Managing the coast in a changing climate

Committee on Climate Change
October 2018

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Foreword

Living on England's coasts comes with a certain level of risk: the infamous 1953 storm surge killed 307 people in England; and storm Xaver in December 2013 caused over £1.6 billion of damage. There are many other examples of coastal floods costing lives and damaging local economies. And as seen in Hemsby earlier this year, whilst coastal erosion does not affect as many people as coastal flooding, it is devastating to those that it does impact.

These risks of flooding and coastal erosion have always existed on our ever-changing coastline– ever since people starting developing settlements on the coast there have been many villages that were lost or abandoned to the sea and there are many stories of damaging floods from the past. However, our new report uncovers how coastal risks will increase in the future - and we are not prepared.

Climate change is causing sea waters to expand and is melting glaciers. Melting of ice caps on a much larger scale is possible unless more urgent action is taken to limit greenhouse gas emissions. We will almost certainly see 1m of sea level rise at some point in the future, possibly within the lifetimes of children alive today, and we must account for this change in long-term land use and coastal defence plans.

Meanwhile, the number and value of assets at risk on the coast has steadily been increasing. Houses, businesses, roads, railways, train stations, power stations, landfill sites and farmland will all be affected by increased coastal flooding or erosion in the future. Many of these assets are protected by coastal defences that date back to the last century, so are deteriorating in the face of rising sea levels and eroding coastlines. The strategies we employ to either defend or roll-back these assets need to be clarified, funded and implemented.

Coastal environments naturally adapt to sea level rise by retreating landwards. Mudflats, wetlands, beaches and sand dunes provide natural protection against flooding, whilst also being some of Britain's most important natural habitats. But on much of our shoreline, the coast's natural protective mechanisms are being squeezed between rising sea levels and human development. We must re-emphasise the value of these environments and ensure that they play a larger part in our adaptation plans for the future.

Above all, we have found that policies and practice for the coast are not facing up to the inevitability of future change. Though government and its agencies have emphasised the need for a strategic approach to coastal management, we find that plans do not reflect the realities of long-term change, are not joined up and are not fully implemented. People who live on the coast are not engaged in the process of planning for future change and are not taking pro-active steps to adapt.

We believe that there is still time to prepare for the coming changes but there is work to be done. Greenhouse gas emissions must be limited to reduce the severity of sea level rise but rising sea levels are not avoidable – they will rise for centuries from now because of temperature increases linked to our past emissions. So, robust adaptation plans are essential. We need to decide where to protect and how much we are willing to spend to do so. In places where it will no longer be affordable or sustainable to protect, timely action is needed so that assets can be relocated or decommissioned in a sensitive way – the time and money required to engage affected communities and help them to adapt should not be underestimated. Taking pro-active steps now will save money in the future and help to create a coastline that is naturally resilient to future changes and valued for its landscape and natural beauty.

Many organisations and people will be involved in restoring a resilient coastline, but central government has a particular responsibility to ensure that risks are realistically assessed and to provide the frameworks and targets that will drive change. The actions in the recently published National Adaptation Programme do not adequately address the risks that we have identified in this report. The Government should begin to remedy these omissions by developing specific metrics for coastal adaptation that will go alongside the 25 Year Environment Plan and by examining how agricultural and environmental policy can be used to incentivise adaptation in rural areas when the UK exits the European Union. The 2019 update of the Flood and Coastal Erosion Risk Management (FCERM) Strategy should set out how and when the hard choices that have to be made on the coast are going to happen. The impacts of sea level rise will be with us, and increase, for many years. Our responses need to face up to these challenges now.

Professor Jim Hall
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Executive Summary

Climate change will exacerbate the already significant exposure of the English coast to flooding and erosion. The current approach to coastal management in England is unsustainable in the face of climate change:

- **Coastal communities, infrastructure and landscapes already face threats from flooding and coastal erosion. These threats will increase in the future.** Development on the coast has not always taken long-term sustainability into account. Natural environments that are resilient to change have been altered by the construction of hard coastal defences. Many coastal communities are particularly vulnerable because populations in coastal areas are often poorer and older than the UK average. Climate change, particularly sea level rise, will increase the pressures that coastal communities and environments face.
- **In the future, some coastal communities and infrastructure are likely to be unviable in their current form. This problem is not being confronted with the required urgency or openness.** Understandably, people living on the coast more often than not prefer to retain the status quo, but building ever bigger defences to protect all coastal communities in the future would be prohibitively expensive. It would also detract from the coastal landscapes that people treasure and further interfere with the coast's natural adaptation to sea level rise. Facing up to inevitable change requires difficult decisions. Coastal communities need to be engaged to plan for their future over several decades, but the capacity and political will to do so does not currently exist.
- **Sustainable coastal adaptation is possible and could deliver multiple benefits. However, it requires a long term commitment and proactive steps to inform and facilitate change in social attitudes.** Reforms to legislation and to the way it is implemented are needed, particularly in relation to the relocation of assets and communities. The Agriculture and Environment Bills provide an early opportunity to start delivering this. Managed realignment and the restoration of natural coastal adaptation offers benefits that people value and is most feasible in areas of low population density, but still requires investment, facilitation and monitoring. Major coastal assets, such as cities and critical infrastructure will require investment in higher standards of protection as sea levels rise. Long-term plans to adapt to changes are required everywhere, with a sharper focus on: long-term resilience; engagement and supporting communities to adapt; integration with other local priorities; and the cost-effectiveness of the policies being proposed.

Key messages

- **It is almost certain that England will have to adapt to at least 1m of sea level rise at some point in the future.** Some model projections indicate that this will happen within the lifetimes of today's children (i.e. over the next 80 years). Coastal structures being built today need to be ready to cope with these rates of sea level rise. Rising sea levels will make the most damaging coastal floods more frequent, as well as increasing rates of coastal erosion in most places. Many of England's coastal defences are likely to be at risk of failure as sea levels rise. For example, a sea level rise of 0.5 m is projected to make a further 20% of England's coastal defences vulnerable to failure. This risk will be even higher if the current rates of deterioration of protective natural environments (e.g. saltmarshes, shingle beaches and sand dunes) continue.
- **In England, 520,000 properties (including 370,000 homes) are located in areas with a 0.5% or greater annual risk from coastal flooding and 8,900 properties are located in areas at risk from coastal erosion, not taking into account coastal defences.** Direct

economic damages from flooding and erosion are over £260 million per year. Transport, energy and waste infrastructure and cultural assets are also exposed to coastal flooding and erosion. Approximately 7,500 km of road, 520 km of railway line, 205,000 ha of good, very good or excellent agricultural land, and 3,400 ha of potentially toxic historic landfill sites are currently at 0.1% or greater risk of coastal flooding in any given year. Power plants, ports, gas terminals and other significant assets are also at risk. The benefits of protecting these different assets are not prioritised in the government's coastal defence spending at present, which focusses on properties.

- **By the 2080s, up to 1.5 million properties (including 1.2 million homes) may be in areas with a 0.5% of greater annual level of flood risk and over 100,000 properties may be at risk from coastal erosion.** In addition, approximately 1,600 km of major roads, 650 km of railway line, 92 railway stations and 55 historic landfill sites are at risk of coastal flooding or erosion by the end of the century. A further 100,000 properties located on complex cliffs could be at risk from coastal land sliding, an area which is not currently considered within England's coastal erosion risk mapping method.
- **The public do not have clear and accurate information about the coastal erosion risk to which they are exposed, nor how it will change in future.** There is no insurance or compensation for losses from coastal erosion for homeowners to mitigate the risk of losing their properties. Consequently, homeowners at risk may not take action to relocate or consider strategies beyond trying to protect their existing asset. Furthermore, the long term future of flood insurance is uncertain - the transition of the flood insurance industry to risk-reflective pricing requires detailed planning and monitoring by government.
- **Today, coastal management is covered by a complex patchwork of legislation and is carried out by a variety of organisations with different responsibilities.** The conflicting aims of meeting housing targets and short-term economic goals versus long-term sustainable management of the environment and communities mean that coastal flooding and erosion are not getting the attention that they merit. This is compounded by deprived coastal communities having limited capacity to prepare for and recover from coastal flooding or erosion.
- **The current policy decisions on the long-term future of England's coastline cannot be relied upon as they are non-statutory plans containing unfunded proposals**. The Shoreline Management Plans (SMPs) provide a long-term plan but the actions in the plans are not rigorously analysed so may not be, in reality, viable. They do not align with the time or spatial scales of other key policy instruments, such as Local Plans or wider government strategies on flooding or environment. Further, research conducted for this report found that up to one third of Local Plans for coastal locations show no evidence of using the SMPs as their required evidence base. This is not an adequate way to plan responses to the climate risks that the English coast and its communities face.
- **We calculate that implementing the current Shoreline Management Plans to protect the coast would cost £18 - 30 billion**[1]**, depending on the rate of climate change, and that for 149 - 185 km of England's coastline it will not be cost beneficial**[2] **to protect or**

[1] These values have not been 'discounted' to present day value, which would be £6.4 – 9.2 billion.
[2] This calculation is based on the costs of implementing England's Shoreline Management Plans (SMPs) as set out in the plans themselves, and an analysis of the benefits of doing so in terms of properties protected only. This is comparable to the current methods used to determine which flood and coastal erosion schemes receive funding and does not capture all the benefits.

adapt as currently planned by England's coastal authorities. This includes 43 - 56 km of the coastline for which the SMP policy is to 'hold the line' - i.e. protect by hard defences - all the way to the end of the century. On a further 53 - 66 km of coastline the SMPs policy to 'hold the line' for part of this century is not cost-beneficial. For these locations, government funding for defences is very unlikely to be forthcoming. A further 1,460 km of the coastline designated as 'hold the line' to the end of the century (71% of the total designated as 'hold the line' to the end of the century or 29% of the total English coastline) achieves a much lower benefit-cost-ratio than the flood and coastal erosion risk management interventions that are government-funded today.[3] On this basis, funding for these locations is unlikely and realistic plans to adapt to the inevitability of change are needed now.

- **To minimise these risks, global emissions of greenhouse gases need to fall dramatically, which would slow sea level rise in the long term. In parallel, the UK needs to strengthen its policies to manage the risks of coastal flooding and erosion.** By the 2080s, in a 2°C world and under an ambitious adaptation scenario[4], the number of people living in England in areas at 0.5% or greater chance of coastal flooding in any given year is projected to increase from 0.95 million to 1.10 million. In a 4°C world with low levels of adaptation[5], this number could increase to 1.55 million people. Ambitious climate change mitigation and adaptation efforts could therefore protect an additional 400,000 - 500,000 people in England from coastal flooding over the course of this century. However, the risks of harmful coastal flooding and erosion cannot be eliminated altogether, so measures need to be in place to forecast, warn of, respond to, and recover from extreme events when they occur.

Recommendations

RECOMMENDATION 1: The scale and implications of future coastal change should be acknowledged by those with responsibility for the coast and communicated to people who live on the coast. At the moment the future risks of coastal flooding and erosion are not fully understood. Improved risk mapping (led by the Environment Agency) and more complete analysis of the full costs and benefits of coastal management options will provide the evidence needed to make realistic plans. This information needs to be communicated (unambiguously but with an appropriate recognition of uncertainties) to communities and policy-makers.

RECOMMENDATION 2: Local government and the Environment Agency need to be enabled by national government to deliver a long-term and appropriately resourced approach to engaging affected communities and stakeholders. Decisions that have a significant impact on communities need to be taken in collaboration with those communities and need to be planned and assessed well in advance of their implementation. These plans need to be dynamic enough to respond to specific events or 'crises'. Difficult decisions (e.g. relocation of existing properties, limiting the approval of new properties) should be considered, discussed and planned with the community and other relevant stakeholders who have specific responsibilities. Adaptation policies can take decades to implement and that process needs be managed with all

[3] 1,460 km of 'hold the line' frontages have a BCR of 2.0 or less, which is much lower the BCR of 8.0 that schemes funded in the most recent capital investment programmes have typically achieved.

[4] This scenario assumes enhanced adaptation in terms of planning policy, land use, property level protection and forecasting/early warning compared to current trajectories. The population assumptions are consistent for all the cases described in this paragraph. For more details, see Box 2.2 in the main report or Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*

[5] This scenario assumes adaptation develops at the 'baseline' rate typical of the present day.

relevant stakeholders engaged throughout. There are few real world examples of successful, long-term engagement strategies such as those proposed here and significant new resources will have to be provided to the relevant organisations (e.g. Environment Agency, local authorities, Regional Flood and Coastal Committees) to plan and implement them.

RECOMMENDATION 3: Defra and MHCLG policy on the management of coastal flooding and erosion risk should specify long-term, evidence-based, quantified outcomes that have the buy-in of the affected communities and stakeholders. The government's 2nd National Adaptation Programme, 1st Flood and Coastal Erosion Risk Management Strategy and the 25 Year Environment Plan have not proposed actions that can be assessed in terms of their impact on overall exposure or risk. These government statements could provide the institutional framework to achieve this aim, but they will have to be strengthened and augmented with new policies and metrics. Defra and MHCLG should enable and require adaptation planning by local government, and should monitor progress. The Agriculture and Environment Bills offer the opportunity to start the reform of legislation to achieve this.

RECOMMENDATION 4: Government should make available long-term funding/investment to deliver a wider set of adaptation actions. Decisions about funding should be based on a broader and more inclusive economic case than is current practice. Current funding streams provide value for money, largely by delivering hard defences where there is the best economic case supplemented with local 'partnership funding' contributions. Places where continued investment in hard defences is uneconomic tend to lose out. However, these places also need funding to assist them to adapt to inevitable changes, so whilst hard defences may not be fundable they still need support for a broader package of adaptation actions, including community engagement, asset relocation and compensation to move households where appropriate. This should be addressed either by altering existing funding formulae or developing a new funding mechanism, which could, for instance, take inspiration from innovative green finance models or community development corporations. The economic case to support long-term funding should be determined not just by the protection of physical assets but should also incorporate environmental implications and social justice considerations.

RECOMMENDATION 5: Plans to manage and adapt specific shorelines over the coming century should be realistic and sustainable in economic, social and environmental terms. A coastline policy is required that clearly identifies areas that need to be defended in the long term, areas that should remain or be returned to a 'natural' environmental state and communities that are currently unsustainable and require more strategic adaptation, such as relocations. Local government need to be able to make realistic adaptation plans that have regulatory teeth. Local Plans and Shoreline Management Plans should be aligned more closely in the time frames and areas that they both consider. Coastal Groups should continue to act to ensure that Local Plans are joined up. New powers may be required, for example by local authorities, to facilitate relocation or by planning authorities to ensure that a longer term planning outlook is taken.

Chapter 1: Introduction

1.1 Background

This report is the first in a series by the Committee on Climate Change's (CCC) Adaptation Committee looking at three aspects of the need to adapt to long-term impacts caused by the changing climate. These reports focus on: i) the coast; ii) land use; and iii) urban housing. In line with the CCC's adaptation remit as defined in the UK Climate Change Act[6], this report focusses on England i.e. the English coastline is examined and the legislation and bodies relevant to managing the English coastline are discussed. However, some of the analysis and messages in this report may also be relevant to coastal locations and authorities in the devolved administrations.

The UK Climate Change Risk Assessment (CCRA) 2017 Evidence Report[7] identified coastal change, alongside flooding in general, as one of the most urgent climate change risks facing England. To build on that conclusion, this report investigates the long-term issues resulting from climate change impacts to the coast and examines the policy and practice responses to these changes. Coastal adaptation is particularly important as sea levels will continue to rise for centuries after atmospheric temperatures have stabilised and will pose existential threats to coastal communities and environments:

- Coastal adaptation entails decisions with long time horizons and impacts for people, which might involve the permanent loss of their most valuable asset (their home) and threaten the viability of entire communities;
- Adaptation strategies to manage long-term coastal changes often conflict with the short-term interests of the people who will be most affected by those decisions: protecting assets retains their value for as long as the protection is effective (though may have downstream consequences); relocating assets (e.g. roads, railways, and businesses) negatively affects the area that they are moved away from, at least in the short-term;
- The cost effectiveness of different measures is also highly dependent on the time and spatial scales over which it is calculated. Whilst a like-for-like replacement for a damaged asset, such as a coastal road, is likely to restore business as usual in the short-term, a long-term perspective will bring other options, such as an initially more expensive road relocation, into the equation as a more cost effective option.

Box 1.1 provides a specific example of this issue and the rest of the report examines how and why England should move to a longer-term perspective of coastal management.

Box 1.1. A379 Slapton Road - a case study

The A379 is a coastal road in Devon that runs through a National Nature Reserve and Site of Special Scientific Interest. The road includes a 3km section that was built on a gravel barrier beach. Barrier beaches are well-known as dynamic features and respond to storm events and sea level rise in relatively predictable ways i.e. by rolling over on themselves and moving landward. This process has the potential to damage any structures that are built on top of them.

In March 2018, Storm Emma washed away around 400m of the 1.5km stretch of the A379 between Slapton and Strete Gate. The required diversion added around 7km to the journey (25km for HGVs) and is expected to be in place for at least 8 months. The road had suffered similar damage in January 2001

[6] HM Government (2008) *UK Climate Change Act*
[7] CCC (2016) *Climate Change Risk Assessment Evidence Report*

Box 1.1. A379 Slapton Road - a case study

when 250m of the road was damaged after a storm. That section of road was re-built 20m further inland to avoid further, short-term storm damage. Later, in 2007, planning permission was sought, and granted, to rebuild further sections of the A379 around 20m further inland in the event of further damage.

However, following the recent damage, the 2007 plan has not been fully implemented. Indeed, there was an initial proposal to leave to road closed indefinitely with a permanent inland diversion. Subsequently, £2.5M was secured from the Department for Transport to re-instate the road very close to its current location.

The re-built road will, however, almost certainly be washed away again in the future. This questions the wisdom of the new investment and the decision making process related to 'responsive' investments. If a long-term and objective decision making process had been applied it is unlikely that this same decision would have been made as the cost-benefit relationship for re-building in the current location is marginal at best.

This case highlights that even when significant time and money has been invested in engaging the local community and developing a forward-looking, adaptive strategy, it is still difficult to implement plans that have taken long-term issues into account. Such plans can be overlooked and a reactive and potentially unsustainable solution can be implemented instead, particularly where authorities are under pressure to respond rapidly to events.

Source: Photograph included with kind permission from Ian Coomber (2018).
Notes: Slapton Sands Beach Management Plan (2018) available at http://www.slaptonline.org/news/news.php?id=145; news stories from: https://www.devonlive.com; Devon County Council: https://new.devon.gov.uk/roadsandtransport/traffic-information/roadworks/a379-slapton-line-realignment/ and communication with other local stakeholders.

1.2 Aims of this report

This report aims to investigate the extent to which responses to coastal change threats are in line with the current level of risk and future changes from climate change, and whether long-term outcomes and plans for the coast need to be revisited.

In particular, the Shoreline Management Plans (SMPs; see Box 1.2 for an overview) will be examined. The SMPs, whilst non-statutory, are the main vehicle that coastal authorities have to outline their long-term strategy for their coastal areas. Local Plans, which outline a planning authority's priorities and policies regarding development and land use, should use the relevant SMP as the evidence base for decisions if the authority has a coastline. However, the Adaptation Committee has previously recommended that the ambition of the SMPs needs to be reviewed and that more preparation is required for coastal communities to adapt to the challenges ahead, particularly in the second half of this century and beyond.[8] In that context, this report:

- Investigates what assets are likely to be at risk from flooding and coastal erosion in the present day and in the future;
- Reviews the policy framework for managing coastal flood and erosion risk in England and assesses the effectiveness of the implementation of those policies;
- Performs a national cost-benefit analysis of the SMP policy decisions;
- Discusses the management of coastal 'crises' that remain an issue despite current planning practices; and
- Considers how long-term planning for the coast could be improved where limitations of current approaches are identified, particularly in relation to 'crises'.

Box 1.2. The Shoreline Management Plans

The Shoreline Management Plans (SMPs) are high-level, non-statutory plans that identify sustainable responses to long-term coastal changes. They were first developed in England and Wales between 1994 and 1999 and underwent a major revision between 2006 and 2011 that resulted in what are sometimes called the SMP2s (although 'SMP' is more commonly still used and this how we will refer to them in this report). There are 22 SMP areas (Figure 1.1) that split the complete coast around England and Wales into distinct stretches (coastal cells) which are reasonably self-contained in terms of coastal processes. The aim is to encourage coastal management based on an understanding of coastal processes rather than administrative boundaries.

The aim of the plans was to assess the risks that exist in each area and to develop a 100-year policy framework for their sustainable management. The SMPs are non-statutory so, regardless of the contents of each plan, any proposed defence work will still have to acquire funding and those funding applications are subject to the usual decision criteria.

Within each SMP area, the coast is split up into smaller sections known as 'policy units' and one of four policies is assigned to each unit for three different time frames. The four possible policies are:

- **Hold the line (HTL)** – maintain or change the level of protection provided by existing coastal defences in their present location.
- **Advance the line (ATL)** – build new defences on the seaward side of the existing defence line to reclaim land.

[8] CCC (2017) *2017 Report to Parliament – Progress in preparing for climate change.*

Box 1.2. The Shoreline Management Plans

- **Managed realignment (MR)** – allowing the shoreline position to move naturally backwards (or forwards) with management to control or limit movement.
- **No active intervention (NAI)** – a decision not to invest in providing or maintaining defences.

The three time-periods used in the SMPs are:

- Epoch 1 or Short-term – 2005 to 2025
- Epoch 2 or Medium-term – 2026 to 2055
- Epoch 3 or Long-term – 2056 to 2105

Furthermore, the National Planning Policy Framework[9] stipulates that areas "likely to be affected by physical change to the coast"[10] should be identified as Coastal Change Management Areas (CCMAs). Where a CCMA is in place, the local planning authority should ensure that "inappropriate development" is avoided. "Appropriate" should be defined in the CCMA in terms of the areas and circumstances where development is allowable and, if necessary, to make provisions for relocation away from the CCMA.

Figure 1.1. The SMP and Regional Flood and Coastal Committee (RFCC) areas.

Source: SMP coastline data is from the Environment Agency via the data.gov.uk portal and should be attributed with "© Environment Agency copyright and/or database right 2016. All rights reserved."
Notes: The 'SMP2' areas, which are shown above, are different to the original 'SMP1' areas. The coastline covered by SMP areas numbered 19 and 22 cover parts of England and Wales - we only analyse the English portions of these SMP areas in this report. RFCC roles are discussed in Section 3.2.

[9] MHCLG (2018) *National Planning Policy Framework*.
[10] This is largely interpreted as excluding policy units with 'hold the line' or 'advance the line' policies, which may be problematic: SMPs are not statutory, so these decisions are aspirations and do not ensure action or funding.

1.3 Terminology used in this report

Coastal management spans a wide range of disciplines from oceanography and geomorphology to extreme event statistics and economics via engineering and ecology. To ensure that we are communicating effectively, we have included Box 1.3 that defines some of the technical language used in this report.

Box 1.3. Technical language and acronyms used in the FCERM (Flooding and Coastal Erosion Risk Management) sector and this report

This Box presents definitions of terms as they are used in this report, which is largely in line with their typical use in the FCERM community.

Risk is usually defined as a measure of the probability of an event occurring multiplied by the impact that the event would have. The **probability** of an event occurring can be expressed as an annual chance (percentage) of occurrence or a return period (see below). Risk is also thought of (in particular in the insurance sector) as being a combination of (i) hazard, which is the potentially harmful event, for which probabilities are calculated, (ii) **exposure**, which is the potential for damage or loss from the hazard (e.g. the number of properties that may be flooded), and (iii) vulnerability, which is the sensitivity of the exposed assets to damage associated with the hazard. Exposed assets are not necessarily **vulnerable** as, for example, a house on a flood plain, and therefore exposed, could take measures to ensure it would not be damaged in the event of a flood.

Coastal flooding occurs when seawater inundates usually dry land, which can occur when sea level exceeds the land elevation or when barriers are overtopped or breached. Coastal floods occur when the sea water level is extremely high e.g. during storm surges and high tides, which may be accompanied by high winds and waves. Longer-term factors (e.g. climate change driven sea level rise, or land subsidence) increase the height of the water level during extreme events, making coastal flooding more likely.

Other sources of flooding include: **fluvial flooding**, which is caused by flooding from main rivers; **surface water flooding**, or **pluvial flooding**, which is usually caused by heavy rainfall that is not drained away effectively so that the water accumulates or flows over the surface; and **groundwater flooding**, which occurs when the water table rises above the land surface. These can all occur at the coast as well as inland.

The probability of flooding is quantified in terms of the annual probability of an event occurring (e.g. an extreme sea water level been exceeded: the Annual Exceedance Probability) or as a **return period**, which is approximately the inverse of the Annual Exceedance Probability and can be thought of as the average frequency with which an event of given severity will occur. For example, an event with an Annual Exceedance Probability of 2% would have a return period of 50 years. These statistics are usually calculated from observations (e.g. tide gauges that measure water levels at many sites around the coast) with some input from predictive models. Sea level rise needs to be taken into account when calculating return periods and uncertainty about future sea level rise makes the likelihood of extreme floods more difficult to estimate in the future.

Sea level rise occurs when ocean water expands upon heating or when land-based ice (glaciers or ice sheets) melt as a result of warming. The rise will not be uniform at all locations as ocean circulation, gravitational effects and land subsidence can modify the sea level.

Coastal Erosion is the process of wearing away a shoreline, which could be a beach, cliff, sand dune or other landform. The eroded sediment can subsequently be deposited at other coastal locations - this process is known as **accretion**. Sea level rise can cause the shoreline to retreat inland even without coastal erosion, simply by submerging the coastal profile.

Box 1.3. Technical language and acronyms used in the FCERM (Flooding and Coastal Erosion Risk Management) sector and this report

Coastal sediments (gravel, sand, mud) and associated **vegetation** (saltmarshes, dunes) provide **natural protection** against coastal erosion and flooding and can naturally adapt to sea level rise. Construction of coastal defences, like seawalls and promenades, along eroding coasts blocks the natural supply of sediment to the coast, encourages coastal erosion and inhibits the capacity of the coast to adapt.

Coastal squeeze occurs where coastal landforms cannot adapt naturally to sea level rise because of the presence of fixed coastal defence structures. Naturally, coastal landforms and habitats will retreat inland as the sea level rises. However the presence of fixed coastal structures like seawalls or embankments prevents this natural landward retreat so the area in between the sea edge and the defence is, therefore, 'squeezed'. This can reduce the natural protection that these environments provide to the built defence by attenuating waves, as well as impacting the ecosystems that exist in these areas.

The **National Coastal Erosion Risk Map (NCERM)** is a dataset of projections of future coastal erosion based on past recession rates of *erodible coasts* i.e. coasts that erode in relatively predictable ways. The dataset covers England and Wales and is split into 3 time windows or 'epochs', which are the same as those used for the SMPs (2005-2025; 2026-2055; and 2056-2105). NCERM excludes the erosion of *complex cliffs* as their past recession cannot be used to infer their future erosion. Instead, they erode via multi-tiered landslides at unpredictable points in time.

The impact of floods and/or erosion can be mitigated by: **defences** that reduce the probability of a flood occurring (these defences can be either **'hard'**, like seawalls that stop seawater inundating land, or **'soft'**, like beach nourishment which increases the natural protection beaches provide by adding sand or gravel dredged offshore); or **property level resilience** measures that reduce the impact of flood water (such as measures that stop water entering properties, allow water to leave buildings quickly or materials, like waterproof plaster, that allow for quick drying and cleaning).

The **Flood Map for Planning** dataset uses local flood models to produce a map/dataset of present day flood risk for England used by spatial planners. It does not include protection from flood defences so represents the 'worst case scenario'. It uses three zones to categorise different levels of flood risk:

- *Flood Zone 3:* where the probability of flooding in any year is greater than, or equal to, 1% for river flooding and 0.5% for coastal/tidal flooding.
- *Flood Zone 2:* where the probability of flooding in any year is between 0.1% and 1% for river flooding or between 0.1% and 0.5% for coastal/tidal flooding. When "Flood Zone 2" analyses are included in this report we include the Flood Zone 3 numbers as well so they represent a coastal flooding probability of greater than 0.1%.
- *Flood Zone 1:* where the probability of flooding in any year from rivers or sea is less than 0.1%.

The **Risk of Flooding from Rivers and Sea** dataset uses a probabilistic model to calculate areas for England of high (greater than 3.3% flood probability in any year), medium (between 3.3% and 1% flood probability in any year), low (between 1% and 0.1% flood probability in any year) and very low (less than 0.1% flood probability in any year) present day flood risk. The model includes protection from flood defences.

Chapter 2: Current and future risks facing the coast

Key messages

It is almost certain that people in England will have to adapt to at least 1m of sea level rise at some point in the future. Some model projections indicate that this will happen within the lifetimes of today's children (i.e. over the next 80 years). Coastal structures being built today need to be ready to cope with these rates of sea level rise. Rising sea levels will make the most damaging coastal floods more frequent, as well as increasing rates of coastal erosion in most places. Many of England's coastal defences will be at risk of failure as sea levels rise. For example, a sea level rise of 0.5m is projected to make a further 20% of England's coastal defences vulnerable to failure. This risk could be even higher if the current rates of deterioration of protective natural environments (e.g. saltmarshes, shingle beaches and sand dunes) continue.

In England, 520,000 properties (including 370,000 residential) are located in areas with a 0.5% or greater annual risk from coastal flooding and 8,900 properties are located in areas at risk from coastal erosion, not taking into account coastal defences. Direct economic damages from flooding and erosion are over £260 million per year, on average. Transport, energy and waste infrastructure and cultural assets are also exposed to coastal flooding and erosion. Approximately 7,500 km of road, 520 km of railways line, 205,000 ha of good, very good or excellent agricultural land, and 3,400 ha of potentially toxic historic landfill sites are currently at 0.1% or greater risk of coastal flooding in any given year. Power plants, ports, gas terminals and other significant assets are also at risk. The benefits of protecting these different assets are not prioritised in the government's coastal defence spending at present, which focusses on properties.

By the 2080s, up to 1.5 million properties (including 1.2 million residential) may be at a 0.5% of greater level of flood risk and over 100,000 properties may be at risk from coastal erosion. In addition, approximately 1,600 km of major roads, 650 km of railway line, 92 railway stations and 55 historic landfill sites are projected to be at 0.5% or greater risk of coastal flooding or erosion by the end of the century. There could be a further 100,000 properties on complex cliffs at risk from coastal land sliding, an area which is not currently considered within England's coastal erosion risk mapping method. These figures can all be reduced with ambitious adaptation and mitigation efforts.

2.1 The risks from current and future coastal flooding

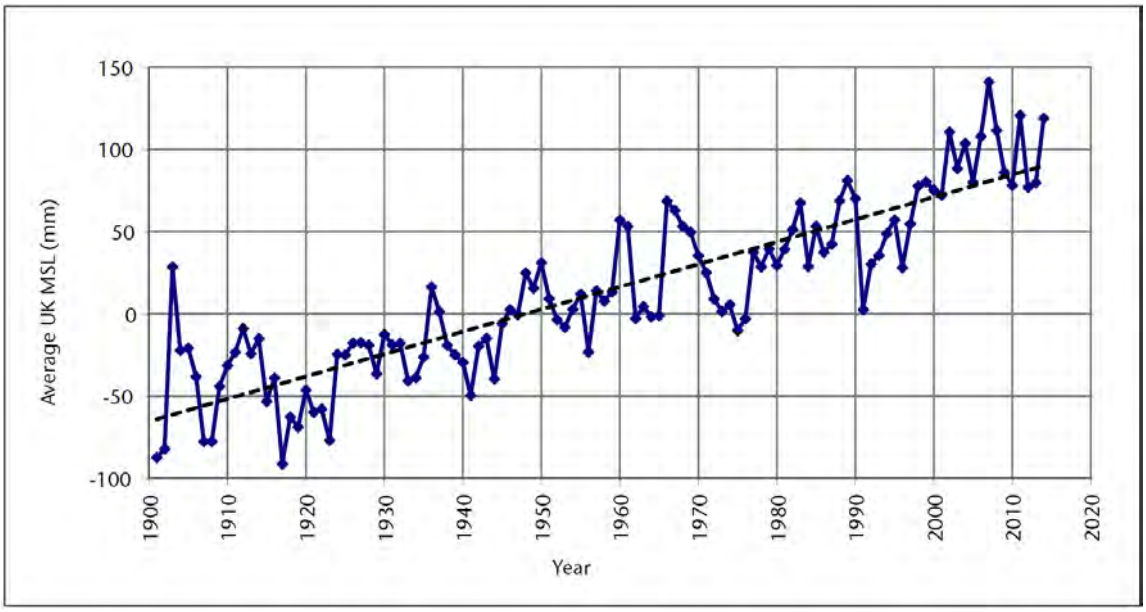
Climate change threatens the sustainability of coastal communities and environments. It is almost certain that England will have to adapt to 1m of sea level rise at some point in the future.

This will make the most damaging coastal floods more frequent, as well as increasing rates of coastal erosion in most places:

- Observations show that sea level around the UK has already risen by 15.4 cm since 1900 (corrected for land movement; Figure 2.1) and the 2009 UK Climate Projections (UKCP09) indicate that sea level is expected to rise by around 50cm, and potentially as much as 80cm, by 2100[11] (Figure 2.2).

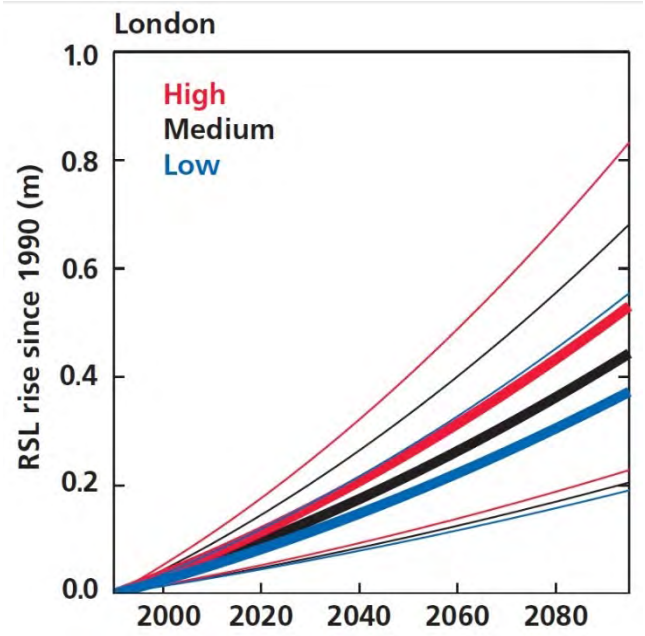
[11] UKCP09 (2009) *Chapter 3: Changes to mean sea level* In UK Climate Projections science report: Marine and coastal projections.

Figure 2.1. Observations of relative (i.e. corrected for land movement) UK mean sea level rise.



Source: Woodworth et al. (2009) *Trends in UK mean sea level revisited.* Geophysical Journal International, 176, 19–30 and updated for the 2017 Climate Change Risk Assessment Evidence Report.
Notes: UK sea level index for the period since 1901 computed from sea level data from five stations (Aberdeen, North Shields, Sheerness, Newlyn and Liverpool). The linear trend line has a gradient of 1.4mm/year.

Figure 2.2. Projections of sea level rise for London, which are similar to the England average.

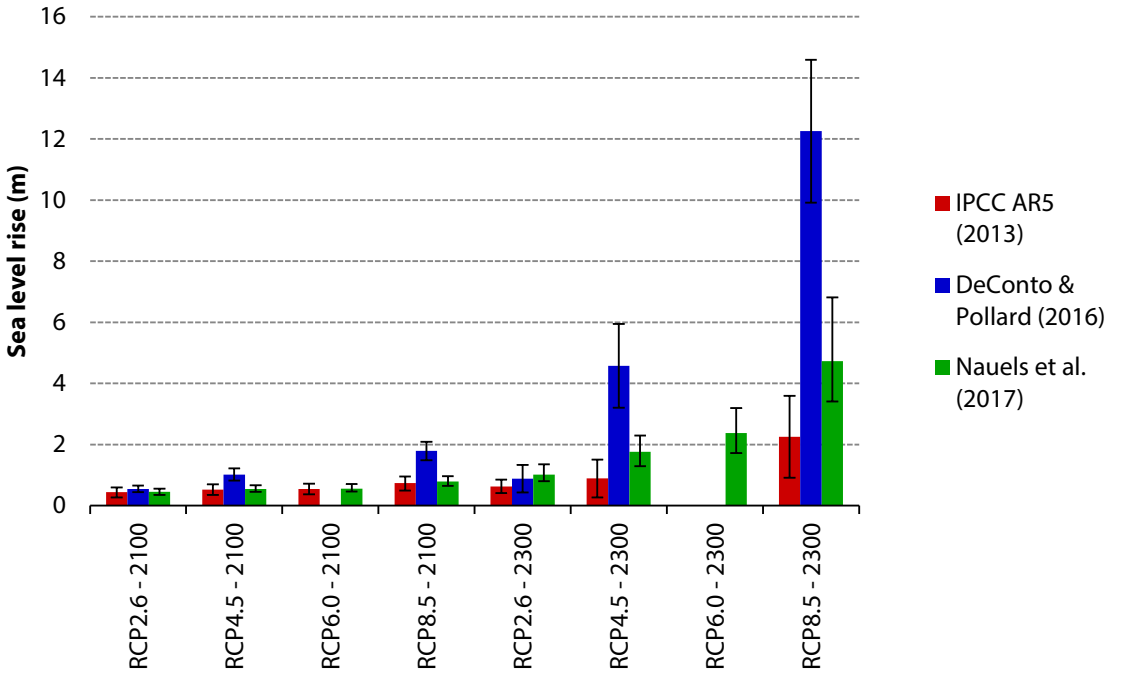


Source: Lowe et al. (2009), *UK Climate Projections science report: Marine and coastal projections.* Met Office Hadley Centre, Exeter, UK.
Notes: The thick line shows the mean and thin lines the 5th and 95th percentiles. At the time of writing (mid-2018) UKCP09 is the most up to date sea level dataset specifically for the UK. This will be updated in November 2018 with the publication of UKCP18 but those data were not available to include in this report.

- Over longer timescales, global sea level is expected to rise for centuries from now regardless of the world's climate change mitigation efforts, due to the long response time of sea level to past emissions of greenhouse gases.[12] Recent estimates project at least 1m of sea level rise by 2300[13] and potentially higher depending on our eventual emissions pathway and on the uncertainties in the way that the major ice sheets in Greenland and Antarctica will respond to climate change[14] (Figure 2.3).
- The 2009 UK Climate Projections (UKCP09) project only modest changes in storm surge intensity and frequency around the UK in the 21st Century.[15] However, there is considerable uncertainty regarding potential changes in the North Atlantic storm track location[16] so it is not possible to rule out more extreme storm surge changes in the future.
- As well as increased flooding and erosion, sea level rise may also result in saline intrusion into groundwater and upstream in estuaries.[17] However, there is considerable uncertainty around the size and extent of this risk due to a relative lack of research in this area.

[12] There is a significant time lag between changes in atmospheric greenhouse gas concentrations, air temperature increases and the thermal expansion of sea water.
[13] Nauels et al. (2017) *Synthesizing long-term sea level rise projections – the MAGICC sea level model v2* Geoscientific Model Development, 10, 2495–2524.
[14] DeConto and Pollard (2016) *Contribution of Antarctica to past and future sea-level rise.* Nature, 531, 591–597.
[15] Lowe, J. A., Howard, T. P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., Bradley, S. (2009), *UK Climate Projections science report: Marine and coastal projections.* Met Office Hadley Centre, Exeter, UK.
[16] IPCC (2013) *Chapter 14: Climate Phenomena and their Relevance for Future Regional Climate Change* In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
[17] Arnell et al. (2015) *The implications of climate change for the water environment in England*. Progress in Physical Geography, 39, 93-120.

Figure 2.3. Global sea level rise projections from three different analyses for different timescales and for different future greenhouse gas emissions pathways (or RCPs, see notes below)



Sources: *Intergovernmental Panel on Climate Change Working Group I contribution to the Fifth Assessment Report* (2013) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.; DeConto and Pollard (2016) Nature, 531, 591–597; and Nauels et al. (2017) Geosci. Model Dev., 10, 2495–2524.
Notes: The error bars show different features for each dataset as each publication used a different method of assessing uncertainty. The IPCC AR5 (2013) error bars show the 90% range of the model ensemble members used in each case; DeConto and Pollard (2016) shows +/- 1 standard deviation of the model ensemble members used in each case; and Nauels et al. (2017) show the 66% ranges of the model ensemble members used in each case. The RCPs, or Representative Concentration Pathways, quantify the impact on radiative forcing of different pathways of greenhouse gas emissions in the future and were used extensively in the 5th Assessment Report of the IPCC. The RCPs shown here represent low-range (RCP2.6), mid-range (RCP4.5 and RCP6.0) and high-end (RCP8.5) future emissions of greenhouse gases. RCP2.6 corresponds to a central estimated rise in global surface temperature of 1.6°C above pre-industrial levels by 2100; the central estimate for RCP 8.5 is 4.3°C (IPCC AR5 WG1).

Even before considering the potential impacts of future climate change, England has many assets exposed to coastal flooding.

- At present, around 520,000 coastal properties (including 374,000 homes) are located in areas with a 0.5% or greater annual risk of flooding in any given year (Flood Zone 3). Flood risk is not limited to properties: there are roads, railways, railway stations, historic landfill sites, agricultural land and important coastal environments that also face a significant coastal flood risk. Table 2.1 summarises the assets at risk from coastal flooding at present. The method used to calculate these numbers is summarised in Box 2.1.
- Coastal floods are also more likely to result in loss of life than river floods: globally, only earthquakes claim more lives per event than storm surges when comparing different

environmental catastrophes[18]; and in the UK there is a long history of coastal floods leading to many deaths.[19]

- The direct economic damages from coastal flooding are of the order of £260 million per year[20] and account for 24% of the Expected Annual Damages from flooding in the UK. This value as defined here includes the costs of property damage only. The overall cost is much higher because of indirect costs that are not currently quantified. These include impacts on health and wellbeing, displacement of people from their homes, disruption to businesses and cascading impacts of direct damages to infrastructure on other assets in other locations.

Table 2.1. A summary of coastal assets at risk from present day flooding in England

Asset category	Flood Zone 2 (0.1% or greater risk of flooding per year)	Flood Zone 3 (0.5% or greater risk of flooding per year)
Residential properties	445,000	374,000
Non-residential properties	173,000	145,000
Motorways and A-roads (km)	930	770
All other public roads (km)	6,550	5,720
Railways lines (km)	522	436
Railway stations	77	59
Historic Landfill (ha)	3,370	2,500
Grade 1, 2 and 3a agricultural land (ha)	205,000	187,000
Site of Special Scientific Interest (ha)	108,000	105,000

Source: Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities.* A research project report commissioned by the Adaptation Committee.
Notes: Agricultural land grades refer to the Agricultural Land Classification. Grades 1 - 3 are defined as high quality agricultural land, with grade 1 being the best quality.

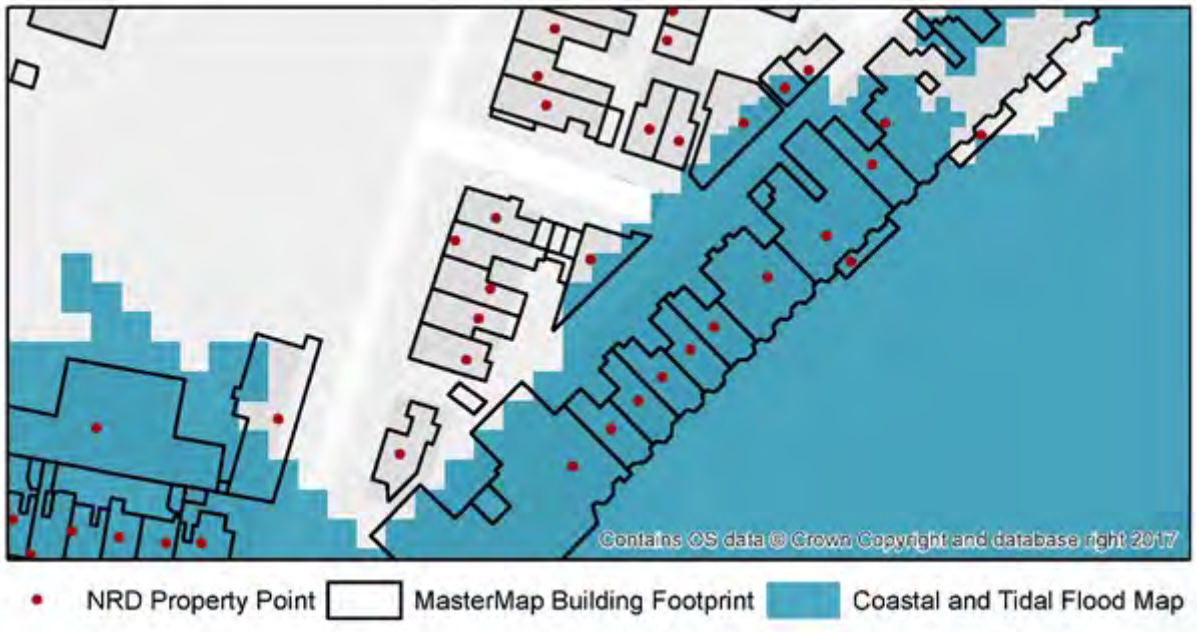
[18] Pears-Piggot and Muir-Wood (2016) *What constitutes a global baseline for worldwide casualties from catastrophes?* International Journal of Disaster Risk Reduction, 17, 123–127.
[19] Haigh et al. (2017) *An improved database of coastal flooding in the United Kingdom from 1915 to 2016* Scientific Data, 4, Article number: 170100.
[20] Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*

Box 2.1. How do we calculate present day flooding and coastal erosion risks?

The risks, or exposures, presented in this report are calculated by overlaying several different spatial datasets. For example, to calculate the number of properties at risk from flooding, we took the Environment Agency's 'Flood Map for Planning (Rivers and Sea)' dataset and their 'National Receptor Database (NRD) 2014 Properties' dataset combined with their 'MasterMap Building Outlines' and, essentially, calculated the number of properties that fully or partially overlap the different Flood Zone extents (see Figure 2.4 for an example). Similar approaches were taken for other assets at risk, such as roads, railway lines, historic landfill sites, agricultural land and so on. A full list of datasets examined and their exposure to flood risk can be found in the research project report (Jacobs 2018 for the CCC) that accompanies this report. The full description of the assumptions and methods used in these calculations can also be found in that report. The Flood Map for Planning data, which exclude the effects of flood defences, are used here to give a reflection of the full number of exposed assets at risk in England.

For coastal erosion, a very similar approach was taken but with the Environment Agency's 'National Coastal Erosion Risk Mapping (NCERM)' dataset, which identifies the areas at risk of erosion. For present day risk, the erosion areas for 2005 - 2025 (i.e. Epoch 1 - see Box 1.2) were used. Here, where we quote numbers of assets exposed to coastal erosion, we include all assets within the full range of uncertainty for the future coastline location (i.e. up to the 5% confidence band, beyond which there is less than a 5% chance of the coast being eroded further inland) and the scenarios assuming 'no active intervention', again to calculate the full potential number of assets at risk in England. These erosion risk areas were then analysed alongside the same NRD dataset used with the flooding data to identify the different assets that overlap with areas at risk of eroding.

Figure 2.4. An example of how property points, building footprints and flood maps are used to identify properties that are at risk of flooding



Source: Jacobs (2018) for the CCC: *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities.* A research project report commissioned by the Adaptation Committee.

By the 2080s, up to 1.5 million properties (including 1.2 million residential) may be located in areas at a 0.5% or greater annual of flood risk and over 100,000 properties may be at risk from coastal erosion.

- In addition, approximately 1,600 km of major roads, 650 km of railway line, 92 railway stations and 55 historic landfill sites are at 0.5% or greater risk of coastal flooding or erosion by the end of the century. There could be a further 100,000 properties on 'complex cliffs' at risk from coastal land sliding; this type of risk is not currently considered within England's coastal erosion risk mapping method.
- Table 2.2 presents results for the assets at risk from future coastal flooding. These results assume a 2°C climate or a 4°C climate, high population growth and baseline (i.e. low level) of adaptation. The method used for these calculations and a brief description of the assumptions applied is outlined in Box 2.2.
- Even with high levels of adaptation, the risk from flooding to properties still increases above present-day levels in the 2050s and 2080s (Figure 2.5).
- The length of major roads and area of agricultural land at risk more than doubles in the 2080s compared to present day. Exposure of other assets also increases in the late 21st Century. This evidence supports the view that flood and coastal erosion risk management strategies and funding would benefit from looking beyond the number of properties protected. The full range of assets at risk, and the interdependencies that they are part of, need to be understood and incorporated in planning decisions.
- As with properties, even in the more ambitious adaptation scenario, the risk is not reduced compared to the present day in any of the categories analysed.[21] These risks could be reduced further with even more intensive adaptation measures than those analysed but this would come at a much higher cost. In the scenarios investigated, even maximising the adaptation measures currently deemed cost-effective will not bring exposure below present day levels in the face of climate change.

Table 2.2. A summary of coastal assets at 0.5% or greater flood risk in the 2080s, for 2°C and 4°C scenarios in any given year in England

Asset category	2°C scenario	4°C scenario
Residential properties (no.) EAD (£millions)	1,271,000 EAD: £146 million	1,265,000 EAD: £163 million
Non-residential properties (no.) EAD (£millions)	212,000 EAD: £222 million	210,000 EAD: £348 million
Motorways and A-roads (km)	1,600	1,600
Railways lines (km)	650	650

[21] Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*

Table 2.2. A summary of coastal assets at 0.5% or greater flood risk in the 2080s, for 2°C and 4°C scenarios in any given year in England

Asset category	2°C scenario	4°C scenario
Railway stations (no.)	93	92
Grade 1, 2 and 3a agricultural land (ha)	385,000	384,000
Historical Landfill sites (no.)	55	55

Source: Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*
Notes: These results are presented from analyses using 2°C and 4°C above pre-industrial temperatures scenarios and assume high population growth and 'baseline' (business as usual) adaptation responses. The values shown are numbers of assets exposed to the 0.5% or greater level of risk plus the annual average 'expected annual damages' (EAD; £ million) where calculated. See Box 2.2 for a description of the method used, particularly in relation to the adaptation assumptions. Landfill was calculated as number of sites rather than area as in Table 2.1. The fields 'All other public roads (km)' and 'SSSI (ha)', which were calculated for 'present day' were not calculated in this future analysis.

Box 2.2. How do we calculate future flood risk?

As part of the Climate Change Risk Assessment 2017 Evidence Report, the CCC commissioned a project looking at projections of future flood risk - the results from that project are used here to show future coastal flood risk. These projections were produced using the 'Future Flood Explorer' tool, which quantifies current spatially varying flood risk for the UK and then manipulates those risk profiles to represent future scenarios of climate change, adaptation responses and socioeconomic factors.

In this work, we present data from the 2°C and 4°C above pre-industrial temperatures climate change scenarios. There are also low and high population growth scenarios that were applied in the model. The climate change adaptation scenarios attempt to represent effect of different interventions on the future risk profile. They make assumptions of the following factors: number of flood defences; changes in land use planning policy; take-up of 'Receptor Level Protection'; and ability to target those at risk more accurately. For the CCRA 2017, these factors were grouped together into six scenarios, which are:

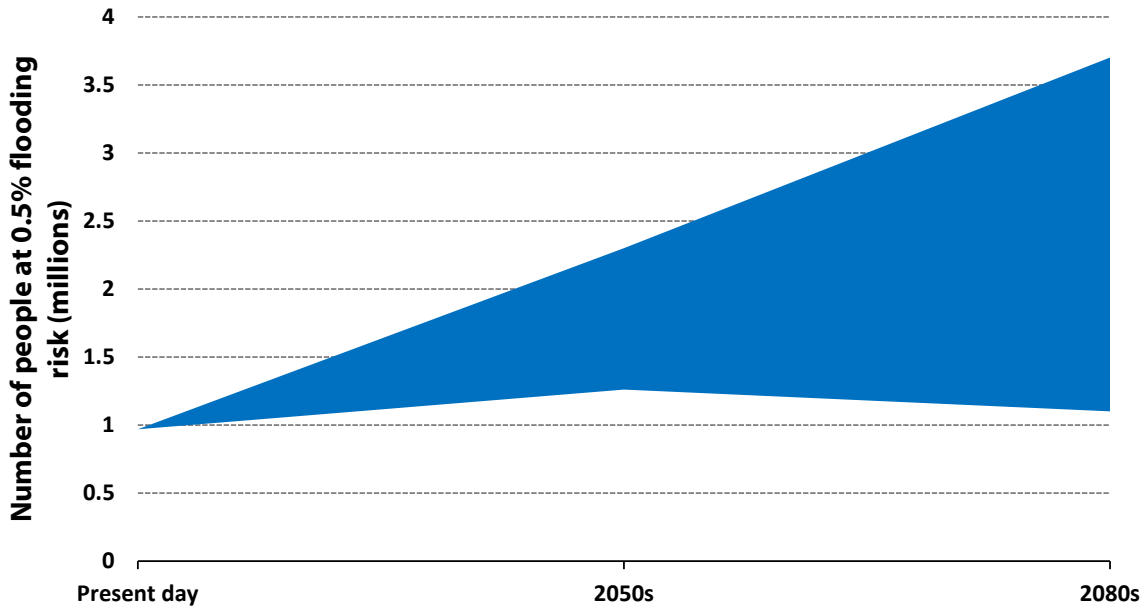
- Baseline - Adaptation measures continue to be implemented as seen in recent years.
- Enhanced 'whole system' - Adaptation is higher than current levels across all adaptation measures.
- Probability focused - Enhanced effort is directed towards the management of flooding probability.
- Exposure focused - Land use planning is strengthened and adaptation measures are increased.
- Vulnerability focused - The vulnerability of the people and infrastructure exposed to flooding has an increased focus, with higher levels of adaptation in this regard.
- Reduced 'whole system' - All adaptation measures are implemented at a lower level than at present.

Whilst Table 2.2 shows the results for the end of the century from two sets of assumptions, Figure 2.5 shows the range of exposure of people covered by permutations of all the climate, adaptation and population assumptions assessed in the CCRA for the 2050s and 2080s. This clearly shows the potential advantages of climate change mitigation and adaptation in terms of reducing exposure to flood risk in

Box 2.2. How do we calculate future flood risk?

the future. Further, even with an assumption of low population change, by the 2080s there could be a difference of 450,000 people exposed to a 0.5% or greater probability of a coastal flood in any given year between a 2°C world with 'enhanced' adaptation (1.10 million people) and a 4°C world with 'baseline' adaptation (1.55 million people).

Figure 2.5. Future population at 0.5% or greater risk of coastal flooding in England in any given year



Source: Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*
Notes: The range plotted here represents the maximum and minimum projections of the number of people at 0.5% or greater risk in any given year of future coastal flooding in the 2050s and 2080s. The full research project produced a suite of projections for different combinations of climate change, population growth and adaptation scenarios but the lower range here is from the 2°C, low population growth and enhanced adaptation measures scenario whereas the higher range is from the 4°C, high population growth and reduced adaptation measures scenario. The results of the other scenarios fall within the range shown here, including the examples used in Box 2.2.

Source: Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*

2.2 Risks from current and future coastal erosion

Coastal erosion affects fewer properties than coastal flooding but the impact is usually irreversible and often assets are totally lost.

- There are currently around 8,900 properties located in areas at risk from coastal erosion in England - Table 2.3 summarises the assets at risk from coastal erosion today. Figure 2.6 shows the areas that are most susceptible to coastal erosion in England, which mainly occur on the softer coastlines of the east of England, in particular East Yorkshire, East Anglia and parts of the south coast. Sea level rise, storm surges and intense waves all contribute to

erosion. The reduction in sediment supply, as a result of seawalls blocking sediment transport, decreases the natural defence of coastlines.

- 7,700 of these 8,900 properties are currently protected against coastal erosion[22], though were these defence structures to fail or be removed, coastal 'rebound' can be expected, with erosion proceeding rapidly inland when the coast adjusts. From this analysis of the NCERM data, 1,200 properties are on eroding coastlines where there are no protective structures.
- No data are collected at the national level on the number of properties actually lost to coastal erosion. Insurance or compensation is not currently available to mitigate against the risk of losing properties. While building surveys conducted by mortgage companies will report on erosion risk, cash buyers could complete a property transaction without knowing if a property they are purchasing on the coast is at risk of erosion.

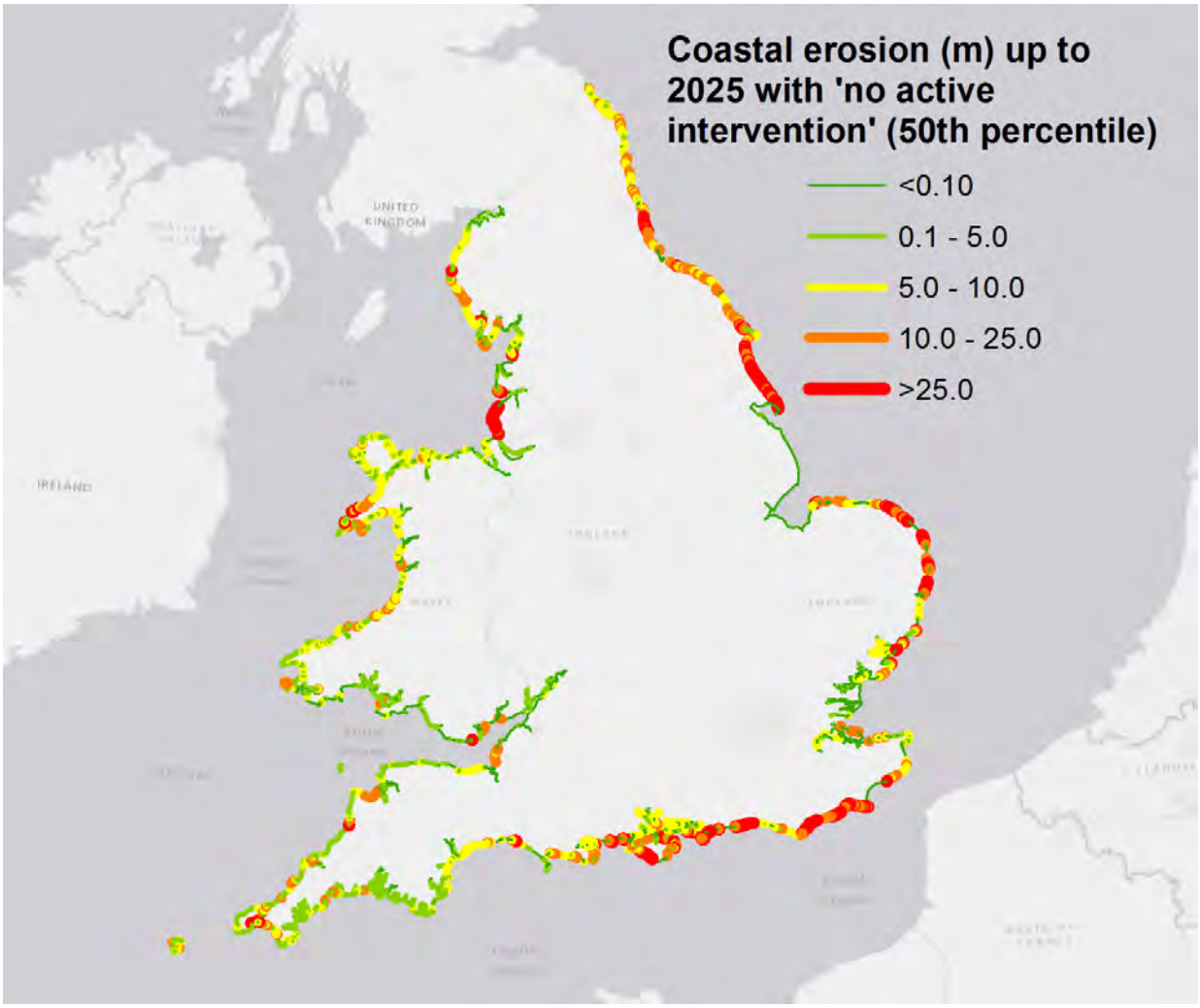
Table 2.3. A summary of coastal assets at risk from present day erosion in England

Asset category	Mid-estimate	High-estimate
Residential properties (no.)	3,535	5,489
Non-residential properties (no.)	2,018	3,451
Motorways and A-roads (km)	5	6
All other public roads (km)	30	49
Railways lines (km)	8	12
Railway stations (no.)	0	0
Grade 1, 2 and 3a agricultural land (ha)	74	98
Historical Landfill sites (ha)	21	31
Site of Special Scientific Interest (ha)	600	800

Source: Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities* A research project report commissioned by the Adaptation Committee.
Notes: These data refer to the NCERM Epoch 1 (2005-2025). 'Mid-estimate' refers to the 50% confidence band of the NCERM data and 'high-estimate' refers to the 5% confidence band i.e. the point beyond which there is only a 5% chance of erosion. NCERM data with 'no active intervention' assumptions are used. Agricultural land grades refer to the Agricultural Land Classification. Grades 1 - 3 are defined as high quality agricultural land, with grade 1 being the best quality.

[22] Calculated as the difference between the number of properties at risk in NCERM Short Term, 5th percentile group with SMP policies and the NCERM Short Term, 5th percentile group with NAI policies.

Figure 2.6. Data from the National Coastal Erosion Risk Map (NCERM) data for England and Wales showing the areas most susceptible to erosion. These data are for the 'mid-estimate' i.e. 50th percentile



Source: The NCERM data for the SMP coastlines presented here are acquired from the Environment Agency via the data.gov.uk portal and is subject to the following attribution: © Environment Agency copyright and/or database right 2016. All rights reserved.
Notes: The map shows the expected extent of coastal erosion between 2005 and 2025 assuming 'no active intervention' at all points - this scenario was used to calculate the current number of properties at risk as protection into the future cannot be assumed.

By the end of the 21st Century, the number of properties at risk from coastal erosion is projected to increase by almost 15 times relative to the present day. This projection is even higher if potential losses from complex cliff erosion are incorporated into the calculation.

- Exposure to coastal erosion losses increase dramatically into the mid- and end-period of the 21st Century. The number of residential properties exposed increases by almost 6 times to around 32,000 into the mid-century period and by nearly 15 times to around 82,000 by the end of the century (not including coastal defences; see Table 2.4).[23]

[23] This refers to the 'high-estimate' (5%) data in order to capture the full level of exposure.

- The potential losses from the erosion of complex cliffs, which are not included in the NCERM dataset but are estimated here[24], are large and need to be analysed and addressed appropriately in order to ensure the sustainability of England's coast.

The number of other assets at risk of future coastal erosion is much lower than those exposed to flooding but most losses would be permanent.

- Unlike in floods, for which damage can be repaired, once homes have been lost due to coastal erosion they cannot be recovered.
- In most cases eroded roads or railway lines are reinstated, involving costly civil engineering works. Re-routing of these infrastructure assets would require a permanent alternative to be developed. If this is not planned for in advance then communities may become isolated or services may be disrupted before an alternative can be put in place. There is little evidence that these losses and the disruption that they would cause are being prepared for. This is discussed further in Section 4.5.

Table 2.4. A summary of coastal assets at risk from future erosion in England

Asset category	Mid-Century, mid-estimate	Mid-Century, high-estimate	End-Century, mid-estimate	End-Century, high-estimate
Residential properties (no.)	21,600	31,800	58,800 (67,500)	82,100 (167,700)
Non-residential properties (no.)	9,700	12,500	19,500 (21,900)	25,200 (43,400)
Motorways and A-roads (km)	38	61	68 (75)	93 (165)
All other public roads (km)	184	254	440 (506)	602 (1,277)
Railways lines (km)	33	42	60 (64)	76 (102)
Railway stations (no.)	3	5	12 (12)	15 (22)
Grade 1, 2 and 3a agricultural land (ha)	240	320	545 (550)	754 (1,450)
Historical Landfill sites (ha)	81	113	181 (184)	239 (314)

[24] See Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities.* A research project report commissioned by the Adaptation Committee.

Table 2.4. A summary of coastal assets at risk from future erosion in England				
Asset category	**Mid-Century, mid-estimate**	**Mid-Century, high-estimate**	**End-Century, mid-estimate**	**End-Century, high-estimate**
Site of Special Scientific Interest (ha)	1,600	2,000	2,800 (3,100)	3,500 (4,400)

Source: Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities* A research project report commissioned by the Adaptation Committee.
Notes: For the 'End-Century' the first value gives the number calculated using the NCERM data alone and the value in brackets is the number calculated using the NCERM data plus an estimation of assets where the erosion of complex cliffs represents an additional risk (see Box 1.3 for a brief discussion of the complex cliffs issue). These complex cliff losses were only included in the 'End-Century' case as there is no reasonable assumption to apply as to when these non-linear processes may occur in each location. 'Mid-Century' refers to Epoch 2 (2026-2055) and 'End-Century' refers to Epoch 3 (2056-2105). 'Mid-estimate' refers to the 50% confidence band of the NCERM data and 'high-estimate' refers to the 5% confidence band i.e. the worst-case-scenario. NCERM data with 'no active intervention' assumptions are used, again, to represent the worst-case-scenario.

2.3 Environmental and socioeconomic components of coastal change

Continued development, combined with concentrations of disadvantaged communities in coastal areas, are likely to compound the future impacts of climate change.

- Research conducted for the National Trust[25] showed that between 2005 and 2014, over 15,000 new buildings were built in coastal areas with either a 1% chance of flooding in any year, or a risk from coastal erosion. Assuming development continued at a similar rate after 2014, 12,000 more properties will have been built between 2014 and the end of the current six-year flood defence funding cycle in 2022.[26] Continued development behind coastal flood defences will increase overall vulnerability to flooding because there is a risk that those defences may fail (e.g. be damaged by increased water levels or overtopped) or may not be maintained in the future.
- Coastal communities tend to have higher than average populations of people aged over 75, higher unemployment, and poorer infrastructure compared to communities inland. [27] The Joseph Rowntree Foundation has calculated a 'flood disadvantage index' based on these characteristics, which is higher in coastal areas (ibid). This 'flood disadvantage' is likely to become more acute in the future as coastal populations are projected to become, on average, older than the population as a whole.[28]

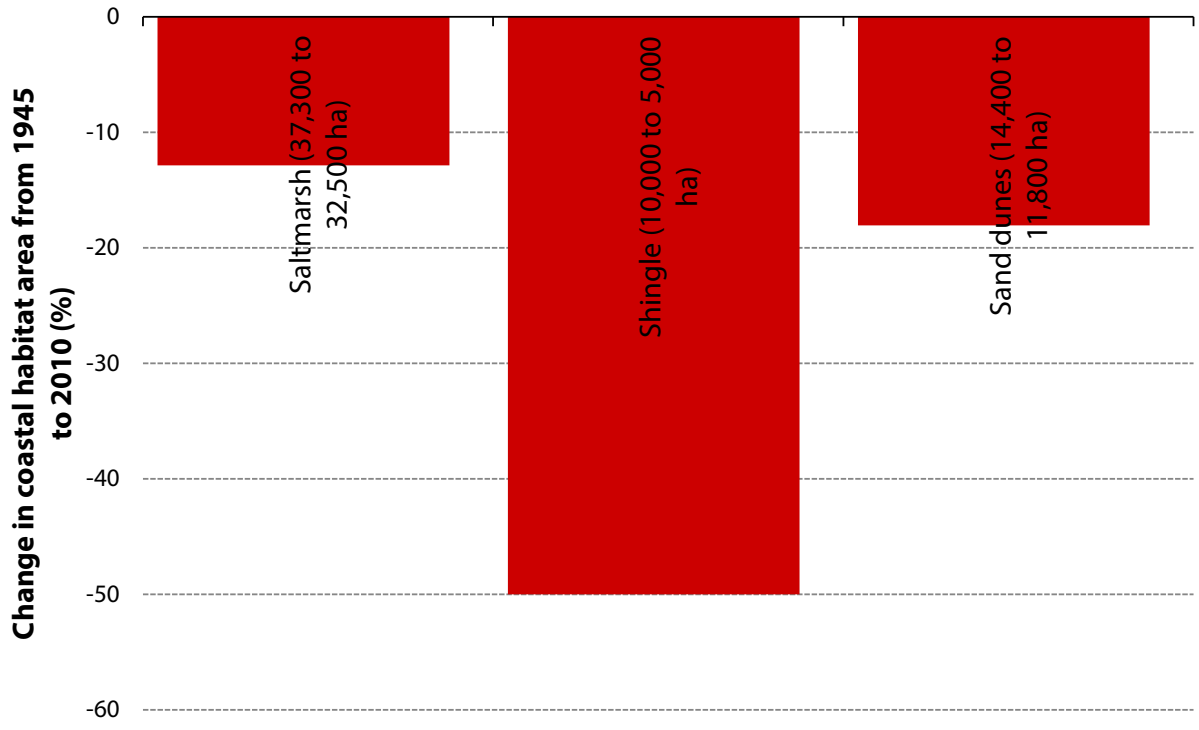
[25] National Trust (2015) *Shifting Shores.*
[26] The CCC's *2017 Report to Parliament – Progress in preparing for climate change* found that up to 90,000 homes will be built in England in the next 5 years in areas with a 1% or greater annual flood risk from all sources of flooding, including coastal flooding. The 12,000 new homes figure assumes that the rate of coastal development continued/will continue at the 2005-2014 rate between 2014 and 2022.
[27] England and Knox (2016) *Targeting flood investment and policy to minimise flood disadvantage*, Joseph Rowntree Foundation.
[28] ONS (2016) *Subnational population projections for England: 2016-based* shows that in 2026, 27 out of 39 of the highest category 'old age dependency ratio' local authorities in England were coastal, which is up from 2016, where it was 23 out of 30 local authorities.

The coastal environments that can provide natural flood defences are deteriorating.

- Coastal environments have significant value to people and wildlife:
  - They act as a buffer in front of sea defences by reducing the wave or tidal energy that impacts those defences. Around half of England's sea defences benefit from this buffering effect.[29]
  - They act as carbon sinks. Coastal margin habitats store at least 6.8 Mt C[30], which is equivalent to approximately 10% of the UK's GHG emissions in a single year.
  - They support biodiversity. Coastal margins support many rare species such as internationally important populations of seabirds as well as commercially valuable populations of fish.[31]
  - They have an important role in tourism and providing cultural services. There are around 250 million visits to the UK's coast every year, which have an approximate value of £17 billion (ibid).
- Saltmarshes, mudflats, shingle beaches, sand dunes and sea cliffs, which provide natural protection against waves and storm surges, are declining in area. Excluding mudflats, these environments have declined in extent by 20% between 1945 and 2010, from around 62,000 hectares to 49,000 hectares (Figure 2.7).[32] These data have not been updated since 2010 so a more up-to-date assessment is not possible here.

[29] CCC (2013) *Managing the land in a changing climate.*
[30] Alonso et al. (2012) *Carbon storage by habitat - Review of the evidence of the impacts of management decisions and condition on carbon stores and sources.* Natural England Research Reports, Number NERR043.
[31] UK National Ecosystem Assessment (2011) *The UK National Ecosystem Assessment Technical Report.* UNEP-WCMC, Cambridge.
[32] CCC (2013) *Managing the land in a changing climate.*

Figure 2.7. Historical decline of coastal environments

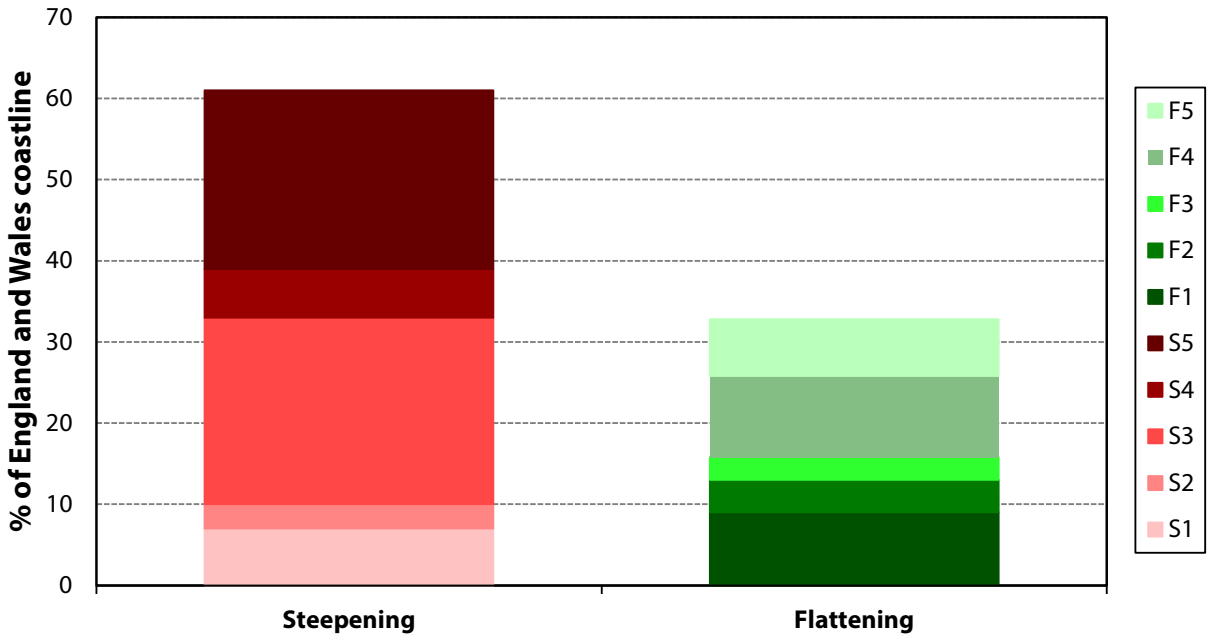


Source: Adapted from UK National Ecosystem Assessment (2011) quoting Jones et al. (1993) and Delbaere (1998) for sand dunes and Morris et al. (2004), Doody (2008) and Cooper et al. (2001) for saltmarsh.
Notes: In total, around 13,000 hectares of coastal habitats (saltmarsh, shingle and sand dunes) have been lost since 1945. This represents 20% of the original area in 1945 of 61,700 hectares of coastal habitats, excluding mudflats.

- Coastal steepening, which is an indication of the area reduction of beaches and other coastal environments, has been observed at over 61% of coastal locations (Figure 2.8)[33] and is likely to be driven by combinations of rising sea levels, interference in sediment transfer (e.g. caused by seawalls affecting sediment flow) and storm surges/waves.
- In the future, up to three-quarters of intertidal coastal environments and habitats may not be able to adapt naturally to sea level rise where they are blocked from migrating inland by hard sea defences, a process known as 'coastal squeeze'.[34] This reduces the ability of these environments to protect sea defences (ibid).

[33] Taylor et al. (2004) *A macroscale analysis of coastal steepening around the coast of England and Wales*, 170, 179-188.
[34] CCC (2013) *Managing the land in a changing climate.*

Figure 2.8. Coastal steepening around England and Wales



Source: Adapted from Taylor et al. (2004) *A macroscale analysis of coastal steepening around the coast of England and Wales.* Geographical Journal, 170, 179–188.

Notes: Taylor et al. (2004) examined 1,084 geomorphologically representative historical Ordnance Survey profile lines across England and Wales. 66 profiles (6%) showed no evidence of steepening or flattening, and these are not included on the bar chart. The remaining profiles were assigned to 5 sub-categories where S5 represents the highest rate of steepening, S1 the lowest rate of steepening and F1 represents the greatest rate of flattening and F5 the lowest rate of flattening.

Chapter 3: The effectiveness of current policies to manage coastal change

Key messages

Today, coastal management is covered by a complex patchwork of legislation and is carried out by a variety of organisations with different responsibilities. The conflicting aims of meeting housing targets and short-term economic goals versus long-term sustainable management of the environment and communities mean that coastal flooding and erosion are not getting the attention that they merit. This is compounded by deprived coastal communities having limited capacity to prepare for and recover from coastal flooding or erosion.

The current policy decisions on the long-term future of England's coastline cannot be relied upon as they are non-statutory plans containing unfunded proposals. The Shoreline Management Plans (SMPs) provide a long-term plan but the actions in the plans are not rigorously analysed so may not be, in reality, viable. They do not align with the time or spatial scales of other key policy instruments, such as Local Plans or wider government strategies on flooding or environmental. Further, research conducted for this report found that up to one third of Local Plans for coastal locations show no evidence of using the SMPs as their required evidence base. This is not an adequate way to plan responses to the climate risks that the English coast and its communities face.

We calculate that implementing the current Shoreline Management Plans to protect the coast would cost £18 - 30 billion[35], depending on the rate of climate change, and that for 149 - 185 km of England's coastline it will not be cost beneficial[36] to protect or adapt as currently planned by England's coastal authorities. This includes 43 - 56 km of the coastline for which the SMP policy is to 'hold the line' - i.e. protect by hard defences - all the way to the end of the century. On a further 53 - 66 km of coastline the SMPs policy to 'hold the line' for part of this century is not cost-beneficial. For these locations, government funding for defences is very unlikely to be forthcoming. A further 1,460 km of the coastline designated as 'hold the line' to the end of the century (71% of the total designated as 'hold the line' to the end of the century or 29% of the total English coastline) achieves a much lower benefit-cost-ratio than the flood and coastal erosion risk management interventions that are government-funded today.[37] On this basis, funding for these locations is unlikely and realistic plans to adapt to the inevitability of change are needed now.

3.1 Legislation in England that relates to coastal flood and erosion risk management

In England there are permissive powers[38] for the government to implement flood and coastal erosion protection.

- Whilst there is no legal responsibility to manage flood and coastal erosion risk in England, there are numerous flood and coastal erosion risk management strategies that give

[35] These values have not been 'discounted' to present day value, which would be £6.4 – 9.2 billion.
[36] This calculation is based on the costs of implementing England's Shoreline Management Plans (SMPs) as set out in the plans themselves, and an analysis of the benefits of doing so in terms of properties protected only. This is comparable to the current methods used to determine which flood and coastal erosion schemes receive funding and does not capture all the benefits.
[37] 1,460 km of 'hold the line' frontages have a BCR of 2.0 or less, which is much lower the BCR of 8.0 that schemes funded in the most recent capital investment programmes have typically achieved.
[38] 'Permissive power' means that an organisation has the power to perform an action but it does not have a legal responsibility to perform that act.

permissive powers to act to reduce the risks. The relevant Acts and Directives are summarised in Table 3.1.

Table 3.1. Summary of relevant primary legislation in England and EU Directives that relate to flood and coastal erosion risk management (FCERM)

Act or Directive[39]	**Key points (elements relevant to England and FCERM only)**
Coast Protection Act 1949	• Permissive powers for coast protection authorities to carry out coastal protection works. • Land may be bought by the authority for coastal protection works but not for other purposes.
Town and Country Planning Act 1990	• Gives the **Planning Inspectorate** power to determine the outcome of planning appeals.
Water Resources Act 1991	• Permissive powers for the Environment Agency (following its formation) to provide sea defences and issue flood warnings.
Environment Act 1995	• Formed the **Environment Agency** and transferred to it functions relating to flood defence. • The Agency is a statutory consultee in relation to planning and development where a flood risk exists.
Planning and Compulsory Purchase Act 2004	• Requires the development of **Local Plans** to outline future development strategy, including safeguarding the environment and adapting to climate change. Local Plans for coastal areas should use the **Shoreline Management Plans** as an evidence base.
Climate Change Act 2008	• The government must prepare a **Climate Change Risk Assessment** every five years. • A **National Adaptation Programme** (NAP) must be presented to Parliament outlining the Government's objectives and policies in relation to adaptation to climate change. • Set up the **Committee on Climate Change** and its Adaptation Committee.

[39] Exiting the EU would not affect the relevance of the EU Directives as they have already been transposed into UK law. However, these UK laws could be changed after exiting the EU.

Table 3.1. Summary of relevant primary legislation in England and EU Directives that relate to flood and coastal erosion risk management (FCERM)

Act or Directive[39]	**Key points (elements relevant to England and FCERM only)**
Flood and Water Management Act 2010 and Flood Risk Regulations 2009	• Environment Agency to develop, monitor, review and update national and local **Flood and Coastal Erosion Risk Management (FCERM) Strategies.** • Defines the roles of organisations involved in FCERM. • Gives 'lead local flood authorities' a duty to prepare Flood Risk Management Plans.
National Planning Policy Framework 2012 (updated in 2018)	• Outlines that local planning authorities should adopt proactive strategies to mitigate and adapt to climate change. • States that areas likely to be affected by physical changes to the coast should be identified as **Coastal Change Management Area** and the authority should be clear as to what development will be appropriate in such areas.
Water Act 2014	• Development of **Flood Re**, which is a reinsurance scheme that aims to keep properties at high risk of flooding insurable by spreading that insured risk across the industry.
EU Water Framework Directive 2000/60/EC	• Sets ecological/biological goals for coastal waters. • Sets freshwater quality goals, including for groundwater that can be impacted by seawater intrusion. • Must be reviewed every 6 years.
EU Floods Directive 2007/60/EC	• Requirement for Member States to assess flood risk. • Requirement for Member States to develop flood risk management plans. • Implemented through the Flood and Water Management Act 2010 and Flood Risk Regulations 2009 in England. • Must be reviewed every 6 years.
EU Habitats 92/43/EEC and Birds Directives 2009/147/EC	• Requirement for Member States to assess, and potentially take compensatory action in relation to the impact on habitats caused by flood management activities.

Notes: More detailed discussion of most of this legislation and its relevance to the coast can be found in the Coastal Handbook.[40]

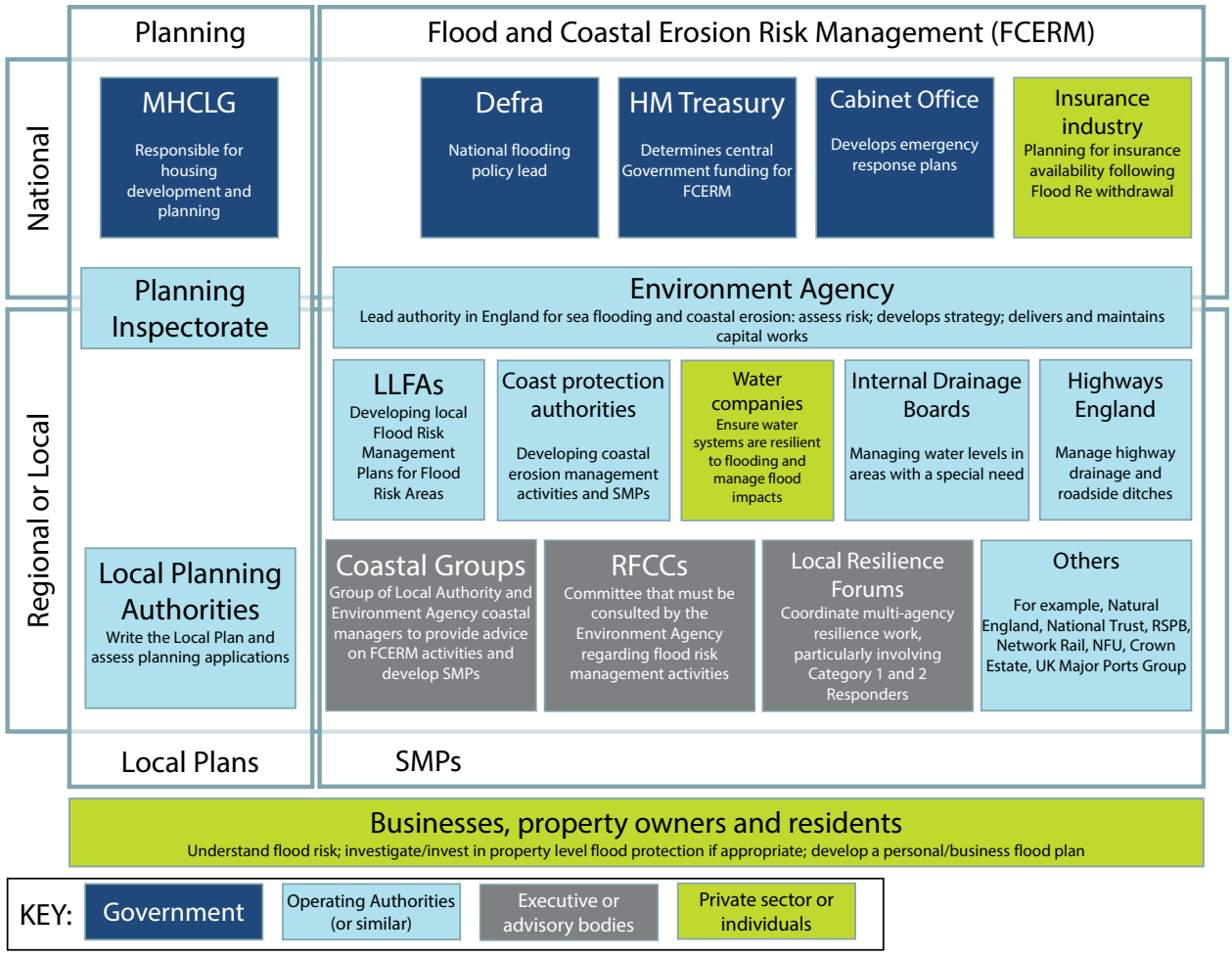
[40] Environment Agency (2010) *The coastal handbook - A guide for all those working on the coast.*

3.2 The structure of the flood and coastal erosion risk management policy makers and practitioners in England

The development and implementation of flood and coastal erosion risk management (FCERM) policies in England has many interacting layers.

- These are generally well defined, particularly since the publication of the FCERM Strategy.[41] However, the large number of different decision making bodies leaves open the possibility of conflicts between priorities. Figure 3.1 summarises the roles of the main bodies at work in this field.

Figure 3.1. Key actors and stakeholders in the Flood and Coastal Erosion Risk Management sector



Notes: The actors and stakeholders have been split by certain characteristics (e.g. spatial scale of operation, sector, planning versus environment) and these splits should be seen illustrative as, in reality, these divisions are not necessarily so distinct. Similar to Table 3.1, these bodies have roles and responsibilities beyond those outlined here. The aim of this diagram is to show how the specific FCERM and spatial planning roles of these bodies sit together.

[41] Environment Agency and Defra (2011) *Understanding the risks, empowering communities, building resilience: the national flood and coastal erosion risk management strategy for England.*

- The current structure of government separates policy making on housing from environment. MHCLG and Defra, as well as agencies such as the Environment Agency, have overlapping responsibilities that can lead to conflicting aims.
  - The government has set an ambitious target to build 300,000 new homes per year.[42] If current trends continue, there is the potential for up to 90,000 homes to be built in the next 5 years in areas with a 1% or greater annual flood risk from all sources of flooding, including coastal flooding.[43] If properly managed, this may not lead to greater damages from flooding in the short-term but developing in areas of flood risk will always increase exposure to the most extreme floods.
  - The implementation of property-level flood resilience measures can have unintended consequences. For example, whilst measures like higher entrance levels, flood gates/doors and higher electrics improve resilience, they can discourage potential homebuyers from choosing a property that appears to be flood prone. Compounding this, the writing of rules relating to new buildings and developments, such as building regulations and property level resilience (PLR) implementation, is owned by MHCLG but has significant impacts on Defra departmental goals. The rules also have to satisfy the home building industry. In recent years this has led to very few changes in building regulations to make PLR measures more common.
  - Combined authorities and Local Enterprise Partnerships (LEPs) can influence whether flood risk is high on the infrastructure agenda locally. However, conflicts can arise if the Strategic Economic Plans and Industrial Strategies are not aligned with flood risk resulting in conflicting objectives.
  - The Environment Agency alongside Defra are responsible for delivering both the FCERM agenda (Flood and Water Management Act 2010) and to protect and enhance the environment (e.g. Water Framework Directive 2000). There are potential conflicts between the two (e.g. building defences that remove or interfere with natural processes and environments) as well as synergies (e.g. natural environment restoration that manages flood risk). The push towards Natural Flood Management (NFM) could drive the two together in a more structured way and a recent set of case studies published by the Environment Agency[44] highlights this.
  - Under the Highways Act 1980 public rights of way (PRoW) are protected and must be maintained by the local highways authority. These authorities are often unable to respond quickly to coastal erosion or landsliding because diverting the PRoW involves complex and often protracted legal processes. There may also be competing priorities in maintaining the PRoW and in letting coastal processes take their normal course. In 2009 the Marine and Coastal Access Act introduced a new kind of coastal path that can respond to coastal processes with greater agility in certain cases, 'rolling back' as the path becomes unsuitable, but this does not apply in all cases.

The primary legislation outlined in here is implemented via a number of different strategies, plans and frameworks. These are reviewed below.

[42] HM Treasury (2017) *Autumn budget.*
[43] CCC (2017) *2017 Report to Parliament – Progress in preparing for climate change*.
[44] Environment Agency (2017) *Working with natural processes*. Project SC150005.

3.3 The implementation of FCERM policy in England

Flood and coastal erosion risk management is coordinated through the Environment Agency's FCERM strategy.

The first FCERM Strategy was published in 2011 and is undergoing it first 6-yearly review and refresh required by the EU Floods Directive and to reflect government priorities for the environment. The updated strategy is due for publication in 2019.[45] The 2011 FCERM Strategy brought together policies and structures from many years of policy and practice development, which simplified and/or more explicitly defined roles and responsibilities. However, the strategy had two limitations. These limitations should be addressed in the 2019 update of the FCERM Strategy:

- The aims and ambitions of the Strategy were not presented in a way that allowed progress towards a target, or targets, to be assessed. For example, the overall aim of the Strategy was to "ensure the risk of flooding and coastal erosion is properly managed". This is subsequently broken down to some extent but not to the level of discrete actions.
- The active timescale of the Strategy was not defined and nor were the ways in which risk management may have to change in the future to respond to a changing risk profile. Whilst the issue of climate change is acknowledged in the document there were no specific strategies outlined that would address the issues raised by a changing and uncertain flood and coastal erosion risk profile in the future.

The government's 25 Year Environment Plan (25YEP) includes high-level ambitions for the environment over the next 25 years, including to manage the risks from flooding, but the steps to achieving those ambitions are not outlined in the plan.

The high-level aims of the 25YEP in relation to coastal flooding and erosion are to:

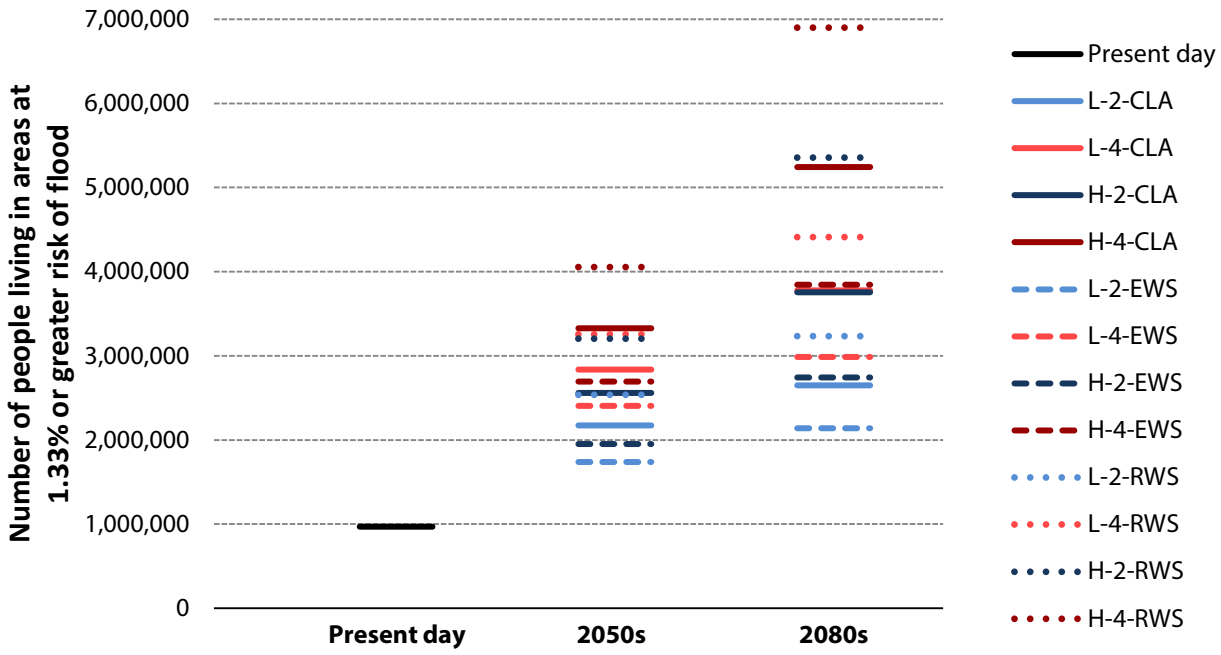
- Reduce the risk of harm from flood and coastal erosion;
- Provide information relating to flood and coastal erosion risk to allow everyone to assess their risk; and
- Ensure current and future flood and coastal erosion risk informs land use decisions, including development.

Whilst these aims are more specific than those from the FCERM Strategy, more detail is required to understand what the success criteria for each aim are, and what actions will be undertaken to meet those aims. To look at one of these aims in particular – to reduce the risk of harm from flooding – research for CCC's Climate Change Risk Assessment 2017 Evidence Report[46] showed that even when applying the most optimistic population, adaptation and climate change assumptions, the number of people exposed to flood risk is projected to increase in the 2050s and 2080s compared to today (see Figure 2.5 in Chapter 2 for an analysis of future coastal flood exposure and Figure 3.2 here for overall future flood exposure). However, depending on the exact meaning of "…reduce the risk of harm…" this could be achieved by improving evacuation systems to ensure that no one is physically harmed, for example. As such, and in order to assess the likelihood of success, the 25YEP and the associated investment plan to achieve these aims

[45] This timeline has been stated in the government's 25 Year Environment Plan.
[46] Kovats and Osborn (2016) *UK Climate Change Risk Assessment 2017: Evidence Report: Chapter 5, People and the built environment*.

requires significantly more detail, including relevant metrics that measure how the risk is changing over time. Publishing this information would be in line with another of the 25YEP's goals: to provide people with the information they need to fully assess their risk.

Figure 3.2. Future populations at risk of flooding from all sources in England



Source: Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*
Notes: Each line represents a projection of future flood risk (river, coastal and surface water combined) for different combinations of climate, population and adaptation scenarios, for the present day, 2050s and 2080s. Blue lines denote projections with a 2°C climate change scenario ("2" in the key) and red lines a 4°C climate change scenario ("4"). Low population growth scenarios are shown by a light shade ("L") and high population growth scenarios by a dark shade ("H"). Solid lines represent a 'baseline' adaptation scenario ("CLA"), dashed lines an 'enhanced' adaptation scenario ("EWS") and dotted lines a 'reduced' adaptation scenario ("RWS"). See Box 2.2 for more details on the assumptions and scenarios. Present day exposure is shown by a black line.

The CCC's assessment of progress in managing flood risk through the National Adaptation Programme (NAP) suggests there is scope for improvement on how coastal adaptation goals are defined and implemented.

The CCC's 2017 Progress Report[47] assessing the 1st (2013) NAP[48] highlighted that progress had been made towards alleviating river and coastal flooding but that significant effort is still required to address adequately the full range of flooding and coastal erosion risks. In particular, the CCC concluded that more work was needed on:

- Minimising increased exposure as a result of new developments in areas at risk of river and coastal flooding;

[47] CCC (2017) *2017 Report to Parliament - Progress in preparing for climate change.*
[48] HM Government (2013) *The National Adaptation Programme: Making the country resilient to a changing climate.*

- Effective and timely deployment of property level flood resilience measures; and
- More generally, to ensure objectives are outcome-focused, measurable, time-bound and have clear ownership.

The government's 2nd (2018) NAP[49] was published in July 2018 and appears to have only partially taken on the Committee's recommendations, and there are some significant gaps:

- The key actions in the 2nd NAP relating to FCERM appear to defer specific targets and actions to other strategies and policies, namely the 2nd FCERM Strategy**,** the metrics related to the 25YEP and the upcoming government policy statement on FCERM; and
- There is no plan outlining the early stages of the transition to risk-reflective insurance in the 2nd NAP (see Section 3.4 for more details)**.**

The 2nd NAP has been written at a time when many environmental policies are in flux as a result of EU-exit. The government's Agriculture and Environment Bills provide a unique opportunity to set out clearer, measurable and ambitious long-term goals and targets for coastal change and land management.

National planning policy aims to steer development away from flood risk areas. It allows development in these areas only when other alternatives have been considered and then only by exception.

- The National Planning Policy Framework[50] (NPPF) outlines the approach to be taken in areas of coastal change via Coastal Change Management Areas. However, a 2016 TCPA assessment[51] of the 64 Local Plans published between 2012 (when the NPPF was first introduced) and 2016 highlighted the "overwhelming' priority" being given to the allocation of housing land and minimal consideration of changing future flood risk.
- The Environment Agency should be consulted on development in areas with at least a present day 1% or greater annual chance of flooding (0.5% or greater in coastal areas). This process appears to be largely effective with recent data showing that only 3% of planning applications have been approved against the Agency's advice.[52]

For local authorities to assess and respond to flooding and coastal erosion risks fully, planners need to be aware of those risks. From an analysis of Local Plans, which outline an authority's approach to development, there is evidence that coastal risks could be overlooked.

- Research carried out for this report found that many of the Local Plans produced by the relevant coastal authorities do not appear to be taking adequate account of coastal risks:
  - 18% (17 out of 94) of active coastal Local Plans that could refer to an up-to-date SMP do not; and
  - 17% (16 out of 94) of relevant coastal authorities do not have an active Local Plan available.

[49] Defra (2018) *The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting - Making the country resilient to a changing climate.*
[50] MHCLG (2018) *The National Planning Policy Framework*.
[51] TCPA (2016) *Planning for the Climate Challenge? Understanding the Performance of English Local Plans.*
[52] CCC (2017) *2017 Report to Parliament - Progress in preparing for climate change.* However, this figure was calculated from incomplete data.

- This situation is likely to worsen as the requirement for the SMPs to underpin coastal development strategies has been removed from the 2018 revision of the NPPF[53] and instead moved into the Planning Practice Guidance.[54] The signpost to the SMPs still exists for local planners but its removal from the NPPF itself undoubtedly gives the appearance of its importance being downgraded.
- Further, the research uncovered additional complications with the incorporation of SMP findings into Local Plans:
  - No Local Plans are 'active' beyond 2036, which is only 10 years into the second time period of the SMPs ('Epoch 2'; 2026-2055) and 18 of the 94 Plans are only 'active' up to 2026. The implication is that Local Plans are not fully responding to the policies of the SMPs up to 2055 and none are taking into account changes in SMP policy after 2055. The mis-match of spatio-temporal scope of Local Plans and SMPs has the potential to introduce unintended exposure to coastal flooding and erosion.
  - Coastal Change Management Areas (CCMAs) are only put in place where SMP policies are 'managed realignment' or 'no active intervention'. This would be acceptable if 'hold the line' was guaranteed in perpetuity, but it is not. Therefore, development may be occurring in areas that planners are assuming will be protected but where future funding may not be secured for 'hold the line' actions.
- On the positive side, however, 43 out of the 94 did state that planning permission for works on the coast must be in line with SMP policy.

3.4 Funding of flood and coastal erosion risk management

Coastal defences protect significant assets but are expensive to build and maintain and need replacing when damaged or inadequate.

- The value of assets at risk from coastal flooding is difficult to quantify[55] but could be in the region of £120 - 150 billion[56] and includes ports, railway stations, roads, schools, care homes, landfill sites and power stations (including substations and nuclear power stations, 12 of which are thought to be at risk from coastal erosion or flooding[57]).
- The building of coastal defences in England to protect these assets accelerated in the 1920-1930s when marine concrete became more readily available[58] and continued to develop as tourism to the coast increased and new technologies were introduced through World War II.[59] The devastating storm surge along the UK's east coast in 1953[60] brought about a renewed effort to repair and extend defences. Since the 1960s, when the understanding of

[53] The old NPPF Paragraph 168 stated: "Shoreline Management Plans should inform the evidence base for planning in coastal areas. The prediction of future impacts should include the longer term nature and inherent uncertainty of coastal processes (including coastal landslip), and take account of climate change."
[54] MHCLG (2018) *Planning Practice Guidance.*
[55] There is no up-to-date assessment of this value – the most thorough assessment is over 15 years old (Halcrow (2001) National Appraisal of Assets at Risk from Flooding and Coastal Erosion, including the potential impact of climate change) - and calculations often assume that there is no flood protection in place.
[56] Parliamentary Office of Science and Technology (2010) *Sea Level Rise.* POSTnote 363.
[57] HM Government (2012) *UK Climate Change Risk Assessment: Government Report.*
[58] Nicholls et al. (2013) *Planning for long-term coastal change: Experiences from England and Wales.*
[59] Fleming (1992) *The development of coastal engineering.*
[60] McRobie et al. (2005) *The Big Flood: North Sea storm surge*. Philos. Trans. R. Soc. A, 363, 1263–1270.

coastal processes improved, there has been more of a focus on 'soft' solutions that aim to work with natural processes.[61]

- After decades of developing coastal flood and erosion protection, England now has a significant stock of coastal protection, some of which dates from the late 19th and early 20th Century. Research for CCRA 2017 Evidence Report projected that 20% of coastal flood protection assets would be vulnerable to failure under a 0.5 m sea level rise scenario.[62]
- Coastal protection also brings indirect costs with it: i) it has starved the coast of sediment, which has reduced the area of natural coastal environments; ii) it has left a legacy of coastal structures that are costly to maintain, replace or adapt; and iii) it has locked in patterns of coastal habitation, that are unsustainable in the context of climate change.
- Since 2015, around £200 million per year has been spent on capital defence projects to reduce coastal flood and erosion risk.[63] Flood defence grant-in-aid spending (government funding) for coastal flood defence schemes is allocated on a cost-benefit basis. Funds are allocated via a formula that tests the technical and financial acceptability of proposals before approval, and not all proposals proceed to the funding stage on this basis.[64] This process is not conducive to developing long-term sustainable plans that meet environmental and housing needs.

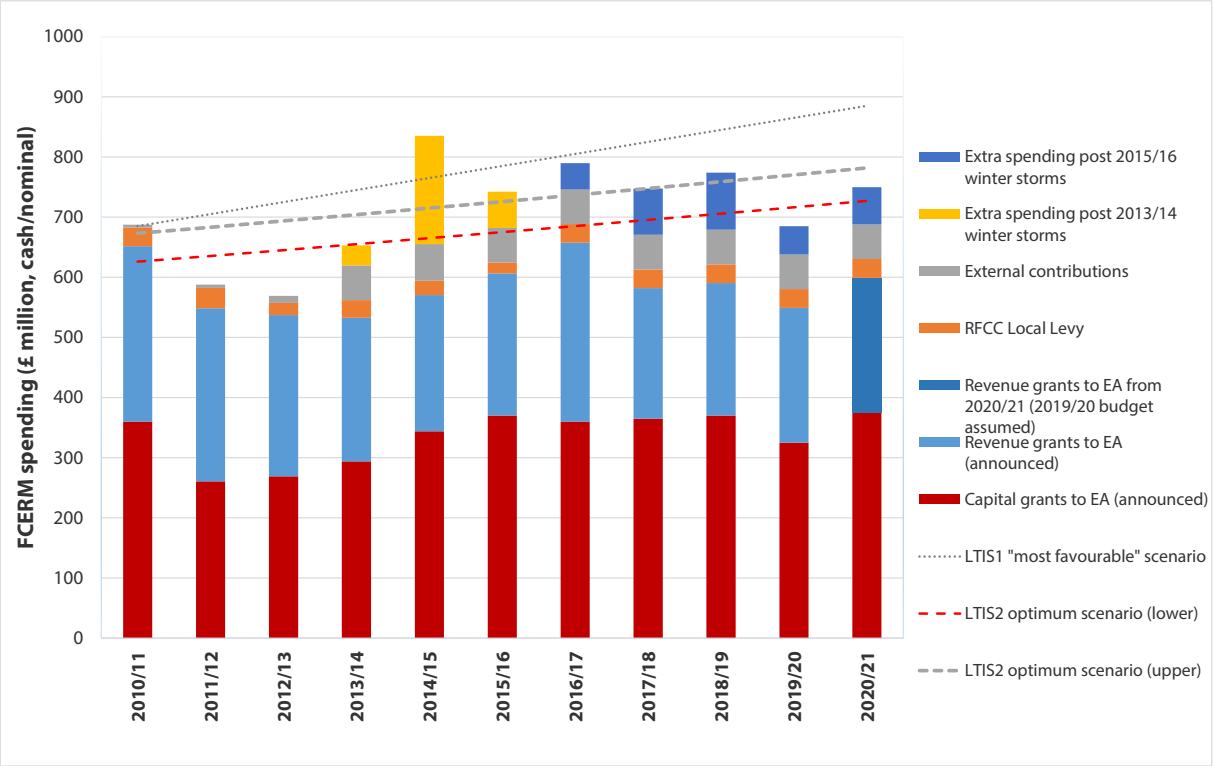
The government's 6-year (2015/16 to 2020/21), £2.3 billion Investment Programme in FCERM has supported several large scale flood defence projects.

- Progress towards the target of better protecting 300,000 homes from all sources of flooding is on track and equates to a 5% net reduction in expected annual flood damages.[65] Examples of coastal schemes funded from the 6-year Investment Programme include: the Boston Barrier; Ipswich Tidal Barrier; Rossall Coastal Defence Improvement; and the Humber Estuary flood defences amongst many others. The Lincolnshire Beach Management project represents a 'soft' coastal engineering programme that has been funded within this time frame.
- Longer term investment planning allows for a clearer assessment of whether funding is in line with the Long Term Investment Scenarios[66] (Figure 3.3). This ensures that works are following a cost-effective spending trajectory, which means spending around £750 million per year now, increasing to around £850 - 900 million per year by the mid-2020s. However, as discussed above, whilst the overall investment levels are sound, the specific schemes that secure funding are not prioritised relative to their importance in long-term sustainable plans.
- Partnership Funding has the potential to include the beneficiaries of flood alleviation schemes as (partial) funders of them, which was one of the Pitt Review recommendations[67],

[61] Fleming (1992) *The development of coastal engineering*.
[62] Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*
[63] Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities.* A research project report commissioned by the Adaptation Committee.
[64] Environment Agency (2014) *Flood and coastal defence: develop a project business case.*
[65] CCC (2017) *2017 Report to Parliament - Progress in preparing for climate change.*
[66] Environment Agency (2014) *Long-Term Investment Scenarios*.
[67] Pitt (2008) *Lessons learned from the 2007 floods*.

but the private sector has so far made only low contributions via Partnership Funding.[68]

Figure 3.3. Spending on flood and coastal erosion risk in England against the long-term need



Source: CCC (2017) *2017 Report to Parliament - Progress in preparing for climate change* based on Defra (Sept 2016) *Central Government Funding for Flood and Coastal Erosion Risk.*
Management in England, and Environment Agency (2014) Long-Term Investment Scenarios.
Notes: Money retained by Defra, and spending by local authorities on local flood risk management, are excluded from the figures. All figures are presented in cash/nominal terms, with inflation included at 1.5% per year. The 'most favourable' long-term investment scenario identified in the Environment Agency's 2009 Long-Term Investment Strategy (LTIS1) required an average of £20 million more plus inflation to be spent each and every year to 2035 in order to avoid an increase in the number of properties in areas of significant flood risk (1-in-75 annual chance of flooding or greater). The optimal investment path identified in the Environment Agency's 2014 Long-Term Investment Scenarios (LTIS2) suggested a lower optimal rate of investment, starting at between £750 million and £800 million in 2014/15.

Despite non-traditional projects demonstrating value-for-money when tested, it is still difficult to secure funding for these schemes.

- The series of Coastal Pathfinder projects that road-tested innovative FCERM approaches between 2009 and 2011 (e.g. Buy and Leaseback schemes, community engagement, regeneration via tourism or business) were assessed to have "delivered a significant number of benefits and represented good value for money overall."[69] However, there are barriers to such schemes going ahead at present as the benefits cannot always be quantified accurately

[68] Priestley (2017) *Flood risk management and funding* Briefing Paper Number CBP 07514 - of the £600 million target for Partnership Funding within the 6-year investment programme it is expected that around 15%, approximately £100 million, might come from private sources with the remainder coming from other public sources.
[69] Defra (2012) *Coastal Change Pathfinder Review - Final Report.*

e.g. community engagement is likely to improve the success of any intervention but the specific value of this is unknown and difficult to quantify.

- For managed realignment schemes, issues related to land ownership and purchase are complex and extremely time-consuming to resolve, and the optimum sites for 'managed realignment' are often where population density is low, which makes the economic case difficult to justify under current funding arrangements.
- The lead local authority flood grant, which is distributed to local authorities in relation to their flood exposure, could be used as a funding source for non-engineering schemes but this grant is not ring-fenced and can be spent on other priorities that the local authority has.

The insurance industry is adapting to changing flood risk profiles, which will take many years.

- Flood Re was set up to aid the transition towards risk-reflective pricing by 2039. It is an industry funded re-insurance scheme that aims to make flood insurance available to those who face significant flood risk. Flood Re has been operating for less than 2.5 years and currently subsidises around 150,000[70] policies.
- The CCC has previously noted concerns about how Flood Re can be used to incentivise the type of action needed to improve flood resilience:
  - A subsidised insurance scheme like Flood Re largely removes the financial incentive for high risk households to take action to prevent flooding. Flood Re recognises this potential paradox[71] and is engaging in further work to understand effective ways to communicate risk and influence householder decisions in this area.
  - Property level resilience (PLR) would be an effective approach to managing the threat to high risk households yet up to 2017 the government's six-year investment plan only included proposals to protect around 500 households per year using these measures. However, analysis for the CCC's 2017 Progress Report showed that at least 153,000 households in England would be cost effective to protect using PLR measures, and this is expected to increase to more than 217,000 by the time Flood Re is withdrawn. Flood Re's progress in promoting the uptake of PLR for high risk properties will be an important part of this plan and Flood Re have recently published a report on the effectiveness of PLR (ibid), which leads them to conclude that "…homeowners should be encouraged to put PFR measures in place." The details of Flood Re's role here will be expanded in the future and could be an important aspect of overall vulnerability reduction.
  - The transition to risk-reflective pricing and the steps towards removing Flood Re were not mentioned in the 2nd National Adaptation Programme[72], which outlines the government's adaptation actions for the period 2018-2023. The removal of Flood Re in 2039 will be a significant event and the NAP has no targets or actions towards managing the transition between now and 2023.

There is currently a lack of information for the public and no compensation available for losses of properties from coastal erosion.

[70] Flood Re (2018) *Annual report and financial statements, year ended 31 March 2018.*
[71] Flood Re (2018) *Incentivising household action on flooding and options for using incentives to increase the take up of flood resilience and resistance measures.*
[72] Defra (2018) *The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting - Making the country resilient to a changing climate.*

- Insurance or compensation for lost properties is not currently available for homeowners to mitigate against the risk of losing their property through coastal erosion. While building surveys conducted by mortgage companies will report on erosion risk, cash buyers could complete a property transaction without knowing if a property they are purchasing on the coast is at risk of coastal erosion. Consequently, homeowners at risk may not take action to relocate or consider strategies beyond protecting their existing asset.

3.5 The effectiveness of Shoreline Management Plans

The non-statutory SMPs propose unfunded policy approaches that are not rigorously analysed from an economic perspective and do not align with the timescales of other key policy instruments.

- The most up-to-date SMPs were developed by the Coastal Groups between 2004 and 2011 with the aim of developing responses to long-term coastal changes - there are more details about the SMPs in Box 1.2.
- The SMPs are not statutory documents and, therefore, have no mandatory role in coastal adaptation policy in England. The SMPs are referred to in other policies and strategies (e.g. Local Plans, the National Planning Policy Framework, 1st and 2nd NAPs, FCERM Strategy), however, whilst they remain without a statutory basis of their own, they could be viewed as a 'wish list' rather than a strategy on which to base other policies.
- There is no financial commitment to implement any actions outlined in the SMPs. FCERM funding decisions take no account of whether a proposal is critical to the success of an SMP. This means that there is no assurance that SMP policy decisions will be implemented and that there is a certain level of risk in taking long-term housing or infrastructure decisions based on SMP policy decisions.
- The SMP timescales (or 'epochs') do not align with other policies' implementation windows. The 25YEP and the 5-yearly NAPs both plan on different timescales and the many coastal Local Plans are not explicit in the timeframes of risk that they use. More effective long-term planning would benefit from consistent time scales being adopted by different sectors.

There is no requirement within SMPs to calculate the overall costs and benefits of the proposed measures.

- The guidance provided to the authors of the SMPs stipulates that plans should be developed "… taking account of technical, environmental, social and economic factors…" but there is no requirement to perform any sort of economic assessment to justify the choice of SMP policy.[73] Given this, it has been previously unknown how cost effective the SMP policies are on a local or national scale.
- Our analysis has shown that in total, the SMP policies will cost around £18 - 30 billion (as a cash value) or £6.4 - 9.2 billion (discounted to present values) to implement (Table 3.2 shows the central estimates using discounted values). These ranges come from the application of a range of climate change uplift factors. The central estimates for these costs are £21.6 billion (cash) or £7.3 billion (discounted).
- These costs refer to the total of all of the policies included in the SMPs to manage flooding and coastal erosion together, added across all three epochs up to 2105. The SMP documents

[73] Defra (2006) *Shoreline management plan guidance - Volume 1: Aims and requirements.*

assessed the costs of implementing all the policy decisions at the policy unit level, which were based on the replacement costs for linear structures such as revetments and seawalls or from the Environment Agency's Unit Cost Database. Maintenance costs for different measures were taken from the National Appraisal of Defence Needs and Costs (NADNAC) study.[74] Jacobs (2018) has compiled those numbers and summed them.

Table 3.2. The costs (£ million, central estimates, discounted, undiscounted in brackets) associated with implementing the SMP policies out to 2105

Region	2005-2025	2026-2055	2056-2105	Total (2005-2105)
North East	345 (431)	346 (783)	541 (3,544)	1,232 (4,681)
Anglian	189 (249)	649 (1,399)	341 (2,726)	1,178 (4,221)
Southern	1,295 (1,600)	979 (2,171)	448 (2,754)	2,723 (6,545)
South West	504 (624)	437 (977)	326 (2,040)	1,267 (3,620)
North West	291 (333)	372 (826)	214 (1,357)	877 (2,487)
Total (England)	**2,624** (3,238)	**2,783** (6,157)	**1,871** (12,421)	**7,278** (21,554)

Source: Sayers (2018) for the CCC**,** and Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities.* A research project report commissioned by the Adaptation Committee.
Notes: These figures have been discounted and represent future costs at present day values in accordance with the HM Treasury Green Book (i.e. a discount rate of 3.5% for years 0-30, 3.0% for years 31-75 and 2.5% for years 76-125). The estimates shown here are central estimates; the full ranges with the climate change uplift factors applied are in the research report. Undiscounted costs use the discounted estimates in Jacobs (2018) and Sayers (2018) and should be regarded as indicative only.

The total benefits of the SMP policies in terms of avoided damages from coastal flooding are estimated to be £9.4 billion (Table 3.3).

The benefits across the three time windows are calculated using the weighted average annual damages (WAADs)[75] method applied to sequences of SMP policy decisions - the method for doing this is outlined in the research project report that accompanies this CCC report.

[74] Defra (2004) *National Assessment of Defence Needs and Costs for flood and coastal erosion management (NADNAC).*
[75] Penning-Rowsell et al. (2013) *Flood and coastal erosion risk management: a manual for economic appraisal.*

Table 3.3. The total benefits (£ million, central estimates, discounted, undiscounted in brackets) in terms of avoided damages from flooding if the SMP policies are implemented as described in the SMP documents

Region	2005-2025	2026-2055	2056-2105	Total (2005-2105)
North East	408 (554)	285 (874)	160 (1,502)	853 (2,931)
Anglian	1,205 (1,638)	806 (2,472)	438 (4,122)	2,449 (8,231)
Southern	1,401 (1,904)	937 (2,874)	509 (4,791)	2,847 (9,569)
South West	1,242 (1,689)	829 (2,541)	454 (4,269)	2,525 (8,499)
North West	374 (509)	249 (763)	135 (1,271)	758 (2,543)
Total (England)	**4,629** (6,294)	**3,107** (9,524)	**1,697** (15,955)	**9,432** (31,773)

Source: Sayers (2018) for the CCC, and Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities* A research project report commissioned by the Adaptation Committee.
Notes: These figures have been discounted and represent future costs at present day values in accordance with the HM Treasury Green Book (i.e. a discount rate of 3.5% for years 0-30, 3.0% for years 31-75 and 2.5% for years 76-125). The estimates shown here are central estimates; the full ranges with the climate change uplift factors applied are in the research report. Undiscounted benefits use the discounted estimates in Jacobs (2018) and Sayers (2018) and should be regarded as indicative only.

The total benefits of implementing the SMP policies in terms of avoided property losses from coastal erosion are £3.9 billion (Table 3.4). The difference in the number of properties lost between the NCERM data with assumptions of 'no active intervention' and 'SMP policies implemented' for the 50th percentile band is used to calculate the benefits of implementing the SMP policies in terms of properties protected, which are assumed to be totally lost if the SMP policies were not implemented. The complete method for doing this is outlined in the research project report that accompanies this CCC report.

Table 3.4. The benefits (£ million, central estimates, discounted, undiscounted in brackets) in terms of avoided damages from coastal erosion if the SMP policies are implemented as described in the SMP documents

Region	2005-2025	2026-2055	2056-2105	Total (2005-2105)
North East	46 (62)	156 (478)	90 (843)	291 (1,383)
Anglian	265 (360)	660 (2,024)	162 (1,522)	1,087 (3,906)
Southern	424 (576)	847 (2,595)	540 (5,083)	1,811 (8,254)
South West	105 (143)	338 (1,038)	180 (1,694)	624 (2,874)
North West	7 (9)	37 (113)	44 (413)	87 (535)
Total (England)	**846** (1,150)	**2,038** (6,248)	**1,016** (9,554)	**3,900** (16,952)

Source: Sayers (2018) for the CCC, and Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities* A research project report commissioned by the Adaptation Committee.
Notes: These figures have been discounted and represent future costs at present day values in accordance with the HM Treasury Green Book (i.e. a discount rate of 3.5% for years 0-30, 3.0% for years 31-75 and 2.5% for years 76-125). The estimates shown here are central estimates (i.e. the 50% band). Undiscounted benefits use the discounted estimates in Jacobs (2018) and Sayers (2018) and should be regarded as indicative only.

Analysing the numbers from Tables 3.2 to 3.4 at the 'policy unit' scale (see Box 1.2) allows us to make the following conclusions about the SMPs and their cost effectiveness:

- 149 -185 km of England's coastline will not be cost beneficial to protect as currently planned by England's coastal authorities. The range reflects the different assumptions that can be applied to the levels of damages as a result of climate change.
- This length of non-cost beneficial coastline includes 43-56 km that is currently designated as 'hold the line' - i.e. protected by hard defences - to the end of the century and a further 95-112 km that is designated as 'hold the line' to some point before the end of the century. Under these circumstances, the assumptions made by local planners as to the long-term status of sections of coastline may be undermined by the weak economic case for protection. These areas are also unlikely to have had been designated as Coastal Change Management Areas (CCMAs), which would limit the development of those areas.
- Elsewhere, investment may become increasingly difficult to prioritise, with approximately 1,460 km of England's coastline currently designated as 'hold the line' (71% of the total designated as 'hold the line' to the end of the century or 29% of the total English coastline) failing to achieve a benefit-cost-ratio (BCR) greater than 2.0. This is much lower than Defra's 'BCR greater than 8.0' outcome for FCERM interventions.[76]

[76] NAO (2014) *Strategic flood risk management*.

Chapter 4: Planning for coastal change - developing robust adaptation responses

Key messages

Policy for coastal management needs to reflect the increasing pressures from climate change, which mean that the status quo cannot be maintained in all locations. Major coastal assets, such as cities and critical infrastructure will require investment in higher standards of protection as sea levels rise. Long-term plans to adapt to changes are required everywhere. Managed realignment and the restoration of natural coastal adaptation offers benefits that people value and is most feasible in areas of low population density, but still requires investment, facilitation and monitoring.

The evidence about the future risks from coastal change needs to be improved and communicated better. This includes more accurate projections of future erosion, which currently contain wide uncertainty ranges and do not properly account for the likelihood of failure of coastal structures and sliding on complex cliffs. Coastal flood maps should better account for the effects of sea level rise and changes to coastal geomorphology.

National Government policy needs to reflect, realistically, future changes on the coast, providing planning policies and funding arrangements that facilitate change. Reforms to legislation and to the way it is implemented are needed, particularly in relation to the relocation of assets and communities. Planning by local government, especially in the Shoreline Management Plans, needs to reflect, realistically, the prospects of change on the coast, exploring and valuing a wider range of adaptation options, including options such as relocation.

Sustainable coastal adaptation is possible and could deliver multiple benefits. However, it requires a long term commitment and proactive steps to inform and facilitate change in social attitudes. Reforms to legislation and to the way it is implemented are needed, particularly in relation to the relocation of assets and communities. Managed realignment and the restoration of natural coastal adaptation offers benefits that people value and is most feasible in areas of low population density, but still requires investment, facilitation and monitoring. Major coastal assets, such as cities and critical infrastructure will require investment in higher standards of protection as sea levels rise. Long-term plans to adapt to changes are required everywhere, with a sharper focus on: long-term resilience; engagement and supporting communities to adapt; integration with other local priorities; and the cost-effectiveness of the policies being proposed.

4.1 Elements of successful, long-term planning for coastal change

Adapting to coastal change involves accepting that universal protection from coastal flooding and erosion is not tenable.

- Our analysis in this report suggests that protecting all coastal locations through hard defences where currently planned is not likely to be cost-effective. Informed decisions and plans regarding where to protect and where to rethink coastal priorities are therefore likely to be required in some places, which would result in more policy units looking to 'softer' adaptation responses. In addition, even the modest amount of managed realignment envisaged in the SMPs is not being implemented at the rate set out in the plans.

To address these long-term issues, we conclude that regulatory reform should take place.

- Firstly, long-term, specific goals are required and the status of SMPs needs to be reinforced in legislation. There is an opportunity to do this through the Environment and Agriculture Bills. The role of the SMPs as the evidence base for coastal Local Plans is adequate in theory but, in practice, it is undermined by the mis-aligned spatial scales and timescales of the two types of plans. Therefore, Local Plans need to examine risks further into the future and be aligned with wider areas in order to ensure the most resilient plans are developed. Alongside this, SMPs need to be more rigorously tested from an economic perspective and given a greater level of commitment to ensure local planners have the robust evidence base they require.
- Secondly, long-term funding streams are required that can facilitate softer adaptation approaches and support the long-term engagement that the affected communities require.
- Thirdly, the transition towards risk-reflective insurance needs to be carefully managed and updated compensation rules, particularly regarding losses to erosion, need to be considered. Our analysis shows that there will be an acceleration in erosion losses and, therefore, new approaches to incentivise or use compulsory relocation powers where needed should be considered.

Four specific things that should go alongside or stem from this regulatory reform are:

- Further consideration of alternative scenarios to 'hold the line';
- Improved access to information on current and future risks;
- Sustained engagement from national and local decision makers with affected communities;
- Flexible adaptation plans that allow actions to change in response to events as they unfold.

Each of the four aspects is explored in more detail below, drawing on case study analysis prepared as part of the supporting material for this report.[77]

4.2 Consideration of alternatives to 'hold the line'

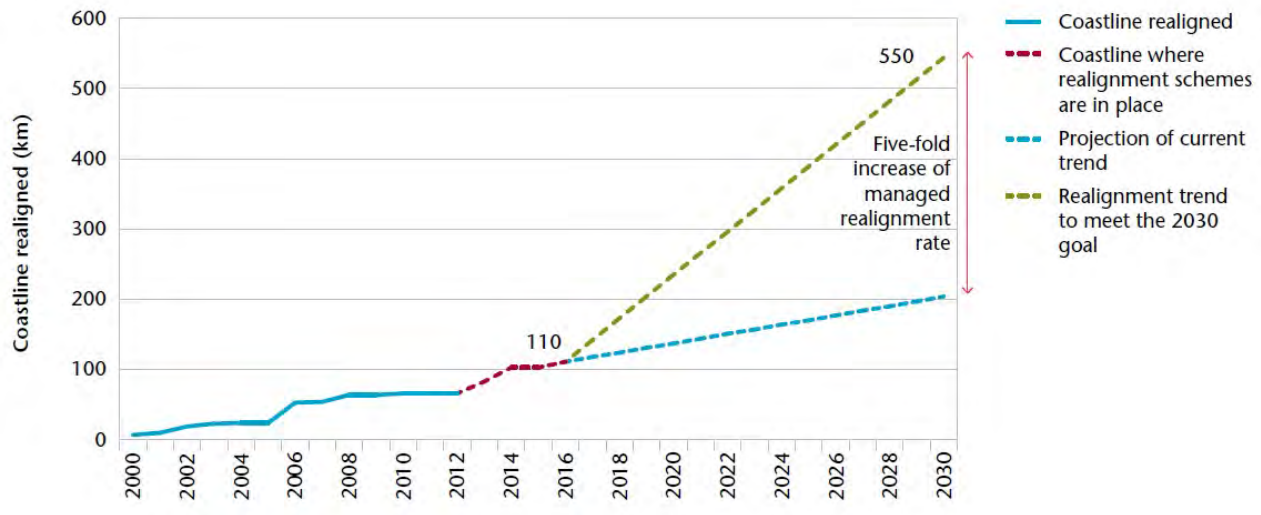
The analysis in chapter 3 of this report demonstrates that 'hold the line' is not likely to be economically justifiable or affordable in certain locations where it is currently the preferred policy.

- The alternatives to policy responses that try to maintain the status quo is to allow for more natural processes to dominate, leading to the coastline realigning itself in response to sea level rise. 'Managed realignment', which is one of the Shoreline Management Plan (SMP) policy options, looks to set back the shoreline and restore coastal environments. This strategy usually involves removing or deliberately breaching flood defences to allow flooding up to higher ground or a new defence line; or realigning coastal cliff frontages to allow cliff erosion. It has advantages in removing long-term financial commitments to maintain defences and in restoring natural environments and processes. Managed realignment can create new habitat area that acts as a natural buffer to coastal waves and is much cheaper to maintain over the long-term.

[77] The case study analysis undertaken by Jacobs used real places as examples of coastal location 'types'. Theoretical adaptation pathways have been applied to those locations to look at the potential for taking pathways approaches in those areas and what the issues are that emerge. Because the pathways are theoretical, the places used in the analysis have been anonymised so as to avoid misinterpretation that the pathways are proposed plans.

- In cases where coastal defences are at long-term risk of failure or are unsustainable in the face of environmental changes, 'managed realignment' will often be a more cost-effective policy option to adopt over the long-term but requires significant up-front costs and long term planning and community engagement to maintain livelihoods and enhance quality of life in any affected communities.
- Research conducted for the UK Climate Change Risk Assessment 2017 Evidence Report[78] showed that around 170 km of coastal defences (approximately 20% of the total in England) will be highly vulnerable to failure by the 2080s assuming a 2°C warming scenario. However, the areas highlighted in the CCRA as being at risk of failure do not correlate with areas where managed realignment is currently planned between now and the end of the century. In addition, managed realignment is not happening at the pace needed to meet the aspirations of the SMPs. Our previous analysis in 2013 also showed that current rates of managed realignment are five times lower than those required to meet the level set out in the SMPs for 2026 (Figure 4.1).
- The benefits of managed realignment at specific locations and working with natural processes in general need to be appreciated, valued and accounted for. The co-benefits of restoring natural environments are hard to quantify but this restoration is an important step towards coastal sustainability.

Figure 4.1. Managed realignment to 2012 and comparison with 2030 aspiration from Shoreline Management Plans



Source: CCC (2013) *Managing the land in a changing climate.*
Notes: Approximately 66 km of the coastline was realigned up to 2012, and planned realignment schemes would bring this to 111 km realigned in total by 2016. The average realignment rate between 2000 and 2016 (6 km per year) would need to increase five-fold to about 30 km per year to meet the Shoreline Management Plans aspiration of 550 km realigned coastline by 2030. About 1,320 hectares had been created by 2012, and habitat creation schemes in place to 2016 would bring this to 2,220 hectares of habitat created in total. The average rate of habitat creation between 2000 and 2016 was around 130 hectares each year. This rate would need to triple (to around 400 hectares created per year) to meet the Shoreline Management Plans aspiration of 7,500 hectares of habitat creation by 2030.

[78] Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*

4.3 Producing and communicating information on current and future risks

More accurate, clearer, simpler data and information on the long-term level of risk from coastal flooding and erosion forms the basis for long term adaptation planning. These data need to be communicated by the government through specific metrics.

The analysis in the previous sections of this report show a mismatch between high level government goals and the reality of future flood risk from coastal flooding (Sections 3.1 - 3.3), and a lack of information about current and future coastal erosion risk (Section 3.4). There are two important steps to achieving a goal of improving data collection and sharing:

- Risks from coastal flooding and erosion need to be calculated and/or assessed for the present day and into the future.
  - There should be a national approach to projecting flood risk so that risks in different areas can be compared and so that information can be made available to the public. To achieve this, coastal flood mapping needs to improve to better incorporate sea level rise.
  - As discussed in Section 2.2, no data are collected at the national level on the number of properties actually lost to coastal erosion. Understanding past impacts is an important step in assessing current risk and verifying projections.
  - Uncertainties in coastal erosion projections need to be reduced, particularly in terms of complex cliffs, which were discussed in Section 2.2 and Box 1.3.
  - The probability of failure of coastal structures needs to be calculated in a more robust fashion.
  - Our understanding of coastal geomorphology, in particular how coastal sediment movements are going to respond to sea level rise, needs to improve.
- The communication of these risks to stakeholders needs to improve so that they understand the implications, and uncertainties, of this information.
  - The communication of coastal erosion risks in general does not always reflect the full exposure - published estimates of the number of properties that may be lost in future from coastal erosion focus on a 'best-case' scenario at present.[79] Sustainable shoreline management requires a realistic presentation of risks as a first step in that process.
  - Information and the associated uncertainty regarding coastal erosion risk is not well communicated to individuals e.g. there is no equivalent to the Environment Agency's 'Long term flood risk information' webpage[80] for coastal erosion. The access to information on specific properties at risk of coastal erosion is not as good as the flooding equivalent and the rights that individuals have when faced with coastal erosion losses are not communicated well.
  - Whilst information on present day flood risk is readily available to those that are at risk, a strategy is required to communicate the likely changes to that risk as a result of climate change and how that risk is changing over time. The government's 25-year Environment

[79] Environment Agency (2017) *Managing flood and coastal erosion risks in England.* – most likely based on NCERM data for the 'short term' with 'Shoreline Management Plan' policies looking at the 95th percentile of likely erosion (i.e. the best-case-scenario)
[80] https://flood-warning-information.service.gov.uk/long-term-flood-risk/map

Plan metrics should include risk metrics related to coastal change. In addition, management of the transition to risk-reflective insurance and communication of the steps individuals can take to minimise their vulnerability is essential. As discussed in Section 3.4, Flood Re are making progress on this front but government oversight does not appear to be strong at the moment.

4.4 Sustained engagement from national and local decision makers with affected communities

There needs to be a long-term and appropriately resourced approach to engaging affected communities and stakeholders.

- Decisions that have a significant impact on communities need to be taken in collaboration with those communities and need to be planned and assessed well in advance of their implementation. These plans need to be dynamic enough to respond to specific events or 'crises'. Difficult decisions (e.g. relocation of existing properties, limiting the approval of new properties) should be considered, discussed and planned with the community and other relevant stakeholders who have specific responsibilities. Adaptation policies could take decades to implement and that process needs be managed with all relevant stakeholders engaged throughout. There are few examples of successful, long-term engagement strategies such as those proposed here and significant new resources will have to be provided to the relevant organisations (e.g. Environment Agency, local authorities, Regional Flood and Coastal Committees) to plan and implement them.
- The success of an adaptation plan may hinge on its acceptance by the affected community as much as its reliance on robust projections of risk and the consideration of socioeconomic impacts. Box 4.1 on the case of Fairbourne in Wales presents an example where deep engagement occurred (and is ongoing), though it was after an important decision had been made.
- The Fairbourne example highlights the extent of resources that are required for engagement activities. Examples of successful, long-term community engagement are rare so lessons need to be learnt in all cases for future situations where difficult decisions have been made. For future cases of coastal changes impacting communities there needs to be more capacity available for early and continued engagement.

Box 4.1. Low capacity and few resources for pro-active, long-term community engagement

Fairbourne is a coastal village in Wales and is home to around 1,000 people. The village is covered by the West of Wales Shoreline Management Plan, which was adopted by the local council in January 2013. The SMP included policy decisions that would see Fairbourne protected until 2025 ('hold the line' in epoch 1), followed by a period of working towards 'decommissioning' the village in 2055 ('managed realignment' in epoch 2 and 'no active intervention' in epoch 3).

This policy decision essentially means that the village will be 'decommissioned' by 2055 as a result of projected environmental changes.

Box 4.1. Low capacity and few resources for pro-active, long-term community engagement

Gwynedd Council has described how the community and stakeholders were engaged in advance of the SMP publication.[81] Amongst other engagement activities, a meeting was arranged in Fairbourne in May 2011 but it appears that this process did not uncover major concerns: "There was no written feedback from the local residents, although concerns were raised and discussed at the meeting. These views were incorporated within the Plan and the Plan highlighted the need for detailed discussion and planning."

The full implications of the SMP policy appear to have become more widely publicised following a BBC programme on the matter in 2014. Subsequently, the Fairbourne Facing Change group was formed by local residents. Their statement of objectives implies that they consider the SMP consultation inadequate: "Our objectives are to inform, engage and involve the people whose lives have been deeply affected by the situation, which could have been considerably lessened, had we been consulted and engaged at the time stated in the Council's timeline".[82]

The Council then formed a group called Fairbourne Moving Forward, which is described as "a multi-agency project that addresses the complex issues identified throughout the journey of the community over the next 40 years, drawing upon expertise and knowledge from a range of organisations including Gwynedd Council, YGC, Natural Resource Wales, Welsh Government, Royal Haskoning DHV, North Wales Regional Emergency Planning Group, the Emergency Services, Welsh Water and the local community".[83]

Subsequently, Fairbourne Moving Forward have developed a 'Masterplan' that works towards the decommissioning of the village over a 36 year period. The plan is supported in its delivery by a number of working groups and aims to have community engagement. However, the process of decommissioning is at a very early stage and there is little evidence as yet of the success of the initiative

The costs related to the Fairbourne Moving Forward group alone in terms of grants from the Council and the Welsh Government between 2014 and 2016 are in excess of £300,000. This does not account for much of the (limited and stretched) staff time that will have been dedicated to post-2014 engagement activities.[84] These are not costs related to the actual implementation of the plan; they relate to community engagement, which will need to continue over the next 36 years as well.

4.5 Adaptation plans that allow actions to change in response to events as they unfold

The precise timing and exact impact of coastal crises are difficult to anticipate. Adaptation plans and disaster response strategies need to be robust to future uncertainties.

- Box 4.2 discusses the benefits of taking decisions that deal with long-term risks at the appropriate point and ensuring that those plans can be funded when action is required.

[81] Gwynedd Council (no date) Frequently asked questions https://www.gwynedd.llyw.cymru/en/Residents/Documents-Residents/Parking,-roads-and-travel/Flood-and-Coastal-Risk-Management/West-of-Wales-Shoreline-Management-Plan-Frequently-Asked-Questions.pdf
[82] http://www.fairbournefacingchange.com
[83] http://fairbourne.info/
[84] http://fairbourne.info/wp-content/uploads/2014/08/Fairbourne-Moving-Forward-Presentation-220116.pdf

Box 4.2. Imminent problems - delayed decisions

Given the time window, or 'epoch', approach to the SMP process, it is possible for the SMP authors to push decisions back into the 2026-2055 or 2056-2015 windows without any strong evidence for making that decision. In some circumstances this makes sense: where a situation requires further monitoring before a definitive decision is taken; where a defence is approaching the end of its life and the plan is to let it deteriorate to the end of its useful life rather than proactively move to a different strategy; or where protection is only required up to a certain date (see Box 4.3 on significant assets).

In other cases, it is likely that difficult problems may have been pushed back as, given all the barriers to effective coastal adaptation, they were too hard to address in the 2005-2025 window. Indeed, cases have been examined where the cost-benefit ratio of certain 'hold the line' (HTL) policy decisions are not favourable and are eventually followed by a 'managed realignment' (MR) policy.[85] In such instances, the case to take action early and start addressing the problems is strong but not consistent with the SMP policy. Policy units where the policy decision is unlikely to ever receive the funding required to implement that policy have a particular problem - these locations need to be identified and the plans re-examined with a more realistic perspective of the funding that is likely to be available.

Meanwhile, the environment continues changing whilst time that could have been used to address those problems passes. Indeed, trigger points for action - an erosion event or a compromised defence, for example - could occur without any significant response having been planned. In particular, the ability to plan and implement relocation of assets could be greatly supported if there were to be a change in government policy and associated funding prioritisation or outcome measures.

However, being given the tools to relocate assets will not be the only answer to the problem, and it needs to be recognised that: (a) property owners may be unwilling to accept relocation to a different area that does not offer the same valued aspects as the current location; and (b) environmental and other planning constraints in the area may mean it is not possible to relocate assets in the first place. It is therefore vital to understand both: (i) what will property owners accept (both in terms of offered relocation and risk of property being lost); and (ii) what will the planning system allow, and this further emphasises the importance of engagement over a period of time with all stakeholders to develop and plan coastal adaptation measures that will be deliverable.

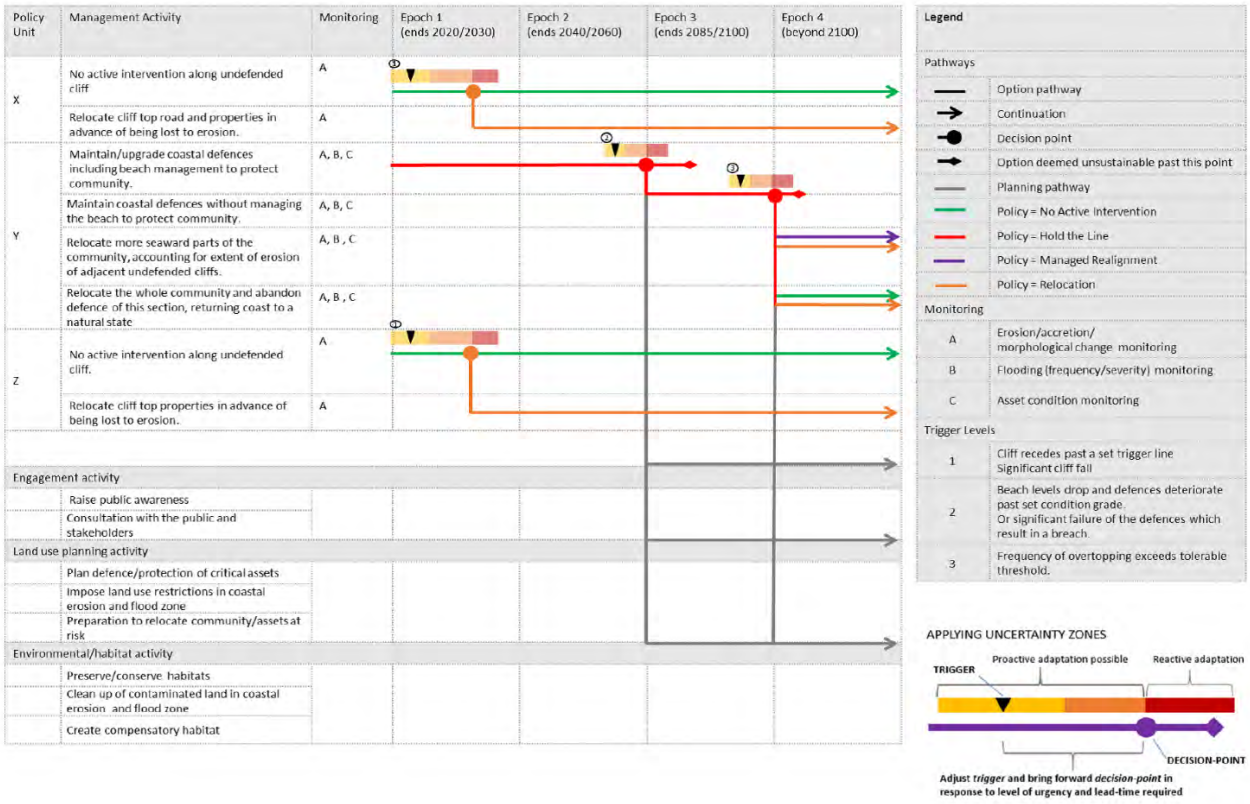
- The timing of coastal 'crises' (e.g. storm surges, landslides) is largely random. Where significant risk exists, pre-emptive actions and/or plans for disaster response and recovery should be implemented at the optimum time even if this means taking some difficult decisions. The discrete nature of the SMP time horizons (or 'epochs') should not be used to delay actions that are critical to sustainability because of practical issues (e.g. funding, lack of political will) and steps should be taken to align timescales across policy implementation vehicles.
- The lack of certainty over the long-term availability and commitment of funding to specific responses in specific locations makes realistic long-term planning challenging. The long-term approach of the SMPs has many benefits but the lack of a rigorous economic assessment of the SMP policy decisions, combined with a lack of financial commitment to implement the decisions, is a significant shortcoming.

[85] Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities.* A research project report commissioned by the CCC.

Adaptation options with long lead times need to be planned and assessed well in advance of their implementation. These plans need to be dynamic enough to respond to specific events and have been developed with the relevant stakeholders.

- Difficult decisions (e.g. relocation of existing properties, limiting the approval of new properties) should be considered, discussed and planned with the community and other relevant stakeholders who have specific responsibilities. New powers may be required, for example, by local authorities to facilitate relocation or by planning authorities to ensure that a longer term planning outlook is taken. Adaptation pathways approaches can help in developing these plans and understanding the wider consequences of the actions that may be take
- Adaptation pathways (Figure 4.2) are a decision making tool based around a number of different potential options, with defined points at which decisions are made as to which option to pursue.
- This is a useful approach to apply to the implementation of the SMPs and in many instances, managing adaptation in general - all the cases here demonstrate the need for more structured and long-term approaches to coastal adaptation. Pathways approaches are useful in adaptation planning where defined thresholds or 'triggers' are known as they can provide the following:
  - A way of demonstrably responding to the many uncertainties in future coastal change.
  - A more comprehensive assessment of the different avenues available to decision makers depending on how a risk unfolds over time. Providing a 'trigger' for a response, which would usually be an event in this context rather than a date, gives a flexible and pragmatic approach to planning. It allows for the different available options to be appraised for the optimum point to respond rather than an arbitrary date.
  - A dynamic approach to avoid lock-in to particular pathways as the way that different responses impact on the ability to subsequently implement other responses is analysed.
  - The ability to compare different options in terms of costs and benefits for different levels of risk. It also identifies points at which particular responses become ineffective or superseded by other responses. If approached from a long-term perspective then the pathways can help facilitate responses that are effective and efficient over the long-term rather than less efficient short-term responses.
  - The provision of different options being implemented over a long period of time allows for a more explicit method to incorporate risk appetite into decision making.
  - A defined point at which decisions need to be made to take more substantial action if the risk increases over time.
- On the negative side, stakeholders are sometimes not keen on 'event-based decision making' so the communication of benefits of preparing to react to chronic problems when a threshold is reached, as opposed to planning defined by fixed 'epochs', would be helpful.

Figure 4.2. Schematic of an adaptation pathway, developed with trigger points and responses taken from different locations with a view to highlighting the potential use of the method



Source: Jacobs (2018) *Research to assess the economics of coastal change management in England and to determine potential pathways for a sample of exposed communities* A research project report commissioned by the CCC.

The protection or relocation of coastal assets requires careful planning to minimise the risk of highly disruptive crises.

- The loss or damage to an asset during a storm or landslide, say, will have immediate implications e.g. loss of a transport link, interruption to power supplies. However, the relocation of that asset would alter the socioeconomic dynamics of the area in the long-term. Planning for such events is complex and requires information on the range of present and future risks as well as the impact on socioeconomic systems. Box 4.3 discusses the situation where the socioeconomic impacts are relevant and pressing.

Box 4.3. Adaptation plans for significant assets at significant risk

Certain coastal locations with significant and increasing flood or erosion risk also house key infrastructure assets such as power stations, mainline railway lines, roads or gas terminals. These assets typically have significant direct value but their indirect value in terms of power supply, transport links or supporting local economies is also significant. Damage to assets like these will have cascading impacts on many people and businesses.

In these situations the policy decision usually remains 'hold the line' (HTL) for as long as the asset is active, potentially with increasing levels of protection required as climate changes increase the risk.

Box 4.3. Adaptation plans for significant assets at significant risk

Considering assets that are largely immovable, the most obvious option is to continue defending the asset to higher levels, which could have other negative impacts such as 'lock-in' to a particular strategy and affecting the visual amenity of the area. There are other options beyond seawalls, which include strategies like the Sand Engine that is being used at Bacton to extend the life of the gas terminal there, but these are largely untested.

However, with assets that could potentially be relocated, like a train line or a road, there are additional options of moving inland or seaward. The trigger for adopting any of these options (i.e. improving defences or relocation) would be related to the frequency of overtopping and flooding or when physical damage occurs to the asset. In some relevant examples (e.g. the Dawlish Railway) these triggers were exceeded before a clear adaptation plan had been adopted, or developed where a plan had been developed but was not implemented when a trigger point was passed (e.g. the Slapton Line/A379). When developing long-term plans for areas that have not exceeded such triggers, though, planners require data on past events and robust projections of future risk.

There are consequences of such relocation strategies, though. Relocation of a rail line inland, and thus away from any risk of coastal flooding and cliff instability, would fundamentally change the basis on which ongoing maintenance of coastal defence at a town like Dawlish is justified. The case would change from one of protecting nationally important rail infrastructure to one of protecting a small seaside town, and the responsibility for doing so would move from Network Rail to the Local Authority and Environment Agency. This could have significant consequences for the community. Depending on the relocation site, the removal of the transport link from its current location would have an adverse economic impact on such a town.

More generally, it could also be argued that the approach in some areas of having alternating HTL and NAI policy units along the coastline itself presents a fundamental problem that would impact other locations. If this approach is taken, then the whole coast would – over time-scales of centuries – become more segmented with communities becoming armoured headlands with embayments forming between them, which will starve down-drift coastal areas of sediment (and so likely have wider adverse impacts). This very long-term consequence should be considered now as it undermines the long-term sustainability of the strategy as a whole. Accepting this reality and developing an acceptable adaptation strategy will be particularly challenging when moderately sized communities are involved i.e. in the order of 1000s of homes.

4.6 Recommendations and how the Adaptation Committee will monitor progress

This report has presented an assessment of coastal management and adaptation in England and identified where further work is required to manage the risks of coastal change in England.

In response, the Committee recommends the following actions with a view to managing or reducing risks related to a changing coast.

- **The analysis presented in Chapters 1 and 2 summarised the scale of the current and future risks facing the English coast, including from climate change. These risks are not well understood or communicated to the public, and more work is needed to understand local level risks and the options to manage them. Chapter 3 showed that the current policies and practices to manage those risks are not realistic about future changes. This needs to be addressed.**

RECOMMENDATION 1: The scale and implications of future coastal change should be acknowledged by those with responsibility for the coast and communicated to people who live on the coast. At the moment the future risks of coastal flooding and erosion are not fully understood. Improved risk mapping (led by the Environment Agency) and more complete analysis of the full costs and benefits of coastal management options will provide the evidence needed to make realistic plans. This information needs to be communicated (unambiguously but with an appropriate recognition of uncertainties) to communities and policy makers.

- **Chapters 3 and 4 examined the impact that coastal change and the required adaptations may have on communities and socio-economic systems. Coastal adaptation needs to happen with the involvement of all relevant stakeholders.**

RECOMMENDATION 2: Local government and the Environment Agency need to be enabled by national government to deliver a long-term and appropriately resourced approach to engaging affected communities and stakeholders. Decisions that have a significant impact on communities need to be taken in collaboration with those communities and need to be planned and assessed well in advance of their implementation. These plans need to be dynamic enough to respond to specific events or 'crises'. Difficult decisions (e.g. relocation of existing properties, limiting the approval of new properties) should be considered, discussed and planned with the community and other relevant stakeholders who have specific responsibilities. Adaptation policies can take decades to implement and that process needs be managed with all relevant stakeholders engaged throughout. There are few real world examples of successful, long-term engagement strategies such as those proposed here and significant new resources will have to be provided to the relevant organisations (e.g. Environment Agency, local authorities, Regional Flood and Coastal Committees) to plan and implement them.

- **The government policies reviewed in Chapter 3 have recognised the need for a strategic long-term approach to managing the coast. The government's 25 Year Environment Plan sets ambitious goals for restoring the environment, but there are not specific outcome-focussed targets for the coast.**

RECOMMENDATION 3: Defra and MHCLG policy on the management of coastal flooding and erosion risk should specify long-term, evidence-based, quantified outcomes that have the buy-in of the affected communities and stakeholders. The government's 2nd National Adaptation Programme, 1st Flood and Coastal Erosion Risk Management Strategy and the 25 Year Environment Plan have not proposed actions that can be assessed in terms of their impact on overall exposure or risk. These government statements could provide the institutional framework to achieve this aim, but they will have to be strengthened and augmented with new policies and metrics. Defra and MHCLG should enable and require adaptation planning by local government, and should monitor progress. The Agriculture and Environment Bills offer the opportunity to start the reform of legislation to achieve this.

- **The discussion in Chapter 3 showed that funding for flood defence schemes has delivered protection to many communities where the benefits of risk reduction greatly exceed the costs. However, the valuation of costs and benefits, as well as the options considered for funding, need to be broadened, especially for those communities where conventional protection schemes will not be affordable.**

RECOMMENDATION 4: Government should make available long-term funding/investment to deliver a wider set of adaptation actions. Decisions about funding should be based on a broader and more inclusive economic case than is current practice. Current funding streams

provide value for money, largely by delivering hard defences where there is the best economic case supplemented with local 'partnership funding' contributions. Places where continued investment in hard defences is uneconomic tend to lose out. However, these places also need funding to assist them to adapt to inevitable changes, so whilst hard defences may not be fundable they still need support for a broader package of adaptation actions, including community engagement, asset relocation and compensation to move households where appropriate. This should be addressed either by altering existing funding formulae or developing a new funding mechanism, which could, for instance, take inspiration from innovative green finance models or community development corporations. The economic case to support long-term funding should be determined not just by the protection of physical assets but should also incorporate environmental implications and social justice considerations.

- **Chapters 2, 3 and 4 have shown that some SMPs are problematic in terms of economic justification and delivery so are unlikely to be implemented in future. Local Plans may still be permitting development in places that will be at risk in the long term.**

RECOMMENDATION 5: Plans to manage and adapt specific shorelines over the coming century should be realistic and sustainable in economic, social and environmental terms. A coastline policy is required that clearly identifies areas that need to be defended in the long term, areas that should remain or be returned to a 'natural' environmental state and communities that are currently unsustainable and require more strategic adaptation, such as relocations. Local government need to be able to make realistic adaptation plans that have regulatory teeth. Local Plans and Shoreline Management Plans should be aligned more closely in the time frames and areas that they both consider. Coastal Groups should continue to act to ensure that Local Plans are joined up. New powers may be required, for example by local authorities, to facilitate relocation or by planning authorities to ensure that a longer term planning outlook is taken.

- **The Adaptation Committee has a statutory role to monitor progress in preparing for climate change. The Committee's monitoring toolkit has been used to report to Parliament on progress in implementing the Government's National Adaptation Programme (NAP). We are continuing to evolve our metrics for successful adaptation, guided by the Climate Change Risk Assessment and the NAP.**

Given the scale, nature and urgency the coastal risks identified in the CCRA and in this report, these risks and associated adaptation actions will continue to be a focus of the Committee's monitoring and reporting. We will update or identify metrics and milestones to track adaptation related to:

- Changing risk from coastal flooding and erosion (including vulnerable people at risk and infrastructure assets), and how the UKCP18 sea level rise projections affect these numbers.
- Production of realistic and costed SMPs, which should include a more rigorous and holistic quantification of the costs and benefits of coastal management and be well aligned with Local Plans.
- Development and investment in coastal defences, including the standards of protection and defence condition of existing and new defences.
- Impacts of coastal flooding and erosion on people, the economy and the environment.
- Implementation of managed realignment, in relation to the targets within the SMPs.
- Extent and quality of coastal habitats and biodiversity.

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