering is required to achieve this. This will be particularly important in locations with a growing risk of supply-demand deficits. There are legal barriers to water companies rolling out universal metering[37] in these areas now, and wider concerns over affordability for some customers.

One important lever for demand management is effective pricing, which is needed to act as a signal of the value and availability of water to consumers. A necessary condition for effective pricing in public water supply is metering.[38] Water meters allow customers to pay for the water they use, rather than a flat rate tied to house size or value. This in turn means that the price paid can be tied to consumption, providing households with a financial incentive to reduce water use. It provides a better mechanism to link the price of water to its scarcity, because the price can respond to how much a customer uses against how much water is available in a particular region or at a particular point in time.[39] It also offers the flexibility to react to seasonal or regional supply-demand imbalances.

We know from other sectors (such as energy) that consumers react to price signals, although this may have to be complemented with flanking measures (such as information and advice) to increase responsiveness on demand ("elasticity") to price changes.[40]

Around 40% of households in England and Wales are currently metered, with the uptake of metering increasing at a rate of about 2% per year (Figure 3.6). If this trend were to continue, 85% of households would be metered by 2035.

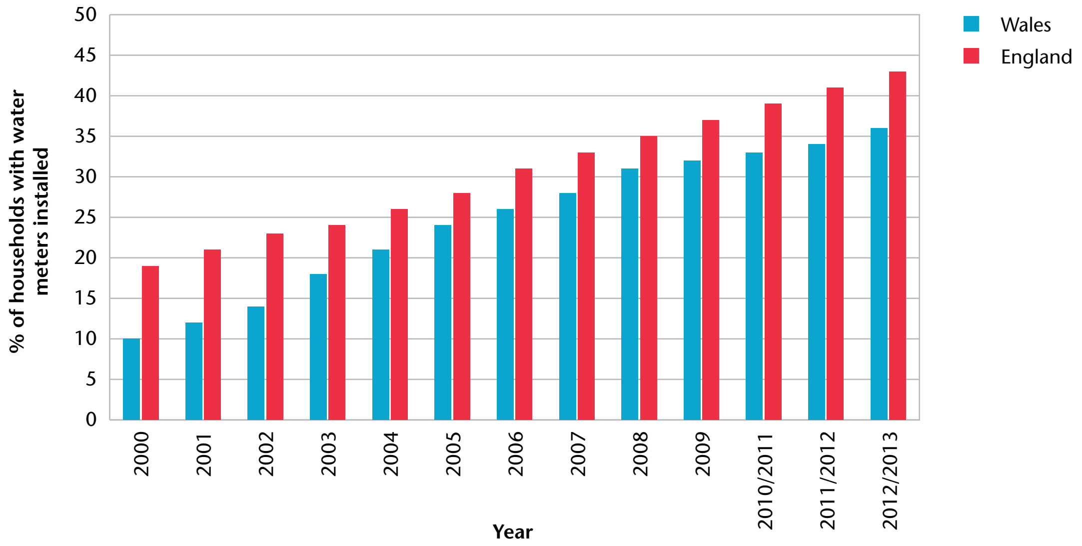
Given the risk of supply-demand deficits in the 2020s, this rate of progress would help enable effective demand management if concentrated in areas most at risk (see Table 3.1). We will continue to monitor trends in the uptake of metering. Further policy intervention may be required if the rate of uptake starts to level off, for example because high-use consumers of water choose to stay unmetered.

The current legal framework that determines where water companies can roll out universal metering may act as a barrier to effective adaptation. There are two main issues:

1. **Factoring in climate change when identifying regions with a supply-demand deficit.** As supply-demand deficits vary across the country, the regional pattern of metering is as important as the total level of metering. Under current legislation, universal metering can only be considered by water companies in areas that are designated as seriously water stressed, as the costs and benefits of installing them universally elsewhere are not clear cut. The current definition of water stress includes consideration of population growth and resource availability, but not the effects of future climate change.[41] Some areas with high projected deficits in the future due to climate change have a relatively low uptake of metering at present (Figure 3.7). Under the current system, some of these areas cannot undertake universal metering now, even though the risk of supply-demand deficits in the near-term is high.

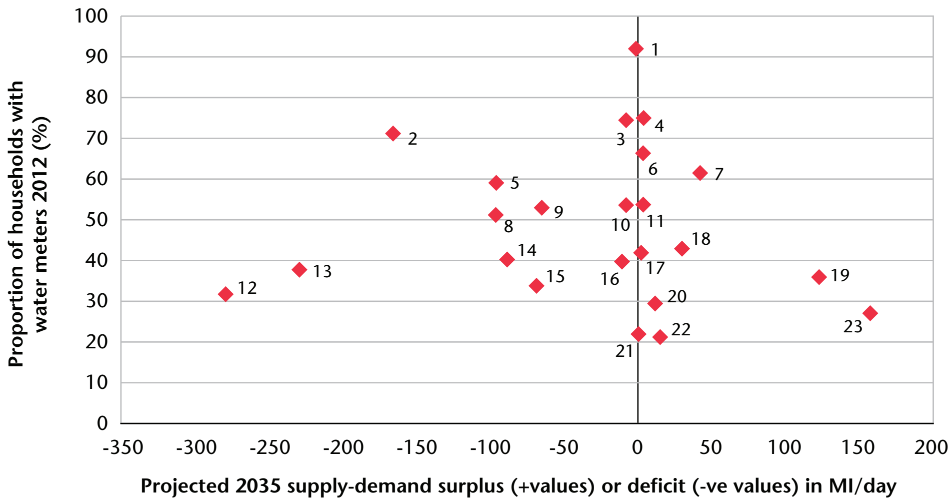
37 "Universal metering" implies that the vast majority of households (e.g. over 90%) are fitted with water meters. It does not imply that every single household has a meter installed, as some dwellings such as blocks of flats are difficult to fit with individual meters.
38 See Section 3.6 for a discussion on non-public water supply.
39 Walker (2009).
40 Waterwise (2011).
41 Defra and the Environment Agency are currently reviewing the definition of water stressed areas.

Figure 3.6: Percentage of households with Water Meters in England and Wales



Source: Ofwat.
Note: These figures are cumulative totals.

Figure 3.7: Percentage of households with meters in 2012 compared to 2035 supply-demand balance projections from 2009 water resource management plans, by Water Company (England and Wales)



Source: 2009 Water Resource Management Plans and Ofwat.
Notes: Each point on the graph represents a different water company region. Note that this plot only uses the Water Resource Management Plan estimates of supply-demand deficit, and not the CCRA analysis, as the regions differ in the CCRA and cannot be directly compared against water company areas. 1 Veolia Water South East; 2 Anglian; 3 South West; 4 Veolia Water East; 5 Southern; 6 Cambridge; 7 Sembcorp Bournemouth; 8 South East (including Mid Kent Water); 9 Essex & Suffolk; 10 Wessex; 11 Dee Valley; 12 Thames; 13 Severn Trent; 14 Bristol; 15 United Utilities; 16 Sutton & East Surrey; 17 Veolia Water Central; 18 Yorkshire; 19 Dwr Cymru; 20 South Staffordshire; 21 Cholderton; 22 Portsmouth; 23 Northumbrian.

2. **Exploiting economies of scale in rolling out water meters.** The Walker Review[42] concluded that near-universal metering could be achieved by 2030 without a planned rollout if there was enough voluntary uptake. However, the review highlighted that the lower installation costs (economies of scale) under a systematic rollout of metering could save between £600 million and £1.5 billion nationally compared to the current system. Allowing companies to consider universal metering now in order to deal with the risks from climate change in the short-term could allow these cost savings to be realised.

The Government is concerned about the impacts of metering on water affordability for some customer groups.[43] Without some flexibility in the tariff, large households in properties with low rateable values would see their bills rise to reflect their actual water consumption if they transferred to a meter. To address this issue, water companies are trialling more innovative approaches, such as seasonal tariffs and rising block tariffs,[44] as well as social tariff schemes.[45] These would lower charges for customers who might otherwise struggle to afford their bills. The outcomes of these trials will help to establish how metering can be rolled out without adversely affecting some households.

Leakage

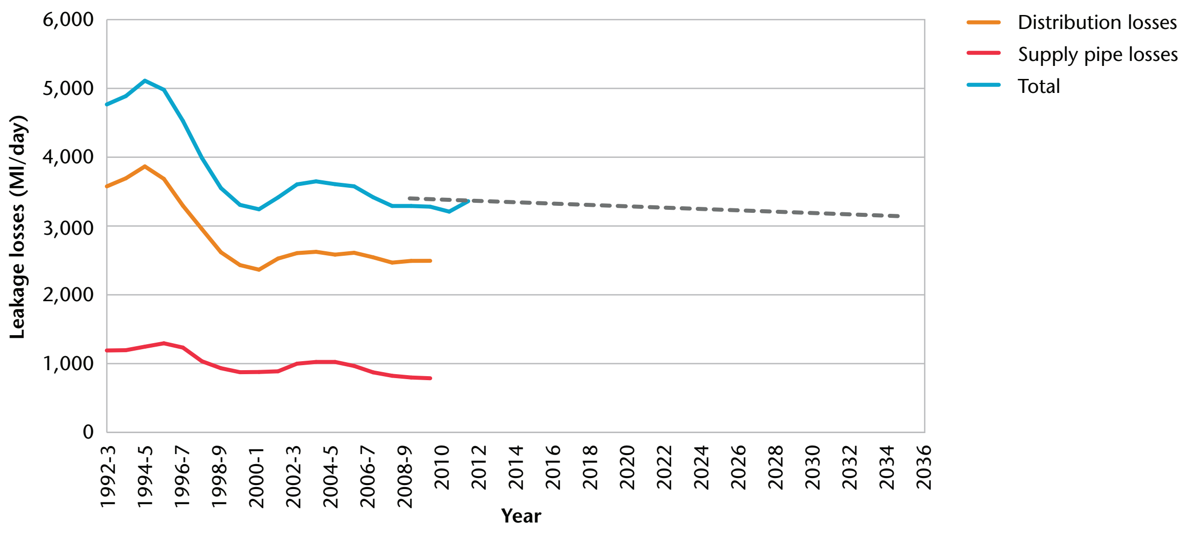
Leakage rates[46] fell sharply after the drought of 1995 (Figure 3.8) but have since levelled off at around 22% of total public water supply. There was a slight increase in leakage rates in 2010 and 2011 when cold winters caused more pipes to burst.[47] Leakage rates in cities in England and Wales (around 25% of supply) fall within the range of other European cities, where leakage levels vary from 5% to 50% of total supply.[48]

Ofwat has approved investments to provide a modest reduction in leakage of 97 Ml/ day[49] (or 2% of current leakage) between 2010 and 2015, stating that more ambitious targets would represent poor value for customers and the environment based on current evidence.[50] Current water resource management plans suggest that leakage rates could be reduced further to deliver water savings by around 240 Ml/day by 2035 (about 9% of total current leakage, and around 20% of the deficit for a mid-range CCRA projection).

Ofwat's targets on leakage are designed to move companies to a Sustainable Economic Level of Leakage (SELL). A zero leakage level is unlikely to be economically viable due to the increasing expense of finding and fixing smaller leaks, once significant leaks are dealt with. The cost of eliminating leakage would outweigh the costs of balancing water supply and demand by other means. However, the Water White Paper noted that the current methodology for calculating SELL does not consider the long-term sustainability of the

42 Walker (2009).
43 Department for Environment, Food and Rural Affairs (2011a).
44 https://southeast.veoliawater.co.uk/stepped-tariff.aspx . Increasing block tariffs require consumers to pay more per unit of consumption when they consume more. This helps to ensure that all consumers, irrespective of household income, are not deterred from using the water they need, whilst at the same time providing a disincentive to profligate use.
45 Department for Environment, Food and Rural Affairs (2012b).
46 Leakage is counted by water companies as a demand measure, but it can also be thought of as a supply measure as it relates to how much water can be delivered to customers, rather than how much they use.
47 http://www.ofwat.gov.uk/mediacentre/pressnotices2008/prs_pn0311performance
48 European Environment Agency (2003).
49 Ofwat (2010).
50 Ofwat (2009).

Figure 3.8: Measured leakage losses for England and Wales (1992-2011) and projected leakage out to 2035



Source: Ofwat
Notes: The dashed line shows the effects of reducing leakage by a further 240 Ml/day by 2035 from 2009 as set out in Water Resource Management Plans. Distribution losses refer to losses from companies' distribution networks; supply pipe losses refer to losses from customers' pipes.

water supply system, including the risks from climate change.[51] Taking into account the effects of climate change on the long-run value of water would make further leakage reductions cost-effective.

Supply Measures

Supply-side options are also likely to be needed to help prepare for future deficits, especially in the longer term. The Environment Agency has calculated that supply-demand deficits still remained in the 2050s even under an assumption that consumption per person decreased to 110 l/day.[52] Although this chapter emphasises demand measures as an effective strategy to deal with climate change uncertainties, implementing demand measures alone is unlikely to reduce the risk of water shortages to an acceptable level in all locations, particularly when considering a high-end deficit projection in the longer-term (2050s and 2080s). The ASC's 2011 report[53] has demonstrated how analysis of a wider range of climate scenarios can help to identify critical decision points in the future for identifying appropriate water supply options.

The CCRA analysis suggested that water sharing[54] between regions (moving water from areas of surplus to areas of deficit) could contribute approximately 100-300 Ml/day to reducing the deficit for a mid-range scenario in the 2020s. This analysis found that water sharing was less effective in a high climate change scenario or in the 2050s, as more regions begin

51 Department for Environment, Food and Rural Affairs (2011a). Work is underway to review how the SELL is calculated.
52 Environment Agency (2011b). Note that these deficits were calculated for public and non-public water supply combined, unlike the CCRA analysis presented above which is for public water supply only.
53 ASC (2011a).
54 Water sharing was also highlighted in the Water White Paper as a measure that water companies should consider first, before submitting proposals for new supply measures.

to experience supply-demand deficits. Some water sharing schemes, and other supply mechanisms such as desalinsation plants, may also carry high carbon emission costs.

Summary of indicators for supply and demand

Our analysis suggests that the potential benefits from demand reduction measures are not being maximised. According to the CCRA, a reduction in average water consumption per person of around 15 l/day could save around 700 Ml/day across England and Wales. This represents a 60% increase over the 440 Ml/day contribution to the deficit from demand measures in latest set of water company plans in 2009.

On the basis of current trends, consumption per person levels could fall to 130 l/day by 2035. Reaching this level over 25 years is cost-effective and readily achievable according to our 2011 analysis, as well as empirical trials. Our analysis also suggested that further reductions to 115 l/day would be cost-effective.

Reducing demand is a low-regret strategy to managing future supply-demand deficits in the face of large climate change uncertainty. However, supply measures appear to have been favoured in the last round of water company plans. This raises a question over whether there is a systematic bias within the current regulatory framework away from measures to manage demand.[55]

Greater uptake of metering will be needed in order to provide the right price incentive for achieving these reductions, particularly in locations with higher risks of supply-demand deficits from climate change. At present, climate change is not taken into account in designating areas of water stress. This is a barrier to timely uptake of metering to deal with risks from climate change.

Leakage targets are currently based on achieving the sustainable economic level of leakage (SELL). On the basis of these plans, leakage reductions could contribute around 240 Ml/day to reducing the deficit by 2035. However, the classification of SELL does not currently include how the value of water will change if it becomes an increasingly scarce resource. Taking into account the effects of climate change on the long-run value of water would make further leakage reductions cost-effective.

Supply-side measures are also likely to be required alongside demand measures to help reduce future deficits. Implementing demand measures alone would be unlikely to leave an acceptable level of risk of supply-demand deficits, especially in the longer term. Planning for supply-side measures should consider a wide range of climate scenarios and seek to identify options that are robust to future uncertainties.

In future, the ASC plans to develop indicators for uptake of water efficiency measures, and supply measures such as total reservoir capacity and water trading. We also plan to look at indicators for water quality and quantity as part of our work in 2013 on agriculture, forestry and the natural environment.

55 Ofwat (2011b). Ofwat have indicated that they will use a consistent method to treat capital (supply infrastructure) and operational (demand management) investments for the 2014 process for the first time. This may remove any systematic bias for one type of measure over another.

3.6 Non-public water supply

Users of water that are not supplied through the public water supply system account for around 40% of total abstraction (Figure 3.9). Putting in place an effective framework that assists these users of water to manage risks from climate change will be an important part of ensuring that water is shared effectively between different users with the least possible damage to the natural environment.

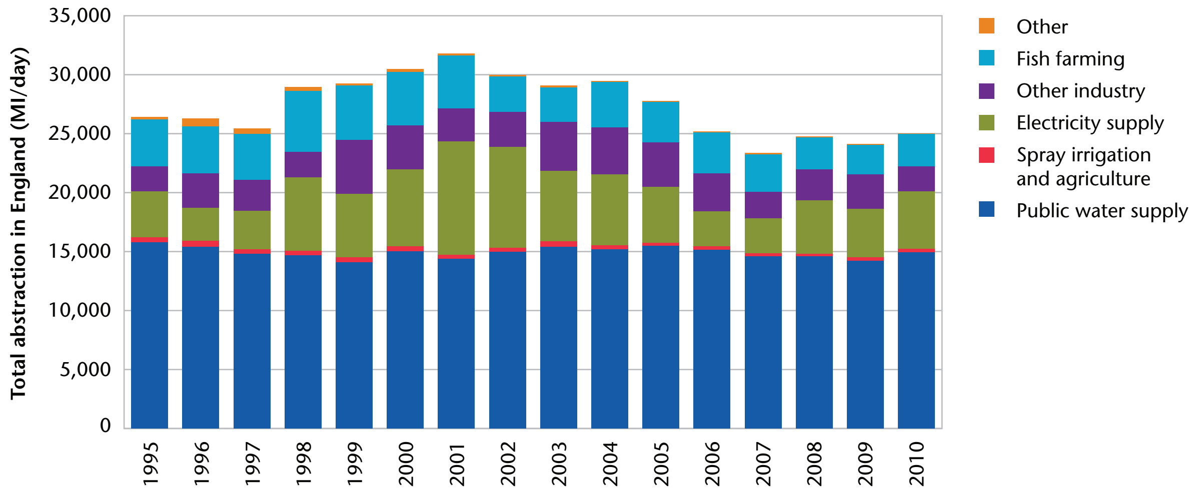
The Government's Water White Paper included a commitment to reform the abstraction system to deal more efficiently with allocation of water between water companies, power stations, heavy industry and agricultural users.[56] Reviewing and reforming the abstraction regime will be a critical adaptation measure in anticipation of climate change. The new regime should establish a pricing framework that is more responsive to changes in water scarcity through time and takes into account the needs of the natural environment. Abstractors outside of the public water supply system, such as the energy, industrial and agriculture sectors, are managed by the Abstraction Licensing Regime operated by the Environment Agency. The current system was designed in the 1960s. The proposed timetable for the reform process is for a consultation in 2013, followed by legislation and implementation by 2027.[57]

In the meantime there is a risk that policy decisions that are sensitive to water availability do not take full account of the risks to future water supply or the underlying requirement to protect the natural environment. The Environment Agency is undertaking research on demand scenarios for different sectors. For example:

- **Energy sector.** Greater reliance in the future on biofuel production, fracking (pumping a water mix underground to extract shale gas) or carbon capture and storage could markedly increase overall demand for water from the energy sector. Some studies have been conducted looking at future water demand scenarios for the energy sector outside of the UK (such as in Spain and California)[58], but there is currently little evidence on how the future energy mix will affect the sector's water demand in this country.[59 60]
- **Agriculture.** Use of water in farming currently accounts for a low proportion (~2%) of total abstraction in England, though it may be increasing.[61] It is higher seasonally in some regions. For example, abstraction for irrigation in the Anglian region is around 16% of total abstraction in the summer. Abstraction for irrigation could increase under a more arid climate,[62] through intensification, or from expansion of the sector. Better time series data will help to monitor changing demand.[63]

56 Ofwat and Environment Agency (2011c).
57 http://www.utilityweek.co.uk/news/news_story.asp?id=196978&title=Abstraction+reforms+'completed+by+2027'
58 National Energy Technology Laboratory (2010).
59 At present, around half of the cooling water abstracted for use in power stations is recycled into rivers, although a substantial amount (30-60%) is evaporated, and therefore consumed in the cooling process. It is not yet known how this compares to other types of energy production in the UK.
60 The Environment Agency is undertaking research on future demand from the energy sector which should be published later in 2012, including exploring how demand for water changes under different scenarios of electricity demand and supply. DECC is also working with Defra and the Environment Agency to include water demand in the 2050 Calculator tool.
61 Department for Environment, Food and Rural Affairs (2011b). Recent monitoring has found that water consumption per hectare increased across several crop types between 2005 and 2010. This was despite 2010 being a wetter year.
62 Downing et al. (2003).
63 Defra have recently commissioned a project to explore a range of future scenarios in potential crop distribution and associated water use and abstraction requirements in England and Wales, taking into account projected changes in climate and commodity prices. The project will inform assessments of future water demand in England and identify options for adaptation in agriculture, and how these can be promoted.

Figure 3.9: Total abstractions for England (1995-2010)



Source: Environment Agency.
Notes: These values are for all freshwater non-tidal abstractions. Note that abstraction (the amount of water taken up) is different from consumption (the amount of water which is used and not recycled back into the river system).

The amount of water abstracted affects the health of the natural environment, which in places is already under stress from over-abstraction. The Environment Agency has identified 263 schemes where it may have to undertake work under the Restoring Sustainable Abstraction programme. In 2011, only 26% of rivers in England and Wales were classified as having good ecological status under the Water Framework Directive classification,[64] with about 4% of rivers thought to be failing due to pressures from over-abstraction[65] and 11% at possible risk from abstraction and subject to further investigation.[66]

3.7 Conclusions

The water sector has seen improvement in some key adaptation indicators.[67] The rate of progress should be sustained to cope with growing demand and the rising risks from climate change.

- Water availability for public water supply is currently fairly resilient to drought events, in that water shortages requiring measures such as standpipes are rare.
- However, only 26% of rivers in England and Wales are currently meeting the requirements for good ecological status set out in the Water Framework Directive. Over-abstraction is causing at least 4% of rivers to fail, and 11% are under investigation.
- Average consumption of water per person has fallen from 150 l/day to 145 l/day over eight years.

64 http://www.environment-agency.gov.uk/research/planning/34383.aspx
65 http://www.environment-agency.gov.uk/business/topics/water/135357.aspx
66 Ofwat and Environment Agency (2011c).
67 Chapter 4 Annex contains an updated list of the ASC's water indicators.

- The number of households with water meters is increasing by 2% per year, with 40% of households in England and Wales currently metered.
- Leakage rates have largely levelled off at 22% of public water supply per year, after a sharp drop between 1995 and 2000.

Climate change is likely to alter annual and seasonal rainfall patterns, but the extent and timing of changes remain uncertain. The latest evidence from the CCRA finds that the risk of demand outstripping supply in public water supply is likely to increase from the combined effect of climate change and population growth.

- Deficits for the 2020s (2010-2039) range from about -15 Ml/day to -3100 Ml/day (19% of existing supply) across England and Wales. These projections are themselves uncertain, but give a sense of the scale of risk.

Managing demand for water is a necessary and low-regret strategy to take in the face of large uncertainties about future supply. Demand management is about both reducing unnecessary consumption, and making consumption more responsive to changes in supply. It provides benefits today and against any future deficit. Demand measures can take time to implement, so early action is required.

- Our analysis suggests that decreasing average national water use per person from 145 l/day to 130 l/day by 2035 is readily achievable through wider uptake of water efficiency measures, supported by metering and awareness raising.
- This pace of reduction would be faster than proposals in the latest water company plans, achieving savings of around 700 Ml/day, compared to 440 Ml/day under current plans for reducing demand.
- Water companies are also planning further reductions in leakage rates, which would contribute around 240 Ml/day to reducing supply-demand deficits by 2035. Taking into account the effects of climate change on the long-run value of water would make further leakage reductions cost-effective.

Managing demand requires the increased uptake of water metering, particularly in areas with growing supply-demand deficits. In order to put in place an effective system to manage demand, the price of water should reflect its availability and how much is used. This is only effectively possible through metering. However, we found no relationship between the current proportion of metered households in water company areas, and their projected future supply-demand deficits.

- The percentage of households with water meters could reach 85% by 2035 if current trends were to continue. However, a stronger policy framework may be required to sustain even this rate of rollout, if the trend slows in the future.
- The risks from climate change are not currently taken into account in the rules that govern where water companies can roll out universal metering. This could act as a barrier to targeted uptake of metering in areas of future water stress.

- Allowing for systematic rollout of metering is also likely to be much more cost-effective for water companies.
- Social and stepped tariffs would help to ensure that water remains affordable for more vulnerable households under a metered system.

Supply-side measures would also be necessary to deal with any remaining risk after low-regrets action to reduce consumption and tackle leakage.

- The degree of risk which water companies choose to plan for (and conversely, how much risk to accept) will determine the scale of supply-side measures required and the timing of their deployment.
- For example, water sharing could (according to CCRA analysis) contribute around 100 – 300 Ml/day to reducing the supply-demand deficit.

Public water supply, although accounting for 60% of the total, is one of several sources of water demand. Adaptation in the water sector will have to cover all sources of demand.

- Overall demand from non-public water supply has been fairly stable over the last 15 years. However, future demands are very uncertain, particularly from the energy sector.
- Planned reforms to the water abstraction system should put in place a more effective price mechanism across all sectors that responds to water scarcity, by the mid-2020s. This is a necessary prerequisite to allow effective demand management of a vital resource under increasing pressure.
- Strategic decisions made in the meantime will affect water demand in the future. Examples include the potential role of fracking in energy supply, the use of low-carbon technologies like carbon capture and storage, and the scale of intensification in the agriculture sector. These sectors should consider the effects of a changing climate on water availability in order to avoid lock-in to unsustainable levels of abstraction. The ASC will review preparedness for climate change in agriculture, energy and provision of infrastructure in future reports.

Chapter 4

Chapter 4
Advice on the UK National Adaptation Programme and next steps

4.1 Introduction

This chapter sets out the:

- ASC advice to the UK Government on the preparation of its National Adaptation Programme, based on our analysis of preparedness for changes in the risk of flooding and water scarcity:
- process for formulating ASC advice to the Government to inform early thinking on the second statutory assessment of the risks to the UK from climate change, due in 2017; and
- ASC forward work programme for applying its toolkit to assess preparedness for the other major climate risks facing the UK.

4.2 Principles for developing the UK National Adaptation Programme

The National Adaptation Programme is an important step for the Government in setting out the UK's long-term approach to preparing for climate change. The programme should take a systematic and proportionate approach to addressing the priority risks from climate change, and assess existing and proposed policies against this. An important part of this will be to examine whether the current and planned actions of public agencies, local authorities, businesses and households are sufficient to address climate risks, or whether changes to the policy framework are required to enable and encourage action.[1]

The programme should set out tangible steps to remove outstanding barriers to adaptation action, in order to:[2]

- increase the uptake of low-regret adaptation measures; and
- ensure that those taking decisions with long-term or systemic consequences, such as local authorities and infrastructure providers, take account of climate change in a way that is transparent and acknowledges the uncertainties.

Section 4.3 sets out opportunities to do this for adaptation to future flood risk and water scarcity, based on the analysis in this report.

1 The Government's Economics of Climate Resilience project, to be published in 2012.
2 For some climate change risks identified in the CCRA, the Government may decide that existing policy mechanisms are sufficient or that they are likely to be addressed by the market (often described as 'autonomous adaptation'). Further policy intervention may not justified because the risks and their uncertainties are considered to be acceptable or the costs of addressing them too great.

The programme should establish an approach for monitoring the effectiveness of Government policies and actions to address climate risks. The indicator framework that the ASC has developed could provide a basis for doing this. Section 4.4 considers this in more detail.

One component of the programme should be to improve the evidence base on future climate risks. The UK's first Climate Change Risk Assessment (CCRA) began to identify some of these key evidence needs, including a better understanding of the scale of the risk from surface water flooding and the risks to the UK from the impacts of climate change overseas. Such evidence gaps should be investigated further as part of the on-going process leading to the next risk assessment in 2017. Section 4.5 considers these issues in more detail.

4.3 Implications of ASC analysis for the UK National Adaptation Programme

The analysis in this report has highlighted where the National Adaptation Programme could help tackle barriers to promote adaptation action in relation to the risks from flooding and water scarcity.

Flooding

Development in the floodplain continues to grow at a faster rate than elsewhere in England. Over the past ten years, most floodplain development has been in areas that are already protected by flood defences, but around a fifth has been in locations currently at significant risk of flooding. This risk is likely to increase further with climate change. Development in the floodplain will leave a legacy of rising costs from protection and residual flood damage in the face of climate change. These costs may outweigh the benefits of development in some locations.

Current levels of investment in flood defences and protection measures for individual properties will not keep pace with the increasing risks of flooding. Climate change could almost double the number of properties at significant risk of flooding by 2035 unless there is additional action. By increasing investment in both flood defences and property protection measures, the number of properties at significant flood risk could be halved from current levels over the same time period.

Hard surfacing is continuing to replace permeable greenspace in urban areas, for example through the paving over of gardens. The current rate of deployment of sustainable drainage systems and other adaptation measures is unlikely to be sufficient to offset the increasing risk from surface water flooding.

In order to remove outstanding barriers and enable effective adaptation to tackle rising flood risk, the Committee advises that the Government should:

- **Ensure more robust and transparent implementation of planning policy in flood risk areas, so that local authorities consistently and explicitly take into account the long-term risks of flooding when deciding on the location of new development.**

- **Support sustained and increased investment in flood defences from public or private sources, given that current spending plans will not keep pace with increasing climate risk; or in the absence of this, identify ways to manage the social and economic consequences of more frequent flooding.**
- **Enable greater uptake of property-level measures to protect against floods, and encourage greater use of sustainable drainage systems to manage surface water.**

Water scarcity

Public water supply is fairly resilient to periodic drought under the present-day climate, though abstraction levels are putting undue pressure on the natural environment in some locations. The risk of water scarcity is likely to increase in the future due to climate change and population growth. Suggested measures to increase supply and reduce demand from water company plans from 2009 only meet a low and mid-range level of climate risk. These plans rely more heavily on supply-side measures than measures to reduce demand for water, and limit leakage.

Water companies could be missing opportunities to bring forward low-regret adaptation measures to reduce inefficient water use. Demand measures provide immediate benefits today to water consumers, and are a good adaptation response in the face of large uncertainties from the combined effect of climate change and population growth. Metering is required to price water based on the quantity used and provide consumers with an incentive to reduce inefficient water use.

In order to remove outstanding barriers and enable effective adaptation to tackle increasing water scarcity, the Committee advises that the Government should:

- **Take further steps to increase household efficiency in water use, including through water metering and pricing. This could include removing legal barriers to metering in areas with high risk of future deficit.**
- **Ensure that water companies are transparent about how the risks and uncertainties from climate change are factored into their long-term investment planning for future water resources.**
- **Ensure current policy decisions that affect future abstraction levels factor in the risks from climate change to avoid locking certain industries or regions of the country into unsustainable patterns of water abstraction.**

4.4 Monitoring the implementation of the National Adaptation Programme

Our analysis has demonstrated that it is feasible to:

- Monitor changes in the magnitude and direction of climate risks. This involves monitoring changes in (i) exposure and vulnerability to flooding and water scarcity, (ii) current levels of adaptation action, and (iii) climate impacts.

- Evaluate preparedness for climate change. This involves analysing decision-making to assess if the amount of adaptation occurring is sufficient to address the risks from climate change.

There are, however, a number of evidence gaps that need to be filled to allow for a more comprehensive assessment. For example, there is a lack of data on the uptake of property-level adaptation actions and water efficiency measures in households, and on the uptake and effectiveness of sustainable drainage systems. Box 4.2 summarises the key gaps we have identified. These are set out in more detail in the Annex to this chapter.

Working with the Government and its delivery partners, the Committee will continue to refine and improve its suite of adaptation indicators. This work will inform the Committee's first statutory assessment of how the National Adaptation Programme is addressing the risks from flooding and water scarcity over time, due in 2015.

Box 4.1: Conclusions from ASC work to develop indicators for flooding and water scarcity

In all cases, we have used existing datasets held by a variety of organisations, such as the Ordnance Survey, Environment Agency and Ofwat. For flooding, we have combined spatial datasets to identify appropriate indicators that provide more local information on climate risks.

Risk indicators

Risk indicators measure changes in society's exposure and vulnerability to weather events. These will be the result of changes in the climate, as well as in society, such as from economic growth and demographic change.

Good national data sets on the number and location of properties are generally available, primarily from the Ordnance Survey's Mastermap series. It has been possible to overlay the property data with the Environment Agency's flood probability maps. These are generally regarded as robust, although the underlying models represent certain flooding situations better than others.

Assessing changes in surfacing requires significantly more computer processing than that required to assess changes in the number of properties, and requires for assumptions about the rate of 'urban creep'. These indicators could be improved by the wider use of remote sensing technology. There is also a need for better indicators of water supply capacity in England and Wales.

Action indicators

These are measures of adaptation action, which aim to measure risk reduction.

It has been challenging to obtain robust, national level data on the uptake of measures such as SuDS, property-level flood protection, and water efficiency.

In most cases, we have relied on local data to estimate uptake of these measures. The Local Government Association's Climate Local initiative[3] may support the gathering of data on the uptake of adaptation actions from those local authorities who sign-up to the scheme once it has been fully launched later in 2012. Ofwat holds most of the data for action indicators related to water.

Impact indicators

These track the realised impacts of weather events on the economy, society and environment. We have found that some national data sets are available (such as on insured losses, environmental flow indicators), but other important impacts are not directly measured or measured in a consistent way (such as disruption to energy/water supply due to flooding).

3 Climate Local is the Local Government Association's initiative to support councils to reduce carbon emissions and to improve resilience to the changing climate. The initiative was announced in June 2012 and includes suggested indicators that local authorities can choose to adopt to benchmark and measure their progress. See: http://www.local.gov.uk/climate-change

4.5 Next steps

This section sets out the work the Committee will do to:

- develop its advice to inform early thinking on the next CCRA;
- apply the ASC assessment toolkit to the other major risks identified by the first CCRA; and
- engage with the devolved administrations so that the ASC assessment toolkit can be used across the UK if requested.

Advising on the next UK Climate Change Risk Assessment

Following the publication of the UK's first CCRA in January 2012, the ASC commissioned two reviews to understand how well the assessment had fulfilled its objectives, and to inform the preparation of future risk assessments.

- Professor Rob Wilby assessed the method and outputs of the CCRA. This review compared the UK's approach with approaches taken by other countries, and examined the role of risk assessment in helping to support adaptation activity in the UK.[4]
- Paul Watkiss Associates assessed the coverage of economic impacts in the CCRA. This assessment recognised that there were additional risks that were not considered, but which are important for estimating the potential impacts of climate change on the UK. The review drew on the existing evidence base to estimate the scale of these risks.[5]

This autumn, the ASC will provide advice to the Government to inform early thinking on the second statutory assessment of the risks to the UK from climate change, due in 2017. Our advice will draw on a broader assessment of costs associated with climate change than in the first CCRA (Box 4.3). It will also identify the research gaps that should be addressed ahead of the next CCRA, for example the magnitude of potential impacts in the UK arising from international climate risks.

4 Wilby (2012) for the ASC.
5 Paul Watkiss Associates (2012) for the ASC.

Box 4.2: Insights from the ASC commissioned review of the coverage of economic impacts in the UK CCRA (Paul Watkiss Associates (2012))

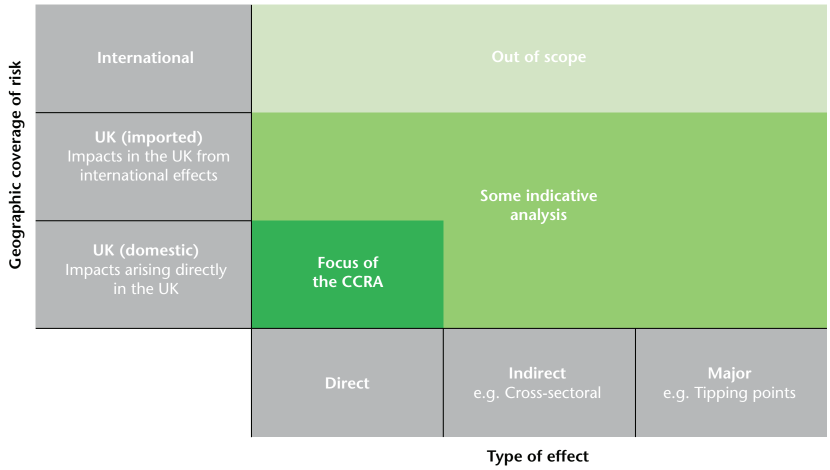
The ASC commissioned a review of the coverage of the economic impacts in the UK's first CCRA to understand what the CCRA can tell us about the potential costs of climate change and the scale of the adaptation challenge in the UK. In doing so the review identified where the evidence base for key impacts should be improved.

The figure below outlines the key components for a comprehensive assessment of the economic costs of climate change, and maps the coverage of the CCRA analysis against this matrix. The matrix assesses the various risks from climate change to the UK, splitting these into:

- *direct effects* – for example, damage to property following a flood event;
- *indirect effects* – for example, the impacts on households and businesses of rising costs of insurance in areas at risk of flooding or the disruption to business supply chains caused by flooding; and
- *major effects* – for example, from tipping points in the climate system such the melting of the Greenland Ice Sheet and resulting sea level rise.

These effects are then mapped against the geographic coverage of the risk; that is whether the risk originates in the UK, originates elsewhere in the world and the impacts are imported to the UK, or is a broader international risk. This final category might not directly lead to effects in the UK, but these risks are relevant to the UK in the context of international policy, development and security.

Coverage of economic impacts in the UK's first CCRA



Key insights from the review:

- The review suggests that the CCRA monetisation and quantification analysis largely focused on direct domestic risks to the UK. Many of these are likely to represent the priorities for early action. However, the analysis only valued around 100 of the approximately 700 risks identified by the CCRA. It also did not consider the wider impacts of these risks beyond their direct effects. These omissions suggest the CCRA has understated the economic costs of climate change to the UK.
- A review of the literature suggests that indirect effects could be as large as, and possibly larger than, the direct domestic impacts for a country such as the UK. At the same time, some adaptation responses could dampen the effects of climate change on the wider economy. For example, in the agricultural sector, farmers may change the type and timing of crops in response to climate risks.
- The increasingly global nature of UK economic activity increases exposure to international climate risks. International trade links spread local impacts across wider geographies. This is particularly the case for climate impacts in countries with established links, for example key UK trading partners and other international financial centres.

The CCRA acknowledged many of these other effects, but found that quantification in these areas was either more challenging or drew on a weaker evidence base. These knowledge gaps need to be addressed now, in preparation for the second statutory risk assessment in 2017.

Applying the ASC assessment toolkit

This report has applied the ASC assessment toolkit to review preparedness for flooding and water scarcity, two of the major risks to emerge from the CCRA.

The Committee's next two progress reports in 2013 and 2014 will apply the toolkit to assess progress in preparing for other key climate risks facing the UK, including:

- risks to and opportunities for agriculture and forestry, including the implications of global climate change on UK agricultural production and food security;
- changes to the natural environment and the functioning of ecosystems, including the role that ecosystems play in enabling adaptation;
- risks to and opportunities for human health and well-being, for example the increasing risk of heat stress and decreasing risk of winter mortality on vulnerable populations;
- implications for energy demand and supply, such as reduced winter heating demand, increased summer cooling demand and weather-related impacts on energy supply and distribution; and
- implications for UK business supply chains and consumer demand, at both a national and international level.

Assessing progress for the devolved administrations

The ASC assessment toolkit has the potential to be applied across the UK in order to assess progress in the implementation of adaptation programmes of the devolved administrations, if the Committee were requested to do so.

- **Wales:** the Committee made an initial assessment of the implementation of Wales' Adaptation Framework in the Committee on Climate Change's (CCC) first annual progress report to the Welsh Government in 2011. The ASC is currently developing a similar set of flooding indicators to those developed for England, which will be published as part of the CCC's second progress report to Wales, later in 2012.
- **Scotland:** the Committee reported on Scotland's progress in preparing for climate change in 2011,[6] and are currently in discussions with the Scottish Government on the role the Committee might play in future progress reporting required on Scotland's statutory adaptation programme. This includes discussions with ClimateXChange, who are developing indicators to monitor the statutory adaptation programme, to ensure compatibility with the ASC toolkit.
- **Northern Ireland:** the Committee is holding initial discussions with the Northern Ireland Executive on a possible role for the Committee to assess progress in the implementation of their forthcoming statutory adaptation programme.

6 ASC (2011b).

Annex: ASC indicators to monitor progress

As set out in Chapter 1, the first step in the ASC assessment toolkit is monitoring climate risks using three broad types of indicator (risk, action, impact). Developing indicators requires locating appropriate and robust datasets.

The ASC previously scoped the types of indicators and available data across the broad types of risks identified by the CCRA.[7] For this report, there has been more detailed work to locate datasets that can be used to develop indicators for assessing changes in flood risk.[8]

The indicators for which data were identified are shown in Tables 4.1 (flooding) and 4.2 (water scarcity), along with the key data sources, the direction of trend and time series.

Data availability can be a limiting factor when developing indicators. Table 4.3 summarises for both flooding and water scarcity the data that were available, as well as where improvements are needed to allow for a more comprehensive assessment of progress in the future.

7 AEA Technology (2011) for ASC.
8 HR Wallingford (2012d) for ASC.

Table 4.1: ASC indicators to assess change in risk of flooding (England only unless otherwise stated)

Note on arrows: the direction of the arrow depicts the trend in that indicator (increasing, decreasing or no significant trend). The colour of the arrow depicts the implications of that direction of trend in terms of risk (red = risk is increasing; green = risk is decreasing; yellow = risk is neither increasing nor decreasing).

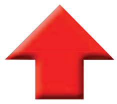
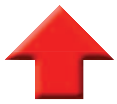
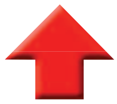
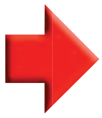
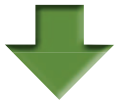
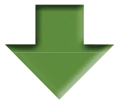
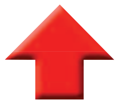
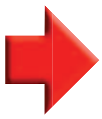
Indicator of	Indicator name	Source	Trend	Time series
Indicators of risk (exposure and vulnerability)				
Number of properties (houses and businesses) in areas of flood or coastal erosion risk (not accounting for defences)	Number of properties in river floodplain	Environment Agency OS MasterMap		2001, 2008 and 2011
	Number of properties in coastal floodplain			
	Number of properties in areas at risk of coastal erosion			
	Number of properties in areas at risk from surface water flooding (1 in 200 year event)			
Annual rate of development (houses and businesses) in areas of flood or coastal erosion risk (not accounting for defences)	Rate of development in river floodplain	Environment Agency OS MasterMap		2001, 2008 and 2011
	Rate of development in coastal floodplain			
	Rate of development in areas at risk of coastal erosion			
	Rate of development in areas at risk from surface water flooding (1 in 200 year event)			
Number of properties (houses and businesses) built in floodplain, accounting for defences	Proportion of floodplain development in areas at significant risk of river/coastal flooding	Environment Agency OS MasterMap		2001, 2008 and 2011
Change in hard surfacing	Area of impermeable surfaces in urban areas	OS MasterMap		2001 – 2011

Table 4.1: ASC indicators to assess change in risk of flooding (England only unless otherwise stated)

Note on arrows: the direction of the arrow depicts the trend in that indicator (increasing, decreasing or no significant trend). The colour of the arrow depicts the implications of that direction of trend in terms of risk (red = risk is increasing; green = risk is decreasing; yellow = risk is neither increasing nor decreasing).

Indicator of	Indicator name	Source	Trend	Time series
Vulnerable populations at flood risk	Number of households within highest 20% of ranked deprived communities in areas of significant flood risk (accounting for defences)	Office for National Statistics Environment Agency	↓	2008 – 2011
	Number of care homes in areas of significant flood risk (accounting for defences)	Environment Agency Care Quality Commission	↓	
	Number of schools in areas of significant flood risk (accounting for defences)	Environment Agency Department for Education	↓	
Indicators of action				
Design of new development in areas at flood risk	Proportion of Environment Agency objections to planning applications on flood risk grounds that are over-ruled by local authority	Environment Agency	→	2005 – 2010
Provision of flood defences	Number of households at reduced risk due to construction of new or enhanced defences		↑	2008 – 2011
	Effective spend in flood risk management activities (capital and revenue) from public and private sources		↑	2008 – 2011
Retrofitting property-level measures	Number of existing properties at flood risk retrofitting property-level measures	Defra	↑	2008 – 2011
Management of surface water in built-up areas	Proportion of new development with sustainable drainage systems	Defra	↑	2008 – 2011
Provision of early warning systems	Uptake of flood warnings by properties in the floodplain	Environment Agency	↑	2008 – 2011

Table 4.1: ASC indicators to assess change in risk of flooding (England only unless otherwise stated)

Note on arrows: the direction of the arrow depicts the trend in that indicator (increasing, decreasing or no significant trend). The colour of the arrow depicts the implications of that direction of trend in terms of risk (red = risk is increasing; green = risk is decreasing; yellow = risk is neither increasing nor decreasing).

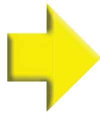
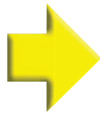
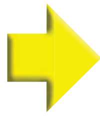
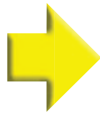
Indicator of	Indicator name	Source	Trend	Time series
Indicators of impact				
Flood damages	Annual insured losses from flooding (UK)	Association of British Insurers		1990 – 2011
Deaths and injuries from flooding	Number of deaths caused by flooding events, per year	CCRA		1950 – 2011
	Number of injuries caused by flooding events, per year			1950 – 2011
	Number of mental illness cases caused by flooding events, per year			1950 – 2011

Table 4.2: ASC indicators to assess change in risk of water scarcity (England unless otherwise stated)

Note on arrows: the direction of the arrow depicts the trend in that indicator (increasing, decreasing or no significant trend). The colour of the arrow depicts the implications of that direction of trend in terms of risk (red = risk is increasing; green = risk is decreasing; yellow = risk is neither increasing nor decreasing).

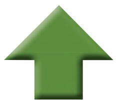
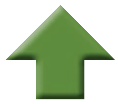
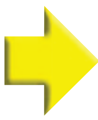
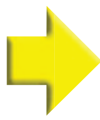
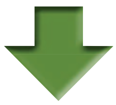
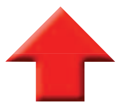
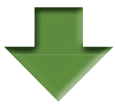
Indicator of	Indicator Name	Source	Long-term (10yr +) observed trend	Most recent year trend (2011 or 2012)	Time Series Length
Indicators of risk (exposure and vulnerability)					
Supply	Security of Supply Index (SOSI)	Ofwat			2002 – 2012
Overall demand	Freshwater Abstractions (non-tidal) by sector	Environment Agency			1995 – 2009
Household demand	Average per capita consumption – all households	Ofwat			2000 – 2011
Household demand	Average per capita consumption – metered households	Ofwat			2000 – 2011

Table 4.2: ASC indicators to assess change in risk of water scarcity (England unless otherwise stated)

Note on arrows: the direction of the arrow depicts the trend in that indicator (increasing, decreasing or no significant trend). The colour of the arrow depicts the implications of that direction of trend in terms of risk (red = risk is increasing; green = risk is decreasing; yellow = risk is neither increasing nor decreasing).

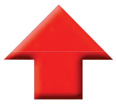
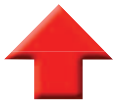
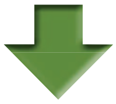
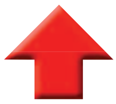
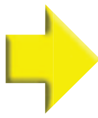
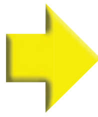
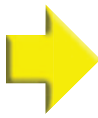
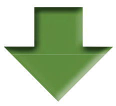
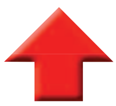
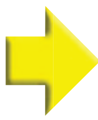
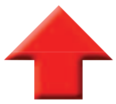
Indicator of	Indicator Name	Source	Long-term (10yr +) observed trend	Most recent year trend (2011 or 2012)	Time Series Length
Indicators of risk (exposure and vulnerability) (continued)					
Household demand	Average per capita consumption – unmetered households	Ofwat			2000 – 2011
Agricultural demand	Average volume of water applied for irrigation per hectare by crop type	Defra	?		2005 and 2011
Indicators of action					
Reducing Demand	% of properties with water meters (England and Wales)	Ofwat			2000 – 2012
Increasing Supply	Total Leakage (England and Wales)	Ofwat			1992 – 2011
Indicators of impact					
Water Availability (Public water supply)	% of Reservoir capacity filled (England and Wales)	Defra		?	1988 – 2009
Water Availability (Economic)	Catchments where water is available for abstraction (England and Wales)	Environment Agency	?		2009 – 2011
Water Availability (Environmental)	Compliance with Environmental Flow Indicators (England and Wales)	Environment Agency	?		2009 – 2011
Water Availability (Social)	Number of drought orders	Defra			1976 – 2012
Water Availability (Social)	Number of water companies issuing hosepipe bans (England and Wales)	Environment Agency			1974 – 2012

Table 4.3: Summary of indicator availability and areas for data improvement			
Available data		**Areas for data improvement**	
Flooding	**Water**	**Flooding**	**Water**
Risk Factor			
• Development trends: number of residential and non-residential properties. • Location of areas at risk from flooding/coastal erosion: both defended and undefended. • Area of hard ('man-made') surfacing, greenspace ('natural' land) and multiple land use (such as gardens).	• Security of supply index (used by water companies in determining risks in not meeting levels of service). • Average per capita consumption (metered and unmetered households). • Total freshwater abstractions.	• Type of development: can only distinguish between residential and commercial. It would be useful to understand number of upper floor flats within floodplain. • Number of non-residential properties: substantial discrepancies between different datasets. • Data on surface water flood risk are less advanced than for river/coastal flood risk. • Infrastructure in areas of flood risk: lack of time series. • Surfacing: no clear record of proportion of multiple land use (such as residential gardens) that is impermeable and how this is changing over time due to urban creep.	• Security of supply index is hard to understand for those outside of the sector, and is relative to a set level of service (which varies between water companies) rather than an absolute measure of supply; comparison between areas and through time is difficult. • Lack of data found on total capacity from supply measures e.g. total volume of water traded, total groundwater and reservoir storage. • Lack of data on agricultural water use (e.g. how much water is used to produce a hectare of a given crop).

Table 4.3: Summary of indicator availability and areas for data improvement			
Available data		**Areas for data improvement**	
Flooding	**Water**	**Flooding**	**Water**
Action			
• Design of floodplain development: proxy indicator of Environment Agency objections to applications. • Flood defence investment: data on number of households benefitting. • Flood defence asset condition: data available on EA assets. • Retrofitting of property-level measures: data on number of properties benefitting through Defra/EA grant scheme. • Uptake of SuDS in new development: data from surveys of local authorities and manufacturers. • Uptake of Flood Warnings: data on number of registered properties by local authority.	• Uptake of water metering (percentage of homes with water meters). • Number of household water efficiency measures installed by water companies. • Total leakage (supply and distribution pipes).	• No nationally available data on uptake of resilience and safety measures in actual developments (both properties and infrastructure). • Benefits of flood defence investment: lack of spatially aggregated data on change in flood likelihood for properties following completion of flood defence projects. • No data available on condition of non-EA flood defence assets or time series on condition of EA assets. • No national data on uptake of SuDS in new development or retrofitting of existing properties. • Data on uptake of flood warnings is not categorised by flood risk area, only for whole of the floodplain. • Data on availability of insurance is not accessible.	• Data on uptake of water efficiency measures on households is limited and does not include measures installed in new build properties or private installations by homeowners. Water efficiency devices can be replaced after installation, which also makes indicators of uptake alone an unreliable measure of total use of efficient devices.

Table 4.3: Summary of indicator availability and areas for data improvement

Available data		Areas for data improvement	
Flooding	**Water**	**Flooding**	**Water**
Impact			
• Insured losses: national data available, but not spatially aggregated. • Some data on health impacts.	• % of reservoir capacity filled (a measure of how the supply from reservoirs varies with changes in rainfall). • Compliance with environmental flow indicators. • Number of drought orders issued (can also be an action indicator). • Number of water companies imposing hosepipe bans.	• No data on disruption to critical services from flooding.	• Lack of systematic data collected on economic impacts of droughts on businesses, people. • Lack of systematic or quantified data on impacts of droughts on natural environment. • The definition of good ecological status is unlikely to remain static over time. • The rules and incentives for water companies to issue drought orders and hosepipe bans will change over time, meaning trends may not be due to climate.

Glossary

Term	Definition	Flooding examples	Water examples
Adaptation action	The adjustment of behaviour to moderate harm, or exploit beneficial opportunities, arising from climate change. Adaptation actions can directly reduce exposure and/or vulnerability to climate change or can minimise the impacts.	Avoiding development in high flood risk areas. Flood defences/protection. Deployment of SuDS (sustainable drainage systems) Emergency planning/ warnings.	Reducing water consumption. Increasing water storage through more reservoirs.
Exposure	The extent to which a recipient (people, livelihoods, infrastructure, economic, social, cultural and environmental assets) comes into contact with a climate impact.	Population located in areas of flood risk and behind eroding coastline.	Population located in areas of supply-demand deficit.
Low-regret adaptation action	A measure that is cost-effective to implement today; where the benefits are less sensitive to precise projections about the future climate; and where there are co-benefits or no difficult trade-offs with other policy objectives.	Property-level flood protection measures (e.g. door-guards, non-return valves).	Water efficiency measures (e.g. low-flush WCs, low-flow showers).
Realised impact	The results of climate impacts on society, the economy and the environment, taking into account current and planned adaptation actions.	Number of deaths/injuries. Disruption to critical services. Economic losses due to disruption. Post-traumatic stress/ mental health problems.	Decline in habitat condition due to reduced water availability. Number of hosepipe bans.
Risk	Combines the likelihood that an event will occur with the magnitude of its outcome. Consequences may be defined according to the economic, social or environmental impact. **Residual risk** is the risk which remains after taking into account an adaptation action.	Expected annual damages from flooding	Supply-demand deficit

Term	Definition	Flooding examples	Water examples
Supply-demand deficit	The difference between water available for use and demand at any given point in time. The balance may be expressed as an overall surplus or deficit. The unit of measurement is megalitres (Ml); 1 megalitre is equivalent to 1 million litres. Water companies typically present projections of supply-demand deficits in a dry year scenario to ascertain the risk of falling short of supply when conditions are drier than normal.	N/A	N/A
Uncertainty	A characteristic of a system or decision where the probabilities that certain outcomes will occur are not precisely known.	N/A	N/A
Vulnerability	The degree to which a recipient is affected, either positively or negatively, by exposure to a climate hazard. Includes the ability of the recipient to prepare, respond and recover from a climate hazard (and conversely to benefit from positive impacts).	Deprived populations in areas of flood risk.	Water consumption per person.

References

Adaptation Sub-Committee (2010). *How well prepared is the UK for climate change?* Available at: http://www.theccc.org.uk/reports/adaptation/1st-progress-report-2010

Adaptation Sub-Committee (2011a). *Adapting to climate change in the UK: measuring progress*. Available at: http://www.theccc.org.uk/reports/adaptation/2nd-progress-report-2011

Adaptation Sub-Committee (2011b). *How well is Scotland preparing for climate change?* Available at: http://www.theccc.org.uk/reports/adaptation/asc-scotland

AEA Technology (2011) for Adaptation Sub-Committee. *Provision of research to identify indicators for the ASC*. Available at: http://www.theccc.org.uk/reports/adaptation/2nd-progress-report-2011/supporting-research-a-data

AEA Technology (2012) for Adaptation Sub-Committee. *Review of international experience in adaptation indicators*. Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

Arup (2012) for Adaptation Sub-Committee. *How land use allocation decisions are accounting for the implications of climate change on flood risk*. Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

Association of British Insurers (2006). *Coastal flood risk – thinking for tomorrow, acting today.* Available at: http://www.abi.org.uk/Publications/ABI_Publications_Coastal_Flood_Risk__Thinking_for_Tomorrow_Acting_Today_fa6.aspx

Cabinet Office (2010). *Full national risk register of civil emergencies 2010 edition*. Available at: http://www.cabinetoffice.gov.uk/resource-library/national-risk-register

Darch, G., Arkell, B. and Tradewell, J. (2011). *Water resource planning under climate uncertainty in London*. Atkins Report for the Adaptation Sub-Committee and Thames Water. Available at: http://www.theccc.org.uk/reports/adaptation/2nd-progress-report-2011/supporting-research-a-data

Davis Langdon (AECOM) and Ecofys (2011) for Adaptation Sub-Committee. *Research to identify potential low-regret adaptation options to climate change in the residential buildings sector*. Available at: http://www.theccc.org.uk/reports/adaptation/2nd-progress-report-2011/supporting-research-a-data

Department for Communities and Local Government (2012). *National Planning Policy Framework and associated technical guidance on flood risk*. Available at: http://www.communities.gov.uk/publications/planningandbuilding/nppftechnicalguidance

Department for Environment, Food and Rural Affairs (2011a). *Water White Paper – water for life*. Available at: http://www.defra.gov.uk/environment/quality/water/legislation/whitepaper/

Department for Environment, Food and Rural Affairs (2011b). *Water usage in agriculture and horticulture: results from the Farm Business Survey 2009/10 and the Irrigation Survey 2010*. Available at: http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-fbs-waterusage20110609.pdf

Department for Environment, Food and Rural Affairs (2012a). *National SuDS (Sustainable Drainage Systems) standards impact assessment*. Available at: http://www.defra.gov.uk/consult/files/suds-consult-annexf-ia-111220.pdf

Department for Environment, Food and Rural Affairs (2012b). *Company social tariffs: guidance to water and sewerage undertakers and the Water Services Regulation Authority under Section 44 of the Flood and Water Management Act 2010*. Available at: http://www.defra.gov.uk/publications/files/pb13787-social-tariffs-guidance.pdf

Department for Transport (2005). *Crossrail race equality impact assessment – first report of the full assessment*. Available at: http://www.crossrail.co.uk/assets/library/document/c/original/crossrailraceequalityimpactassessment2005.pdf

Downing, T.E., Butterfield, R.E., Edmonds, B., Knox, J.W., Moss, S., Piper, B.S., Weatherhead, E.K., and the CCDeW Project Team (2003). *CCDeW – Climate Change and Demand for Water.* Research Report. Available at: http://ncsp.undp.org/sites/default/files/24_Downing_Water_Demand.pdf

Eigenbrod, F., Bell, V.A., Davies, H.N., Heinemeyer, A., Armsworth, P.R., and Gaston, K.J. (2011). *The impact of projected increases in urbanisation on ecosystem services*. Proceedings of the Royal Society. Available at: http://www.southampton.ac.uk/biosci/about/staff/fe1y09.page#publications

Environment Agency (2009a). *Investing for the future – flood and coastal risk management in England, a long-term investment strategy*. Available at: http://www.environment-agency.gov.uk/research/library/publications/108673.aspx

Environment Agency (2009b). *The costs of the summer 2007 floods in England.* Available at: http://publications.environment-agency.gov.uk/PDF/SCHO1109BRJA-E-E.pdf

Environment Agency (2010). *Managing water abstraction*. Available at: http://publications.environment-agency.gov.uk/PDF/GEHO0310BSBH-E-E.pdf

Environment Agency (2011a). *Development and flood risk in England, annual monitoring report 2010/11*. Available at: http://www.environment-agency.gov.uk/research/planning/33704.aspx

Environment Agency (2011b). *The case for change – current and future water availability.* Available at: http://publications.environment-agency.gov.uk/PDF/GEHO1111BVEP-E-E.pdf

Environment Agency (2012). *Drought prospects for spring and summer 2012*. Available at: http://publications.environment-agency.gov.uk/PDF/GEHO0312BWDT-E-E.pdf

European Environment Agency (2003). *Indicator fact sheet: water use efficiency in cities-leakage*. Available at: http://www.eea.europa.eu/data-and-maps/indicators/water-use-efficiency-in-cities-leakage

Evans, E., Ashley, R., Hall, J., Penning-Roswell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A. (2004). *Foresight: future flooding scientific summary*. Office of Science and Technology. Available at: http://www.bis.gov.uk/foresight/our-work/projects/published-projects/flood-and-coastal-defence/project-outputs

Hallegate, S. (2011). *How economic growth and rational decisions can make disaster losses grow faster than wealth*. The World Bank, Sustainable Development Network. Available at: http://econ.worldbank.org/external/default/main?pagePK=64165259&theSitePK=469382&piPK=64165421&menuPK=64166093&entityID=000158349_20120410132621

Houston, D., Werritty, A., Bassett, D., Geddes, A., Hoolachan, A. and McMillan, M. (2011). for the Joseph Rowntree Foundation. *Pluvial (rain-related) flooding in urban areas: the invisible hazard.* Available at: http://www.jrf.org.uk/sites/files/jrf/urban-flood-risk-full.pdf

HM Treasury (2011). *The Magenta Book – guidance for evaluation*. Available at: http://www.hm-treasury.gov.uk/data_magentabook_index.htm

HR Wallingford (2012a) for Department for Environment, Food and Rural Affairs. *The Climate Change Risk Assessment – evidence report*. Available at: http://www.defra.gov.uk/environment/climate/government/risk-assessment/

HR Wallingford (2012b) for Department for Environment, Food and Rural Affairs. *Climate Change Risk Assessment for the floods and coastal erosion sector.* Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

HR Wallingford (2012c) for Department for Environment, Food and Rural Affairs. *Climate Change Risk Assessment for the water sector.* Available at: http://www.defra.gov.uk/environment/climate/government/risk-assessment/

HR Wallingford (2012d) for Adaptation Sub-Committee. *Development of spatial indicators to monitor changes in exposure and vulnerability to flooding and the uptake of adaptation actions to manage flood risk in England*. Available at: http://www.theccc.org.uk/reports/adaptation/3rd-progress-report-2012/supporting-research-a-data

IPCC (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation.* Cambridge University Press. Available at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#SREX

Jenkins, G.J., Perry, M.C., and Prior, M.J. (2008). *The climate of the UK and recent trends.* Available at: http://ukclimateprojections.defra.gov.uk/22539

Lindley et al. (2011) for the Joseph Rowntree Foundation. *Climate change, justice and vulnerability*. Available here: http://www.jrf.org.uk/publications/climate-change-justice-and-vulnerability

National Audit Office (2011). *Flood Risk Management in England.* Available here: http://www.nao.org.uk/flood-management-2011

National Energy Technology Laboratory (2010). *Estimating freshwater needs to meet future thermoelectric generation requirements* – 2010 update. Available at: www.netl.doe.gov/energy-analyses/pubs/2010_Water_Needs_Analysis.pdf

Ofwat (2009). *Future water and sewerage charges 2010-2015: Final determinations – protecting consumers, promoting value, safeguarding the future*. Available at: http://www.ofwat.gov.uk/pricereview/pr09phase3/det_pr09_finalfull.pdf

Ofwat (2010). *Service and delivery – performance of the water companies in England and Wales 2009-10*. Available at: http://www.ofwat.gov.uk/regulating/reporting/rpt_los_2009-10.pdf

Ofwat (2011a). *Future impacts on sewer systems in England and Wales.* Summary of a hydraulic modelling exercise reviewing the impact of climate change, population and growth in impermeable areas up to around 2040. Available at: http://www.ofwat.gov.uk/sustainability/climatechange/rpt_com201106mottmacsewer.pdf

Ofwat (2011b). *Capex bias in the water and sewerage sectors in England and Wales – substance, perception or myth?* A discussion paper. Available at: http://www.ofwat.gov.uk/future/monopolies/fpl/pap_tec1105capex.pdf

Ofwat and Environment Agency (2011c). *The case for change – reforming water abstraction management in England*. Available at: http://publications.environment-agency.gov.uk/PDF/GEHO1111BVEQ-E-E.pdf

Ofwat (2011d). *Regulatory compliance – a proportionate and transparent approach. Consultation document*. Available at: http://www.ofwat.gov.uk/regulating/prs_web201203regcompliance

Palutikof, J.P., Subak, S. and Agnew M. D. (1997). *Economic impacts of the hot summer and unusually warm year of 1995*. Report to Department of Environment. Norwich: University of East Anglia.

Parker, D.J. (1995). *Floodplain development policy in England and Wales*. Flood Hazard Research Centre, School of Geography and Environmental Management, Middlesex University.

Paul Watkiss Associates (2012). *Scoping study: reviewing the coverage of economic impacts in the UK's climate change risk assessment*. Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

Ranger N., Millner A., Dietz S., Fankhauser S., Lopez A. and Ruta G. (2010) for Adaptation Sub-Committee. *Adaptation in the UK: a decision-making process*. Policy brief from Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy. Available at: http://www2.lse.ac.uk/GranthamInstitute/publications/Policy/docs/PB-Ranger-adaptation-UK.pdf

Rodda, J.C. and Marsh, T.J. (2011). *The 1975-76 Drought – a contemporary and retrospective review.* Centre for Ecology & Hydrology. Available at: http://www.ceh.ac.uk/data/nrfa/nhmp/other_reports/CEH_1975-76_Drought_Report_Rodda_and_Marsh.pdf

Royal Haskoning (2012a) for Adaptation Sub-Committee. *Assessing the economic case for property level measures in England.* Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

Royal Haskoning (2012b) for Adaptation Sub-Committee. *Costs and benefits of sustainable drainage systems.* Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

Severn Trent Water (2007). *Gloucestershire 2007. The impact of the July floods on the water infrastructure and customer service.* Available at: http://www.stwater.co.uk/upload/pdf/The_Final_Gloucester_2007_Report.pdf

Three Regions Climate Change Group (2008). *Your home in a changing climate – retrofitting existing homes for climate change impacts*. Available at: http://www.london.gov.uk/trccg/docs/pub1.pdf

UK National Ecosystem Assessment (2011). *The UK National Ecosystem Assessment: Technical Report.* UNEP-WCMC, Cambridge. Available at: http://uknea.unep-wcmc.org/

Walker, A. (2009). *The independent review of charging for household water and sewerage services.* Available at: http://www.defra.gov.uk/publications/files/walker-review-final-report.pdf

Waterwise (2010). *Evidence base for large-scale water efficiency in homes – Phase II interim report*. Available at: http://www.waterwise.org.uk/data/resources/14/evidence-base-for-large-scale-water-efficiency-in-homes-phase-ii-interim-report.pdf

Waterwise (2011). *Fairness on tap – making the case for metering*. Available at: http://www.waterwise.org.uk/data/resources/7/fairness_on_tap_report.pdf

Wilby, R. (2012). *Frameworks for delivering regular assessments of the risks and opportunities from climate change: an independent review of the first UK climate change risk assessment*. Available at: http://www.theccc.org.uk/reports/adaptation/2012-progress-report/supporting-data-a-research

Committee on Climate Change
7 Holbein Place
London
SW1W 8NR

www.theccc.org.uk

Designed and typeset by The Digital Parent Company Ltd, www.digitalparentcompany.com