

A photograph of a flooded street under a bridge. Several cars are driving through the deep water, creating large splashes. The bridge structure is visible above the cars, and the water level is high enough to submerge the lower parts of the vehicles. The scene is captured from a low angle, emphasizing the depth of the flood.

ANNEX C: FLOOD RESILIENCE

The Second National Infrastructure Assessment: Baseline Report

**NATIONAL
INFRASTRUCTURE
COMMISSION**

Better infrastructure for all

November 2021

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FLOOD AND DRAINAGE INFRASTRUCTURE

SURFACE WATER FLOODING – RAINFALL CANNOT DRAIN AWAY QUICKLY ENOUGH

3.2 million properties at risk

Rainfall

SLOWING AND STORING



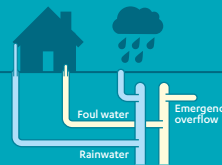
Underground storage tanks



Mimicking natural systems (such as ponds) to hold and slow the flow of water into surroundings

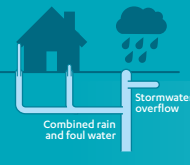
TRANSPORTING AND CONTAINING

Separate system

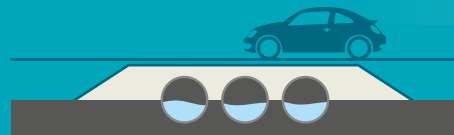


Sewers: separate or combined pipes for foul and surface water

Combined system



to rivers or the sea



Culverts – engineered pipes or channels for water courses

RIVER FLOODING – RIVER OVERFLOWS OR BURSTS ITS BANKS

Rainwater runoff and drainage

2.5 million properties at risk

SLOWING AND STORING



Tree planting and restoring peatland in the upper river catchments slow flows into rivers



Washlands – controlled flooding of land close to rivers

TRANSPORTING AND CONTAINING



Embankments and walls hold rivers within their banks during high flow

to the sea



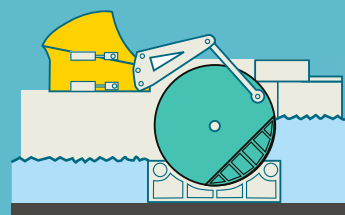
Diversion channels – extra channels to take flows during peak times

COASTAL FLOODING – COMBINATION OF HIGH TIDES, STORMS SURGES AND WAVES

The sea



Walls - hold back high tides and waves



Movable barriers – hold back high tides and surges in river estuaries

to the sea

C.1 Sector overview

Flood infrastructure

Flood infrastructure reduces the risk of communities being flooded when sea levels are high, rivers are swollen or when there is heavy rainfall in built up areas or over saturated or very dry land. It is not possible to eliminate all risk, but flood infrastructure helps minimise disruption to communities, business and other services.

Flood infrastructure primarily aims to protect people from the following types of flooding:

- **Coastal flooding** occurs when usually dry land is submerged by seawater. It mostly happens because of a combination of high tides, storm surges and waves.¹ Coastal erosion is the permanent loss of land close to the sea.
- **River flooding** occurs when flows can no longer be contained in river channels and the water spills onto adjacent land. It is generally caused by prolonged periods of intense rainfall.²
- **Surface water flooding** occurs when the volume of rainfall exceeds the capacity of drainage systems. Water cannot quickly drain away or soak into the ground. Instead, it collects at low points causing flooding.³ Surface water flooding can occur in rural and urban settings.
- **Groundwater flooding** occurs when water levels in the ground rise above surface levels. It is most likely to occur in areas underlain by permeable rocks.⁴ The flooding occurs with a delay following a prolonged rainfall and can last for long periods of time. Groundwater flooding is often very localised and there are limited options to provide protection through traditional flood defences.⁵ Individual property measures are usually needed such as drainage or pumps to divert water away.⁶

Flood defences include hard engineering assets such as sea walls, embankments and drainage systems. These are complemented by schemes that use natural processes to slow flows or store flood water to minimise the impact of surface water, river or coastal flooding. Flood risk management also entails non-engineering measures such as: floodplain zoning, which helps to avoid inappropriate development in the floodplain; preparing and responding to flood incidents through flood forecasting and warning systems; and increasing the ability of communities to recover following a flood event.⁷

Responsibility for flood risk management policy is devolved to the governments of Scotland, Wales and Northern Ireland. The Commission's remit in this area covers England only.

The most comprehensive understanding of flood risk assets is provided by the Environment Agency. It maintains around 77,000 flood and coastal risk management assets.⁸ These include defences on main rivers, as well as tidal and coastal defences and structures. The Environment Agency also inspects a total of 175,000 flood risk management assets, including those it maintains, those of other flood risk management authorities, listed in section C.2, and some belonging to landowners and private individuals which it does not maintain.⁹

The government has estimated the value of its existing flood and coastal defence assets at £25 billion, which provide an estimated reduction in annual average flood damages of £2.8 billion.¹⁰

Properties at risk of flooding

In 2020, more than five million properties in England were at risk of flooding.¹¹ This refers to a total number of properties in areas in all categories of risk of flooding, from very low (less than 0.1 per cent of annual likelihood of flooding), through low, medium and high (more than 3.3 per cent of annual likelihood of flooding).¹² These figures account for the existing level of protection by flood infrastructure. The number of properties at risk changes over time due to: pressures from new development; increasing impacts of climate change; aging flood defences that may not have been maintained; or investment in new and upgraded flood defences. Of those properties, 3.2 million are at risk of surface water flooding, which is more than the combined total of 2.5 million properties at risk of river and sea flooding.¹³ Furthermore, according to the Environment Agency's research, more than 65 per cent of properties in England are served by infrastructure that is located in areas at risk of flooding.¹⁴ However, this does not account for the existing flood resilience measures for infrastructure asset sites.¹⁵ Flooding causes great disruption and economic impact to communities. Whilst insurance can cover some impacts it cannot address all the issues such as the wellbeing of communities. Mental health problems can persist three years after a flood event.¹⁶

C.2 Governance and regulation

Flood risk management responsibility in England is shared across several public sector bodies, along with the private water sector. Responsibility depends on the source of flood risk. Roles and responsibilities of each body are set out in the Flood and Water Management Act 2010.¹⁷

Box C.1: History of the flood infrastructure sector

The Land Drainage Act 1930 began the process of an integrated approach to flood risk management.¹⁸ Responsibilities continued to evolve after the Second World War as part of wider changes to the management of water resources. Changes included consolidating 'catchment boards' which then became 'regional water authorities'.¹⁹ In 1989 the privatisation of the water industry resulted in the responsibility for the role of public sewers in draining land falling to the new water and sewerage companies.²⁰ At the same time, the remaining responsibilities of the regional water authorities were taken on by the National Rivers Authority. The responsibilities of the National Rivers Authority were given to the Environment Agency when it was established in the 1990s.²¹

This evolution over time has resulted in the wide range of different organisations that are now designated as Flood Risk Management Authorities.²²

Over time, weather forecasting and flood warning technology has developed. This helps in preparing and evacuating communities prior to major coastal or river flooding events.²³

The Department for Environment, Food and Rural Affairs (Defra) is responsible for setting flood and coastal erosion risk management policy in England.²⁴

The Environment Agency provides the strategic overview to tackle all sources of flooding. It publishes the National Flood and Coastal Erosion Risk Management Strategy setting out the approach to delivering the government's policies. The Environment Agency also directly manages the risk of flooding from designated 'main rivers' (larger rivers and streams where flooding would affect a significant number of properties) and the sea.²⁵ It develops flood risk management plans for these sources.

Other flood risk management authorities are jointly responsible for delivering national policy:²⁶

- **Lead local flood authorities** (unitary authorities or county councils) lead the management of the risk of surface and ground water flooding, and flooding from ‘ordinary watercourses’ – rivers that have not been designated as main rivers. They work in collaboration with other risk management authorities as well as owners of land located on the banks of a river and are responsible for producing flood risk management plans for flood risk sources other than those covered by the Environment Agency.
- **Internal drainage boards** are independent public authorities, covering around 10 per cent of England, managing water levels in low lying areas. The boards work in partnership with other authorities and undertake work to reduce flood risk and manage water levels for agriculture and the environment.
- **Highways authorities** include county and unitary authorities and National Highways. They provide and manage highway drainage and some roadside ditches in relation to the roads for which they are responsible. Highway authorities carry out drainage works on highways or adjoining land.
- **Water and sewerage companies** deliver and maintain clean water and sewerage services. They have a duty, under the Water Industry Act 1991, to effectively drain their areas.
- **District councils** carry out flood risk management works on minor rivers outside internal drainage board areas. Councils also work with lead local flood authorities and other risk management authorities to ensure risks are managed effectively, including taking decisions on housing developments in their area.

These authorities are required to cooperate with each other on flood risk management and to contribute to sustainable development.

Regional Flood and Coastal Committees are made up of risk management authorities from the local and regional level. They have a role in approving regional investment decisions. For example, the Committees will approve the Environment Agency’s requests to raise local levies or approve implementation of regional programmes.²⁷ Private individuals and organisations with watercourses within or adjacent to their land also have responsibility for maintaining their flood defence assets, such as weirs or sewers.²⁸

Box C.2: Governance and regulation in the devolved nations

Flood risk management is a devolved policy area, with each devolved nation responsible for developing its own strategies and delivery plans.

Wales

Flood risk management in Wales is governed by the Flood and Water Management Act 2010,²⁹ although statutory powers and delivery responsibilities are devolved. The Welsh Government produces the national strategy for flood and coastal erosion risk management in Wales. This sets out priorities for flood risk management and coordinates delivery across risk management authorities, with Natural Resources Wales leading on major risks and local authorities managing local risks.³⁰

Scotland

While not governed by the same legislation as England and Wales, flood risk management in Scotland broadly resembles the systems found in England and Wales. The Scottish Government is responsible for setting overall policy and legislation on flood risk management in Scotland.³¹ Flood management strategies and flood forecasting are the responsibilities of the Scottish Environment Protection Agency, while local authorities are responsible for producing local flood risk management plans. Scottish Water is responsible for the drainage of surface water from roofs and paved ground within property boundaries.³²

Northern Ireland

In Northern Ireland, flood risk management is mainly the responsibility of the Department for Infrastructure. The department maintains Northern Ireland's flood risk assessment and flood risk management plan, identifying major flood risks and setting out measures to mitigate them.³³ Unlike in England, Wales and Scotland, planning and delivery of flood risk management policy is mainly centralised, with relatively limited roles for local authorities. However, Northern Ireland Water plays a significant role in ensuring that its water and sewerage infrastructure is resilient to flooding and provides sufficient drainage.³⁴

The role of the planning system

The land use planning system plays an important role in reducing demand for flood risk infrastructure. The National Planning Policy Framework and relevant planning practice guidance steers new development away from areas of flood risk.^{35, 36} In 2019-20 over 95 per cent of all planning decisions were in line with the Environment Agency's advice on managing flood risk.³⁷

The Commission has previously recommended that all new property development is resilient to flooding and does not increase flood risk elsewhere. The government has revised the National Planning Policy Framework to improve consideration of flood risk and has recently committed to further strengthening controls.^{38, 39}

C.3 Funding and financing

Funding

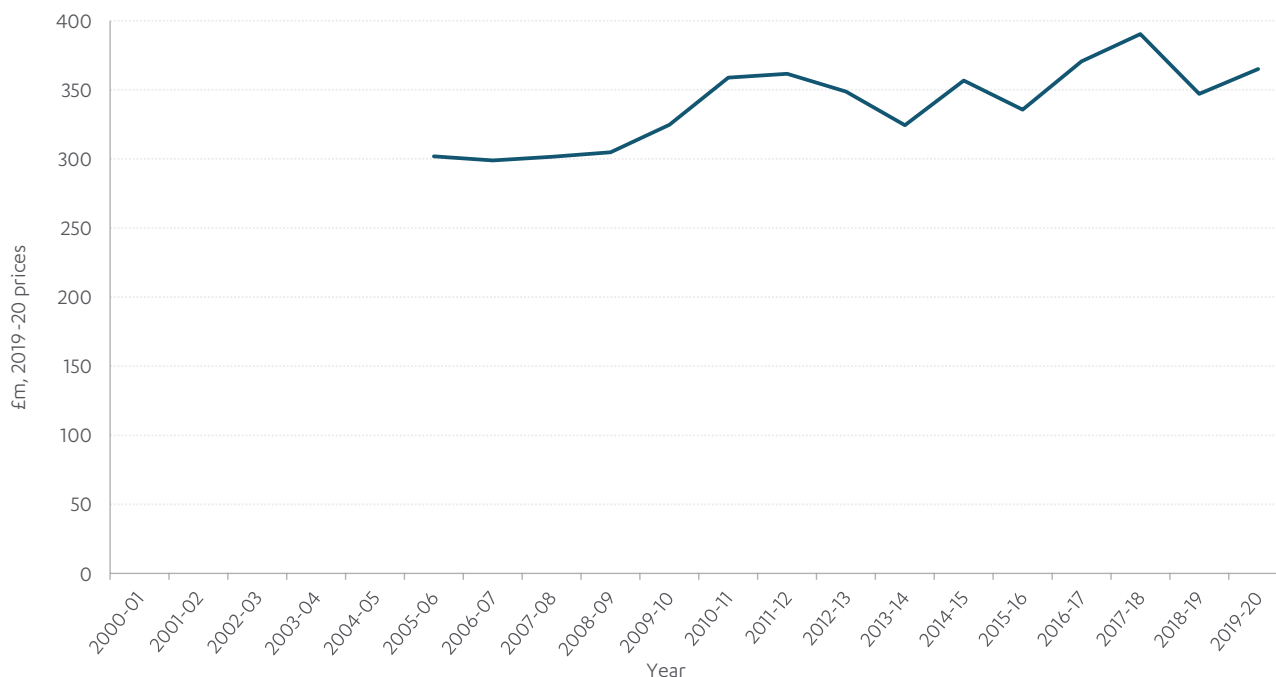
Flood risk management is funded through a combination of central and local government funding, water and sewerage customer bills and flood risk insurance. A small amount of funding is also provided by the private sector element of partnership funding. Data on all sources of funding for flood infrastructure is not centrally collated. This means that a full assessment of levels of funding is not available.

Central government funding is split between resource and capital (see Financing section). Resource funding has fluctuated annually, averaging approximately £350 million a year over the last decade. Amongst other areas, resource funding supports spending on routine maintenance of flood defences. Funding for the Environment Agency's maintenance budget has been agreed for varying periods of time, from four year periods to annually.^{40,41} This can make planning for and undertaking maintenance of flood assets less efficient. However, on average, the Environment Agency spent £200 million a year

to maintain flood risk assets between 2015 and 2020.⁴² In March 2020 the government announced a £120 million package for 2020-21 to conduct repairs and bolster defences from damage caused by the floods in the winter of 2019-20.⁴³

Figure C.1: Resource funding has fluctuated over time

Central government resource spending on flood coastal and risk management between 2005-2020



Source: Defra Central Government Funding for Flooding and Coastal Erosion Risk Management in England (2021)

Consumers also fund the sewerage network, which provides both drainage and flood protection, through their water and sewerage bills. Details on funding water and wastewater infrastructure are discussed in *Annex D: Water and wastewater*.

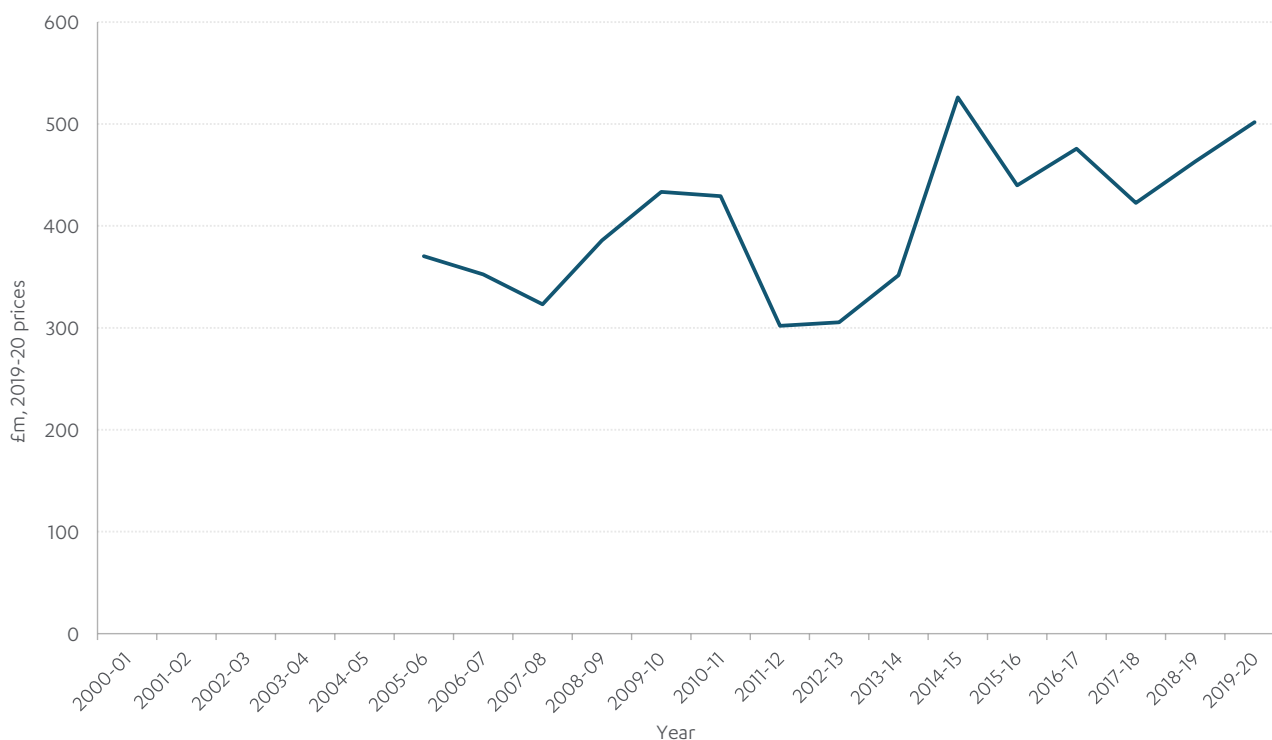
Flood risk insurance protects properties and belongings against potential losses from floods. This mitigates the financial risk of flooding but not the physical risk. A government study in 2018 showed the annual average median cost of home insurance for those at risk of flooding is £328, while the annual average median cost for low or no risk homes is £276.⁴⁴ The government set up the Flood Re scheme, a reinsurance company, to promote increased uptake and affordability of flood insurance to those who own and live in properties in flood risk areas.⁴⁵ It is fully owned and funded by the insurance industry.⁴⁶ According to a 2020 report, all domestic policyholders help to subsidise the scheme at a cost of about £10.50 each annually.⁴⁷

Financing

Investment in flood risk infrastructure is publicly and privately financed. Central government capital investment between 2005-6 to 2019-20 has varied, but overall has increased from £370 million to £502 million.⁴⁸ In 2014, central government adopted a long term investment programme for flood and coastal erosion risk management in England.⁴⁹

Figure C.2: The central government investment in flood infrastructure has increased over time

Central government capital investment for flood and coastal erosion risk management in England between 2005-2020



Source: Defra Central Government Funding for Flooding and Coastal Erosion Risk Management in England (2021)

The investment that local authorities and National Highways make in roads and highways drainage is not included in the flood risk investment programme budget allocations and this data is not available. Water and wastewater companies also invest in, and maintain, flood protection and drainage assets. The details on investment in water and wastewater company owned assets are discussed in Annex D: Water and wastewater.

C.4 Performance

Summary

Performance data for flood risk management is less developed than in other sectors. There are no comprehensive measures of quality, price, resilience or the environmental impact. The available data was collected and is discussed below.

The Commission's social research shows that the public's confidence in flood protection assets meeting their needs over the next 30 years has increased since its last research in 2017, but overall confidence is lower than in any other infrastructure sector.

The Environment Agency states that each year since 2011, around 44,000 households are "better protected" through improving the existing and creating new flood infrastructure.⁵⁰

This measure does not account for benefits that the enhanced and new flood assets bring to non-residential properties, infrastructure or agricultural land. The measure also does not reflect the properties that may have less protection each year due to flood asset deterioration, or that may now be at increased risk due to climate change.

Overall, central government current spending on flood risk management per household in England is low at about £15 per year. Capital investment has been around £19 per household per year. However, the cost per house protected is high at around £8,600 per property protected. The data is not available to estimate a full price of flood infrastructure that also accounts for insurance costs, taxes and other costs.

The Commission does not have a comprehensive indicator to measure the impact the flood sector has on the environment. There is some evidence that flood risk management has led to improvements in the quality and quantity of habitats, but it is hard to understand the scale of these impacts.

The condition of all flood assets is not assessed and reported in a consistent format. The condition of the majority of English flood walls and river embankments meets the Environment Agency's minimum required condition. However, the Environment Agency's own internal target for the maximum number of properties at risk due to assets not meeting the required condition has not been met on four occasions between 2014 and 2020.

Quality

Flood infrastructure received the lowest level of confidence (61 per cent) in meeting people's needs in the next 30 years in the Commission's social research, compared to other sectors.⁵¹ However, this has increased from 49 per cent in the Commission's previous social research conducted in 2017.⁵²

The Environment Agency uses the number of properties 'better protected' as a key indicator of flood risk management investment outcomes. 'Better protected' means that houses were moved to a lower category of flood risk through improved flood risk management.⁵³ The government's investment between 2015 and 2021, which equates to £2.6 billion, has improved protection from all types of flooding for 300,000 homes at a cost of around £8,600 per property better protected.⁵⁴ Over the lifetime of the flood defences, this £2.6 billion investment is expected to save the economy more than £28 billion in avoided damages as well as improving or creating valuable natural habitats.⁵⁵

This investment included a range of river, coastal, surface water and groundwater flooding management schemes.

The National Audit Office highlighted that whilst 'homes better protected' is an easy to understand measure of performance, it does not provide a good view of progress in tackling overall flood risk.⁵⁶ Using the indicator of 'homes better protected' as a target does not account for other properties that have become less well protected over the period due to factors such as climate change or the condition of flood assets,⁵⁷ and does not provide an indication of changes to flood risk for commercial properties, agricultural land or other infrastructure. Currently, there is no comprehensive way to measure whether the overall level of flood risk in England has improved over the past years and by how much.⁵⁸

The benefit of flooding infrastructure to businesses and agricultural land is assessed as avoided cost of damages and disruptions during flooding events.⁵⁹ Between 2015 and 2020, the wider benefits from enhancing and providing new flood infrastructure⁶⁰ included 'better protecting':

- 200,000 hectares of agriculture land
- 7,000 km of roads

- 440 km of rail
- 43,000 commercial properties.

Severe flood events can result in casualties and cause disruption and significant economic cost. In the last two decades England experienced a number of severe flooding events, with the most recent one being the floods of winter 2019-20. This particularly affected the North of England, with economic losses of £333 million.⁶¹ Following the 2019-20 winter floods, the avoided economic damages from existing flood protection were estimated at £4.6 billion to £9.3 billion.⁶²

Community preparedness for floods helps to minimise the effects of flooding on livelihoods and can enable quicker recovery. The Environment Agency provides a free flood warning service limited to warnings about flooding from rivers and the sea and some groundwater flooding. It currently does not cover flooding from surface water.⁶³

As of 31 March 2020, there were over 1.5 million properties registered to receive flood warnings, a seven per cent increase from the previous year.⁶⁴ The number of flood warnings peaked in the year to March 2020 with more than 4,800 flood alerts sent to property and business owners. This was likely caused by the winter floods of 2019-20.⁶⁵

Price

The existing flood defence assets that are operated and maintained by the Environment Agency and Lead Local Flood Authorities are done so at a cost of around £15 per household in England per year. In addition, over the period between 2015 and 2021 government invested the equivalent of around £19 per household in England per year to improve flood defences (a total of £2.6 billion over the 6 years in current prices).^{66,67}

These costs are shown as approximate tax burdens by the main flood management authorities and do not account for all flood risk management spending, as that data is not currently available. Water and sewerage companies are responsible for sewers which form an essential part of surface water flood infrastructure. The cost of these is paid for through customers' bills.⁶⁸ More on water and sewerage bills can be found in Annex D: Water and wastewater. Highway drainage also plays a key role in flood protection and spend is covered by local authorities and Highways England.⁶⁹ Currently data is not available to distinguish the contribution to flood protection.

Environment

The main emissions from flood defences arise during their construction. The Environment Agency reports 148,000 tonnes of greenhouse gas emissions per annum from the construction of flood defences. Pumping to alleviate floods and drought also results in annual emissions of 17,000 tonnes of greenhouse gases.⁷⁰ The Environment Agency is committed to becoming net zero by 2030. This target also includes emissions produced by the supply chain and considers emissions across construction, operations and maintenance phases of projects.⁷¹

The Environment Agency reports that, in 2019-20, Risk Management Authorities enhanced 164 km of waterbodies and 485 hectares of habitat.⁷² Between 2015 and 2021, they created or enhanced 650km of waterbodies and 4,700 hectares of habitat.⁷³ More frequent use of natural flood management can enhance the wider ecosystem services of flood mitigation assets.

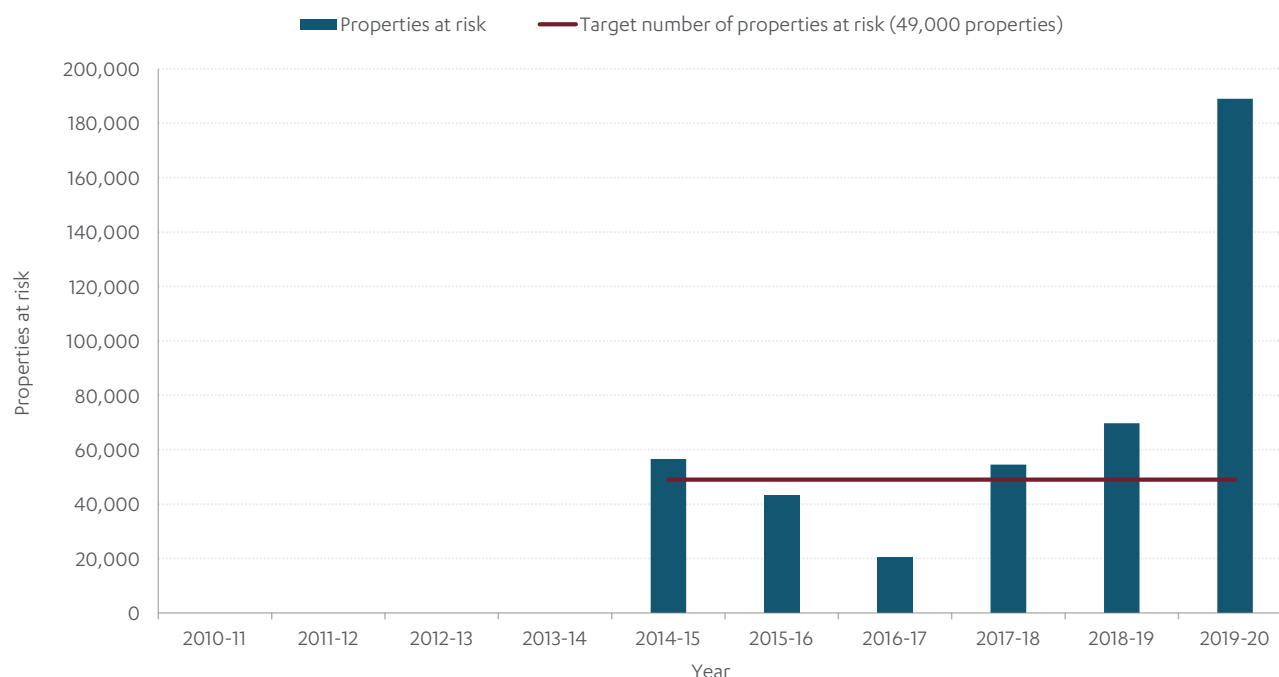
Resilience

The core function of flood infrastructure is to provide flood resilience services to communities and infrastructure. Over time, flood assets deteriorate and require maintenance to retain their standard of service.⁷⁴ The Environment Agency maintains its assets and monitors the condition of other organisation's assets. The structures and defences such as embankments and walls are managed based on a condition grade between 1 (Very Good) and 5 (Very Poor). The required condition is grade 3 (Fair) or above. This would mean defences have some defects but with low risk of failure.⁷⁵ Data is not consistent for all categories but, according to the report for Flood Re in 2021, approximately 94 per cent of flood walls and river embankments are in a fair or better condition in England.⁷⁶ Other methods are used for assessing condition of other assets such as river channels and pumping stations.⁷⁷

The Environment Agency also reports on the condition of river and coastal defence assets protecting densely populated areas. Ninety six per cent of its assets in densely populated areas were in the required condition in 2020.⁷⁸ This is against an internal Environment Agency target of 98 per cent, which has only been met twice in the last six years.⁷⁹ Each flood asset contributes to property protection from flood risk. The Environment Agency also has a target for the number of properties at risk as a result of assets being below the required condition. A large number of properties were exposed to higher flood risk in the last six years due to poor asset condition. Almost 190,000 properties were at an increased risk due to the condition of Agency assets in 2019-20, which is a result of damage caused by the floods in the same year.⁸⁰

Figure C.3: The Environment Agency's target for maximum number of properties at risk due to insufficient asset condition has not been met on four occasions between 2014 and 2020

Number of properties at risk in England as a result of the Environment Agency's structures and defences being below required condition.



Source: National Audit Office, Managing Flood Risk (2020)

C.5 Looking ahead

Climate change will continue to increase the risk of flooding and pressure on flood risk management and drainage infrastructure. This has been highlighted by the recent surface water flooding events over the summer.⁸¹ More flood management and drainage assets are likely to be required and existing assets may deteriorate at a faster pace than anticipated making maintenance more challenging in the long term.⁸² In particular, for surface water flooding, the challenge is made greater by the need to coordinate planning and action from many different organisations with responsibility for drainage.⁸³

In its first Assessment, the Commission's recommendations were based around developing a national standard of flood resilience.⁸⁴ This standard focused on coastal and river flooding because of the lack of data to support recommendations around surface water flooding. Although the government did not endorse a national standard, it has set out its approach to flood risk management in its policy statement and the Environment Agency's strategy.^{85,86} These include a range of measures addressing the Commission's wider set of recommendations, including significant new investment of £5.6 billion between 2021 and 2027, more than doubling the investment in the previous period 2015 to 2020. Further measures being taken forward by the government include developing a suite of indicators to assess flood resilience, reforming local flood risk management plans and a commitment to control development in areas of high flood risk. The government's approach also recognises and promotes the benefits of natural flood risk management and innovation.^{87,88} It has committed to planning for at least a two degree increase in global temperatures and being adaptive to accommodate a potential four degree increase.⁸⁹

The changing climate and more frequent severe weather events mean it will not always be possible to fully protect properties, assets and land from flooding. The Commission developed a resilience framework as part of its 2020 report *Anticipate, react, recover: Resilient infrastructure systems*,⁹⁰ of which recovery is a key part. The government responded in September 2021, agreeing with key recommendations of the Commission's report, subject to the outcome of the National Resilience Strategy call for evidence.⁹¹

The Commission will continue to monitor and report government progress in flood risk management as part of its Annual Monitoring Report.⁹² While the government's approach to flood risk management includes measures to address surface water flooding, the challenge remains significant. In October 2021 the government asked the Commission to undertake a study on reducing the risks of surface water flooding.⁹³ This will build on the need for improved data identified in the first Assessment.

It is expected that new and modified flood schemes will be required to deliver biodiversity net gain as part of the government's commitment to improve the environment. The government's commitment to address discharges from stormwater overflows underlines the fact that measures to reduce the risk of surface water flooding will need to deliver wider benefits to society and the environment.

The Environment Agency has indicated to the Commission that the pandemic has impacted on inspections and routine maintenance of flood defences. This meant assets damaged during floods in the winter of 2019-20 were not returned to their required condition as quickly as planned. However, the pandemic is not anticipated to have any direct long term impact on flood infrastructure.

C.6 Challenges and opportunities

The second Assessment will carry out new analysis and develop recommendations on two challenges that will affect the flood resilience sector:

Challenge 5: Asset management and resilience – the Commission will consider how asset management can support resilience, barriers to investment, and the use of data and technology to improve the way assets are maintained.

Challenge 6: Surface water management – the Commission will consider actions to maximise short term opportunities and improve long term planning, funding and governance arrangements for surface water management, while protecting water from pollution from drainage.

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