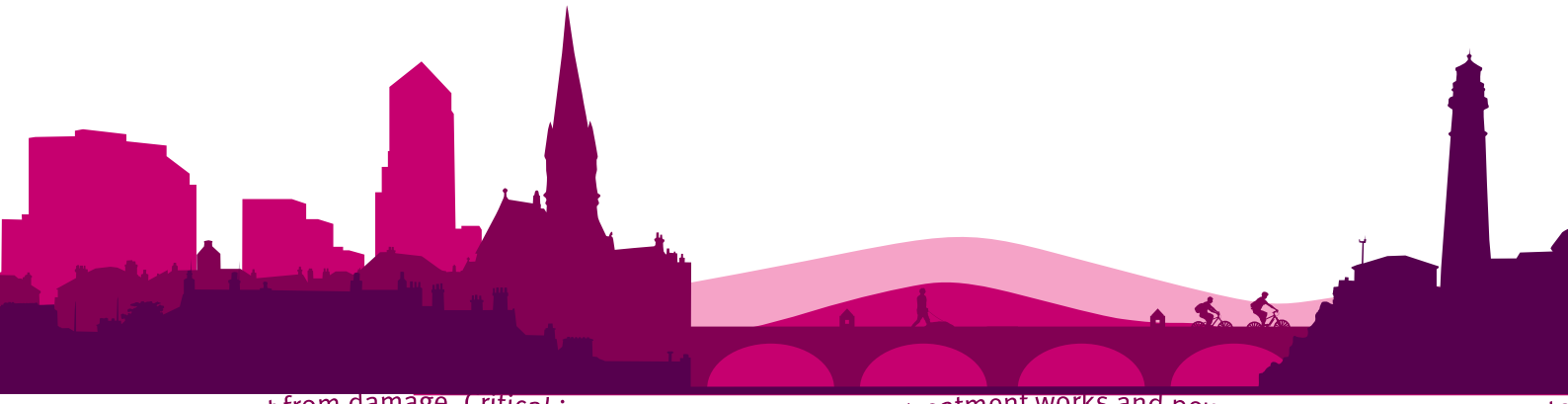
Asiantaeth yr Amgylchedd Cymru
Environment Agency Wales

future flooding in Wales: flood defences

Possible long-term investment scenarios



omes that are at threat from damage. Critical infrastructure such as water treatment works and power stations are often close to
ure. It is neither technically feasible nor economically affordable to prevent all properties from flooding. We therefore take a risk
cations for new building or development in flood and coastal risk areas. Our interventions help control development and preven
pact of flooding can reduce if we continue to invest in flood warnings and public information campaigns. They help householder

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Published by:

Environment Agency Wales
Cambria House
29, Newport Road
Cardiff CF24 0TP

Tel: 08708 506 506

Email: enquiries@environment-agency.wales.gov.uk
www.environment-agency.wales.gov.uk

Ministerial Foreword

The impacts and consequences of flooding and coastal erosion can be devastating and with one in six properties across Wales at risk of flooding we face significant challenges to ensure we are better prepared and can manage flooding and erosion to minimise the impacts on those at risk.

Current climate change predictions outlined in UKCP09 suggest that across Wales and the UK we face significant risks from flooding. As our climate changes, bringing increases in the volume and intensity of rainfall, rising sea levels and increased storminess means that more frequent and more severe flooding events, coupled with intensified coastal erosion, seem inevitable.

It is clear that we must reconsider our approach to flooding and coastal erosion in Wales. Simply building more and bigger defences will not be enough, and we need to consider other ways of managing the risk. We also need to consider where and how to invest our funding.

The Welsh Assembly Government invested £36 million in flood and coastal erosion risk management in 2009/10. Supplemented by additional funds from our Strategic Capital Investment Fund and European funding, our total investment across Wales stands at £42 million for 2009/10. This is a significant sum, but we recognise that in the future even more may be required.

Difficult decisions will have to be made in the coming years and it is important that we have a clear baseline from which to make them.

This document has been prepared by the Environment Agency and outlines several funding scenarios for flood and coastal erosion risk management in Wales. The aim of the document is to stimulate debate about how and where we should invest Government funds, and also whether there is a case for local communities contributing towards their own defences.

Later this year I will be consulting on a national strategy for flood and coastal erosion risk management in Wales. As part of that consultation I would like to consider investment and I trust that this document will allow you to consider the arguments and contribute to a national debate on the future direction of flood and coastal erosion risk management.

Jane Davidson AM
Welsh Assembly Government
Minister for Environment, Sustainability and Housing

Contents

1. Introduction

Flooding is a natural phenomenon that can have devastating effects on the people, property, infrastructure, environment and economy of Wales. It can occur from a number of sources, including rivers, the sea, small local watercourses, below ground drainage systems and direct surface water run-off. Understanding both the sources of and reasons for flooding, ensures that the risk management authorities in Wales can take steps to manage and reduce the risks of flooding.

Over many years a variety of measures have been put in place to manage flooding. These have primarily involved the construction of extensive networks of flood defences, which provide protection against flooding from main rivers and the sea, and below ground drainage systems, which carry rainwater and surface water run-off away from communities and reduce the risk of flooding.

There are currently 220,000 properties in Wales at risk of flooding from rivers or the sea, with 357,000 people, or 1 in 9 of the population, living in these properties. The impacts of climate change are expected gradually to increase the risk of flooding from all sources. Rising sea levels and increasingly severe and frequent rainstorms are predicted to increase the likelihood of flooding. The damage and devastation caused by flooding is also expected to increase.

Building defences can be technically difficult and may not be affordable in all locations in the future. A wider range of actions may be necessary to manage the impacts of current and future flooding.

This assessment considers the possible costs of building and maintaining river and coastal flood defences over the next 25 years. It also considers the potential impact of this investment on reducing flood risk from rivers and the sea, which are the primary responsibility of the Environment Agency. It does not include surface water flooding or the potential investment required in the below ground drainage network, although it is recognised that these will also require significant investment in the future.

Choices will need to be made about how and where investment in managing flood risk is best directed. This document provides information to help make what may be difficult choices.

2. What is flood risk?

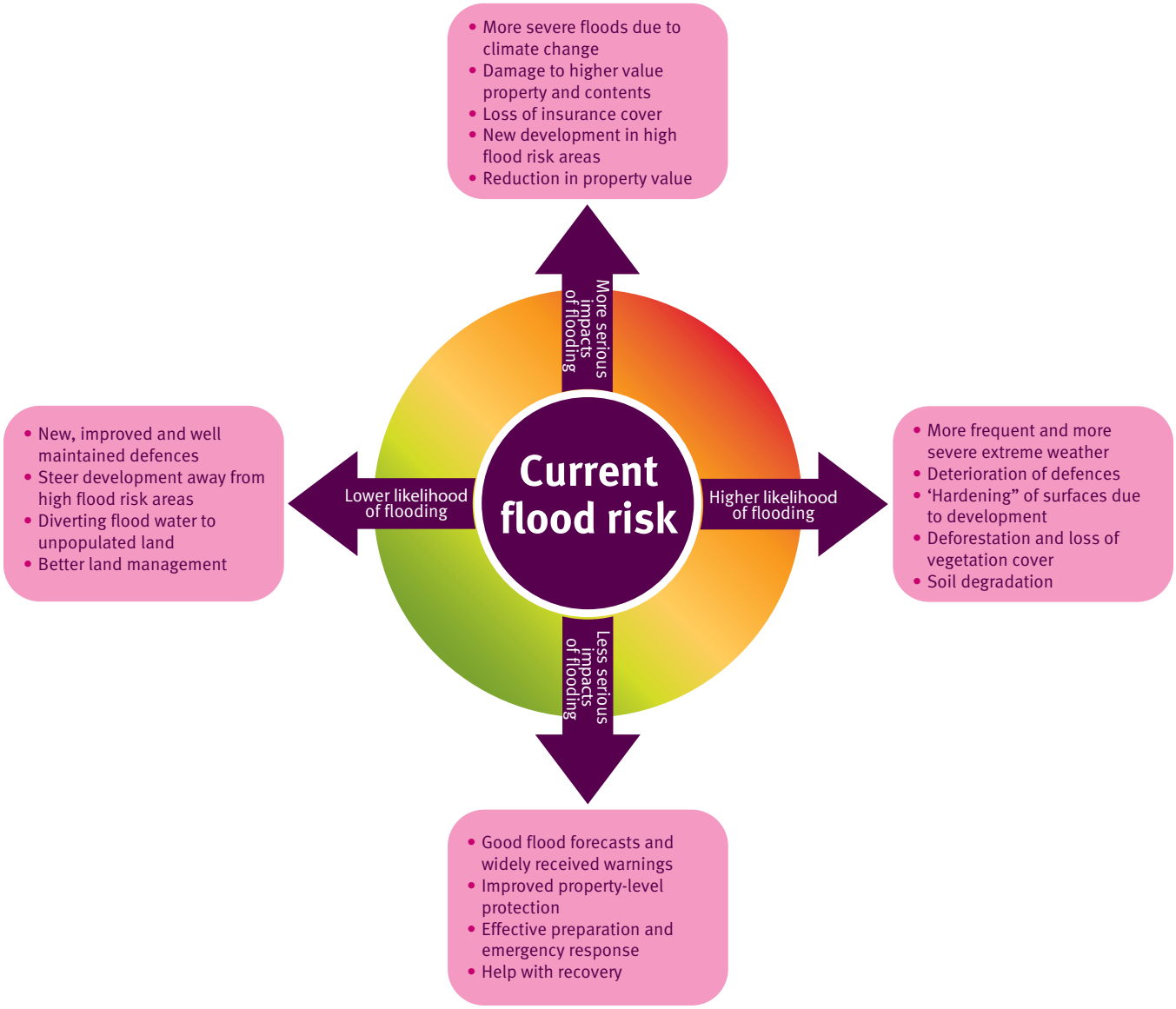
Floods are a part of nature and can have both positive and negative impacts.

Flooding of undeveloped floodplain areas can be positive for the natural environment and wildlife, and can also help to reduce the risks of flooding downstream by providing natural storage areas. However, where flooding coincides with people, property and essential infrastructure, such as water and electricity supplies, it can cause misery, and its consequences can be long-lasting and devastating.

Defining flood risk

Flood risk is the product of the **likelihood** or chance of flooding, **multiplied by** the **consequences** or impacts of flooding. The diagram below shows how various factors can change the risk of flooding.

Figure 1: Managing flood risk – addressing likelihood (or chance) and consequences (or impacts)



Defining likelihood of flooding

The **likelihood (or chance)** of flooding occurring in any one year can be expressed as a probability or an annual chance. For example:

- a 1% annual probability of flooding, or
- a 1 in 100 chance of flooding at a location in any year

Table 1: Flood likelihood categories[1]

Flood likelihood category for a location	The likelihood (or chance) of flooding in any year at that location	
Low	Less than 0.5%	Less than a 1 in 200 chance in any year
Moderate	0.5-1.3%	1 in 200 to 1 in 75 chance in any year
Significant	More than 1.3%	More than a 1 in 75 chance in any year

Defining consequences of flooding

The **consequences (or impacts)** of flooding can have serious effects not only on people and property, but also on essential services, infrastructure and the environment. For example, flooding to electricity and water infrastructure in Gloucestershire in summer 2007, caused widespread and prolonged impacts on people and local communities. The national grid switching station at Walham, north of Gloucester, provides electricity to half a million homes in Gloucestershire and South Wales. In 2007 the switching station was seriously threatened by flooding and only remained operational due to the construction of temporary barriers around the site. This example illustrates that the consequences of flooding can be felt far from where the flooding occurs.

The floods in Cumbria in November 2009 also demonstrated the enormous community disruption and distress that can result from the loss of bridges and roads as a result of flooding.

Wales has been fortunate not to have experienced such widespread devastating flooding in recent years. However, we have experienced similar floods in the past. There was extensive flooding to Cardiff and the South Wales Valleys in December 1979 and some 2,800 properties were affected by flooding in the coastal town of Towyn in February 1990. In October 1998 a prolonged period of heavy rain resulted in flooding across mainly South Wales, including the communities of, Aberfan and Merthyr Vale, Llandovery, Builth Wells, Pencoed and in the Vale of Glamorgan.

More recently, repeated flooding to the Conwy Valley in 2004 and 2005 seriously affected the people and businesses of Llanwrst and Trefriw. In July 2007 the town of Barry in South Wales was seriously affected by local flooding.

The Pitt Review[2] into the 2007 floods highlighted the significance of the impacts of flooding on health. This included the stress caused by being flooded; the loss of irreplaceable personal items; the length of time before people can return to their homes; and the huge cost to people if they are inadequately insured. Jane Davidson, Welsh Assembly Government Minister for the Environment, Sustainability and Housing has said that while Wales was fortunate to have escaped the worst of the 2007 weather there are clear lessons to be learnt for Wales. Lessons learnt from the Pitt Review have been taken into account in Wales via the New Approaches Programme[3] and will be further mainstreamed into flood and coastal erosion risk management policy via the Welsh Assembly Government's national strategy, due for consultation in the summer of 2010.

1. Flooding in Wales: A National Assessment of Flood Risk, Environment Agency Wales 2009
2. Sir Michael Pitt (2008). Learning Lessons from the 2007 Floods. Final Report. Cabinet Office, London. http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html
3. Welsh Assembly Government, New Approaches Programme; http://wales.gov.uk/topics/environmentcountryside/epq/waterflooding/flooding/newapproaches/?lang=en

The justification of flood risk management activities includes consideration of the economic costs and benefits of these activities. The indicators used in this analysis are explained in the next sections. However, decisions about individual investments in flood risk management are not only based on an economic appraisal. They also consider technical and environmental issues and importantly issues of social equity.

Quantifying flood risk – Annual Average Damages

Flood risk is generally quantified in monetary terms as **Annual Average Damages (AAD)**. This has units of '£/year' and is a function of both the likelihood and consequences of flooding. Annual Average Damages take account of a wide range of floods, from the relatively frequent, to rare and more severe incidents. Rare incidents have a low likelihood but may have high consequences and may therefore be a significant risk.

The AAD to residential and non-residential properties in Wales at risk from flooding from rivers and the sea, including hospitals and schools, is currently estimated at about **£200million**[4]. The full cost to Wales of flooding from all sources is, however, significantly higher. This is partly due to the impact of surface water flooding, which is not currently included in this figure. It is also because the wider impacts on society and business, such as loss of essential services, transport delays, disruption to businesses and impacts on agriculture and the environment, are not included in the calculation of AAD.

Deciding where to invest - flood risk management benefits

The benefit from a flood risk management intervention is measured by the flood damages avoided. This can be quantified in £ terms.

Public money is invested to reduce flood damages. This investment is economically justified if the amount of 'benefit' (or damages avoided, calculated from the AAD) exceeds the amount invested (or the 'cost').

So, for example:

- if £0.6 million is spent on flood defences to reduce the likelihood of flooding to a group of properties, and the total flood damages avoided (benefit) over the life of these defences is, say, £1 million, then;
- the **net benefit** of this investment (benefits – costs) is £1m - £0.6m = £0.4m, and;
- the **benefit cost ratio** for this investment (benefits/cost) is £1m/ £0.6m = 1.7
- the positive net benefit and a benefit cost ratio greater than 1 demonstrate this is an economically justified investment.

But:

- if the total flood damages avoided (benefit) are only, say, £0.2m, then;
- the **net benefit** of this investment is £0.2m - £0.6m = minus £0.4m, and;
- the **benefit cost** ratio for this investment is £0.2m/ £0.6m = 0.3
- the negative net benefit and the benefit cost ratio less than 1 indicate this is not an economically justified investment.

Generally, the higher the value of the net benefit and benefit cost ratio, the more economically robust the investment decision. It is possible for investment options to have the same net benefit but different benefit cost ratios. For example, a programme with £5m worth of costs and £7m of benefits has a net benefit of £7m - £5m = £2m, and a benefit cost ratio of £7m/£5m = 1.4. A different programme of £8m costs and £10m benefits would have the same net benefit of £2m, but a different benefit cost ratio, at £10m/£8m = 1.25.

When deciding where to invest to reduce flood risks, the broader benefits, including the consequences for health and critical infrastructure, such as power and water supplies also need to be considered.

4. Flooding in Wales: A National Assessment of Flood Risk, Environment Agency Wales 2009

Investing in managing the consequences

Alternatively the £0.6m from the earlier example, could be invested in actions to manage the consequences of flooding, rather than the likelihood. This could involve works to the properties, to either prevent flood water entering, or to enable the properties to be habitable more quickly after flooding occurs, such as raising the electrical sockets above flood levels and the use of tiled or stone surfaces which are less susceptible to flood damage and quicker to clean up after a flood. The £0.6m could be used to provide timely flood warnings. These reduce the risk to life and property by giving people and the emergency services advance warning, thereby enabling them to take action to reduce the consequences of flooding. Provided the benefits of these actions exceed the costs, these would be economically justified investments.

If the £0.6m could be used to purchase the properties at flood risk and relocate the residents to equivalent properties outside of the flood risk area, this could also be an economically justified investment option. This option would remove the flood risk completely.

What is a risk management approach?

A risk management approach to flooding requires a mix of actions to manage both the likelihood and the consequences of flooding. The removal of existing properties from flood risk areas, directing new development away from flood risk areas or the construction of flood defences all reduce the likelihood of flooding. Actions to raise flood awareness, to provide timely flood warnings, or to make individual properties more resilient to flooding, reduce the consequences of flooding. The risk management approach to flood risk is discussed more fully in Section 7.

3. Extent of current flood risk in Wales

The purpose of this section is to give an overview of the current flood risk in Wales from rivers the sea and surface water sources. Surface water is included in this overview for completeness. However, as this report is concerned with possible investment in river and coastal defences only, surface water flooding is not included in the financial analysis described in later sections of this report.

Flood risk can be expressed in terms of the numbers of properties or people at risk of flooding. As the number of people occupying properties can change, the number of properties is more often used as a more stable indicator of flood risk, and is used in this report.

Properties

There are **220,000 properties** in Wales at risk of flooding from rivers and the sea[5], which can be broken down as follows:

- 65,000 at significant likelihood of flooding
- 73,000 at moderate likelihood of flooding
- 82,000 at low likelihood of flooding

This is around **11%** of all properties in Wales at risk of flooding from the sea or rivers (nearly 1 in 9). Of the 220,000 properties at risk, 65,000 are commercial properties.

People

357,000 people live in these properties in areas at risk of river or sea flooding. This is approximately **11%** of the population of Wales, split as follows[6]:

- 97,000 in areas at significant likelihood of flooding
- 119,000 in areas at moderate likelihood of flooding
- 141,000 in areas of low likelihood of flooding

Many more people work or travel through the areas at risk of flooding. Sixty percent of Wales' population lives and works in the coastal area, with many of the main towns and cities located on the coast.

Essential Infrastructure

Nationally important infrastructure such as oil refineries (Milford Haven) and power stations (Wylfa, Aberthaw, Uskmouth, and Pembroke) are located on the coast.

Other essential infrastructure located around the coast and within inland flood risk areas include water supply and treatment facilities, electricity supply and distribution sites as well as police, fire service and ambulance stations.

Tourism

Coastal flooding and erosion threatens beaches and therefore tourism in Wales, which contributes over £2.5 billion each year to the Welsh economy. The coastal and marine environment supports (directly and indirectly) 92,600 jobs[7].

5. Flooding in Wales: A National Assessment of Flood Risk, Environment Agency Wales 2009
6. In England, for comparison, 8.4% of all properties and 8.2% of people are at risk. Looking only at the significant likelihood category, 3.1% of the population of Wales are in this category, compared with 1.4% in England. Proportionally more properties and people are at risk in Wales, and more are in areas of significant likelihood of flooding, than in England.
7. Valuing our Environment-Economic Impact of the Coastal and Marine Environment of Wales – National Trust (November 2006)

Natural Environment

Coastal flooding and erosion impacts on the environment and biodiversity of the coastal areas. Approximately 75% of the coastline of Wales is currently protected and designated for its environmental importance[8].

Surface water flooding[9]

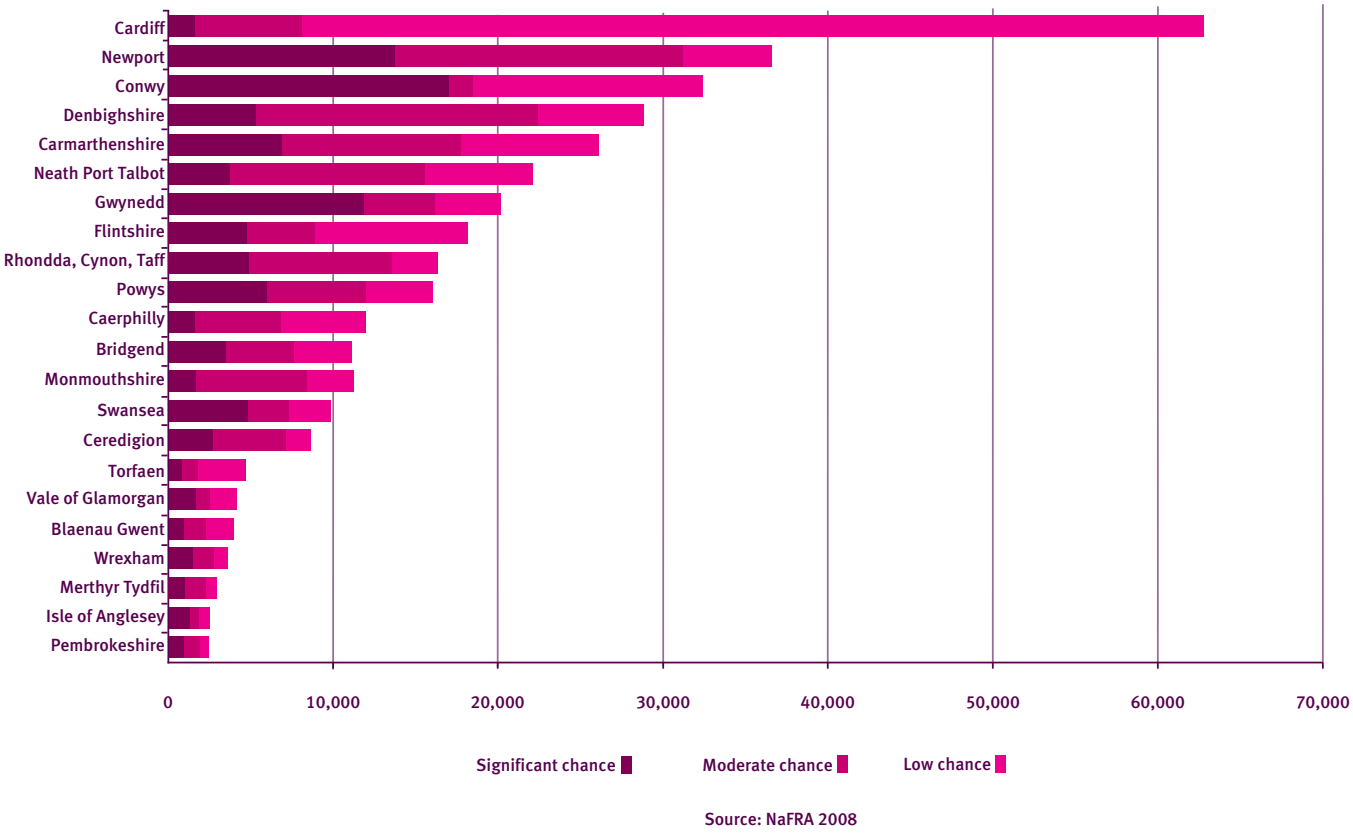
Flooding from surface water sources is a major risk across Wales and can affect people more frequently than flooding from rivers and the sea. Despite this, the risks of surface water flooding have not been understood or managed in the same way as the risks from rivers and the sea. This is being addressed and we now know that of the 220,000 properties in Wales at risk of flooding from rivers or the sea, 97,000 are also at risk from surface water flooding, and another 137,000 properties are at risk from surface water flooding alone. This means that approximately 360,000 properties in Wales, or around 1 building in every 6, is currently at risk of flooding from rivers, the sea or surface water. Around 600,000 people, or 1 in 5 of the population are estimated to live in properties at risk from all types of flooding.

Work to manage the risks of surface water flooding remains at the early stages, with pilot studies being undertaken across Wales to provide better understanding of the risks and consequences.

Flooding from rivers and the sea by location

Figure 2 below shows the number of people at risk of flooding from rivers and the sea by Local Authority, in the three chance categories.

Figure 2: Local Authorities in Wales ranked by number of people at risk of flooding (Source: *Flooding in Wales*)

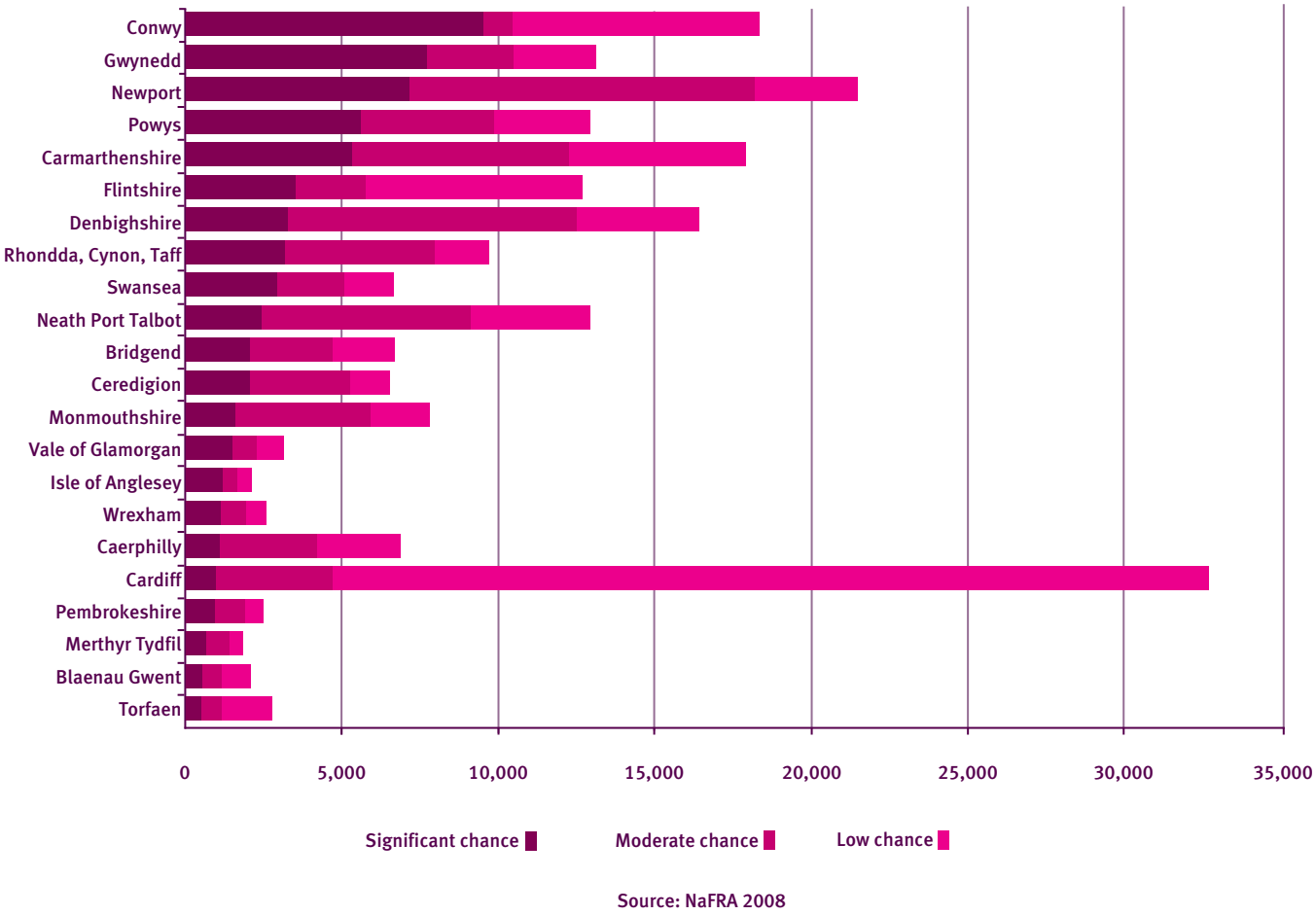


As can be seen from this figure, Cardiff has the highest numbers of properties at risk from flooding from rivers or the sea. However, many of these are at low risk (less than 1 in 200 chance in any year), mainly because of the flood defence structures in place in Cardiff. Although Cardiff is well defended, if these defences were to be overtopped, or poorly maintained, then the consequences could be severe.

8. Protecting Welsh Seas, A draft Strategy for Marine Protected Areas in Wales, September 2009. Welsh Assembly Government
9. Source: Flooding in Wales: A National Assessment of Flood Risk, Environment Agency Wales 2009

Figure 3 shows the number of properties at risk of flooding from rivers and sea in Wales, ranked in order of numbers in the significant chance category.

Figure 3: Local Authorities in Wales ranked by number of properties at significant chance of flooding (Source: *Flooding in Wales*)

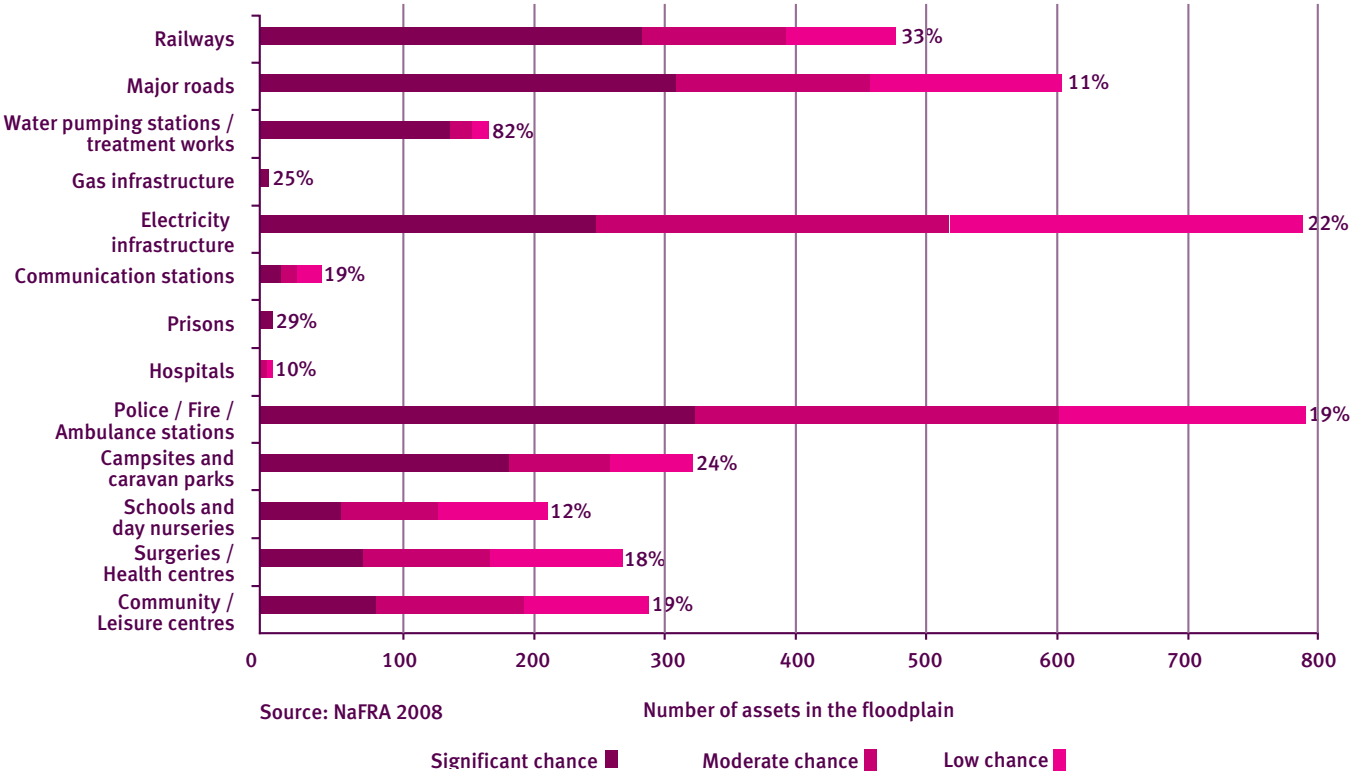


This figure shows that Conwy, Gwynedd and Newport appear at the top of the list, mainly because of the flood risk from the sea.

Flooding from rivers and the sea – National infrastructure assets

Figure 4 shows some of the key services that are located in flood risk areas.

Figure 4: National infrastructure assets in flood risk areas in Wales, by total numbers and by percentage of all such assets (Source: *Flooding in Wales*)



Water related infrastructure, such as water supply treatment works, pumping stations and sewage treatment works, is generally located close to rivers as their operation depends on access to the water. As a result more than 80% of pumping stations and water treatment works in Wales are in flood risk areas.

Other types of important national infrastructure are also at risk. Nearly 800 electricity infrastructure sites, some 22% of all such sites in Wales, are at risk from flooding. There are also nearly 800 police, fire and ambulance stations, and about 11% of main roads and 33% of railways, within flood risk areas. In addition, many infrastructure sites are interdependent. For example, a pumping station may not be at direct risk of flooding but it may rely on an electricity sub-station that is in a high risk location.

Summary

Only around 6.7% of the total land area of Wales is at risk of flooding from a rare extreme flood event of up to a 1 in 1000 (0.1%) chance in any year.[10] Although this is only a small proportion of the land area, the above graphs illustrate that flooding has the potential to impact on communities, Local Authorities and essential public infrastructure across Wales. With more than 80% of water related infrastructure and some 22% of electricity infrastructure at risk, the potential for serious disruption to communities across Wales, due to flooding from rivers and the sea, is considerable.

10. Flooding in Wales: A National Assessment of Flood Risk, Environment Agency 2009

4. Future flood risk

Impacts of climate change

Climate change is likely to increase the risk of flooding over time, both in terms of likelihood and consequences. The UK Climate Impacts Programme (UKCP) has produced projections of climate change. The analysis underpinning this report uses the mid-range projections from the latest information, which was reported in 2009, (UKCP09[11]).

The frequency and severity of rainstorms are projected to increase. These increases mean more locations will flood in the future and the flooding will be deeper and faster flowing in places where it already floods now. If climate change forecasts are correct surface water flooding will also become more frequent, more severe, and more widespread in the future.

Sea levels could rise by as much as one metre over the next century. It is also expected that the coastline will be subjected to more frequent and severe storms and wave action. This will increase coastal erosion, damage to coastal defences and the likelihood and consequences of coastal flooding.

The damages and costs of flooding are predicted to increase due to climate change. The 2004 Foresight *'Future Flooding' report*[12], stated that the annual economic damages in Wales will potentially increase 18 fold from 2004 to the 2080s, under the most likely scenario. Led by the UK Government's Chief Scientific Adviser Sir David King, with a team of 60 top scientists, this report is the most wide-ranging analysis of flood risk in the UK to date. The 2008 update[13] to this report, states that the challenge may be even greater. For example, it states;

'Communities living behind good coastal defences currently protecting them against a flood with a chance of occurrence of 1 in 100 each year would experience a drop in standard of protection by the end of the century to as low as 1 in 5 each year if we were to follow a business-as-usual flood management policy.'

Short term flood risk management decisions and actions should be set within a longer term strategic planning framework. In Wales there are plans in place to address the increasing flood risk and to guide adaptation to climate change.

The strategic plans are:

- Catchment Flood Management Plans[14] – produced by Environment Agency Wales. Main documents were completed in March 2009 and Summary Reports completed in January 2010[15].
- Shoreline Management Plans[16] – Produced by Coastal Groups, composed of maritime Local Authorities, Environment Agency Wales, Countryside Council for Wales and others.

Catchment Flood Management Plans consider inland flood risk now and in the future, up to 100 years ahead, and assess the potential impacts of climate change and land use change on future flood risk. They identify flood risk management policies that are integrated and seek to balance environmental, social and economic needs over the long term.

Similarly, Shoreline Management Plans assess the threat to the coast from erosion and flooding. These plans look at the current and future scenarios over a 100-year timeframe. Shoreline Management Plans produce policies for the long term alignment of the shoreline and a wide range of actions to deliver these policies. A major review of Shoreline Management Plans is continuing and is due to be completed in 2011. The policies used in the analysis in this document derive from the existing Shoreline Management Plans.

Both Catchment Flood Management Plans and Shoreline Management Plans are subject to periodic review as new information becomes available. The policies and actions set out in the plans may change with time to reflect adaptation to increasing risks and climate change.

11. UKCP09: http://ukcp09.defra.gov.uk/
12. Foresight Study on Future Flooding (2004) http://www.foresight.gov.uk/Previous_Projects/Flood_and_Coastal_Defence/index.htm
13. (2008) An update of the Foresight Future Flooding 2004 qualitative risk analysis. Cabinet Office, London.
14. CFMPs are high level non statutory plans for inland flood risk produced by Environment Agency Wales

5. Investing in flood defences: scenario modelling

This report uses financial modelling to consider the current levels of investment in building and maintaining river and coastal flood defences, and the predicted impacts on flood risk of various changes in investment in the future.

Current investment in flood defence construction and maintenance

The majority of expenditure on river and coastal flood defences in Wales comes from public funds allocated by the Welsh Assembly Government. Most of these funds go to Environment Agency Wales to manage flooding from the rivers and the sea and to Local Authorities to manage flooding from local watercourses and coastal erosion.

The total funding (capital and revenue) allocated by the Welsh Assembly Government to Environment Agency Wales and Local Authorities for building and maintaining flood defence assets in **2009/10 is £32m.**

Environment Agency Wales and Local Authorities own and maintain 74% (by length) of the flood defence assets (including coastal erosion assets). The remaining 26% of assets (by length) are in private ownership. The level of expenditure on these private assets is not known. For the purposes of this document, it is assumed to be at the same level, *pro rata*, as for the public sector, i.e. Environment Agency Wales and Local Authorities. The total amount of expenditure in Wales on flood defence asset construction and maintenance is therefore estimated at **£44m in 2009/10.**

Investment scenario modelling

This assessment considers **investment in river and coastal flood defence construction and maintenance only.**

The modelling:

- includes the expenditure on coastal and river flood defences, plus the costs associated with protection from coastal erosion;
- includes the expenditure by Environment Agency Wales and Local Authorities and an estimate of the expenditure by the private sector;
- excludes the expenditure on managing surface water flooding;
- excludes the expenditure on other flood risk management measures, such as development control; awareness raising; household flood resistance and resilience measures; flood forecasting and warnings; emergency planning; incident response; and recovery;
- excludes the expenditure on defences for local small watercourses and on controlling groundwater flooding.

The modelling also:

- uses 2009/10 as the baseline year, with total annual expenditure of £44m and 220,000 properties at risk of flooding from rivers and the sea;
- uses the mid-range climate change projections from UK Climate Projections 2009 (UKCP09) to assess future flood risk;
- assumes inflation is 2.7% a year until 2015, and 2% per year thereafter.

15. CFMP Summary Reports, http://www.environment-agency.gov.uk/research/planning/33586.aspx
16. SMPs are high level non statutory plans for coastal erosion and flooding produced by Coastal Groups

Investment Scenarios

Five different investment scenarios (see Box 1) have been used to examine a wide range of investment options. Scenarios 1 and 2 are financially constrained, whereas 3 to 5 are not limited by finances but by the requirements of the scenarios.

All flood and coastal defence assets have a finite design life. Over this design life they are maintained to ensure they perform to their required standard. All defence assets eventually reach the end of their design life and further investment is required to replace them if the benefits are to be maintained. Over the next 25 years investment will be required to maintain the existing asset stock, construct new defences and replace those defences that reach the end of their design life. In addition, climate change impacts will progressively reduce the level of protection provided by current defences and will increase the requirements for maintenance investment. This is particularly the case around the coast, where defences will be subjected to more frequent and violent storms and wave action. The five investment scenarios take into consideration these factors.

Box 1: Investment scenarios modelled

1. 2009/10 allocation with inflation increase going forward;
2. 2009/10 allocation with inflation plus £1m year-on-year increase as suggested in the *Future Foresight Flooding report*;
3. Allocating and costing the policies contained in Catchment Flood Management Plans and Shoreline Management Plans;
4. Target those properties at significant risk of flooding, where the benefits of doing so are at least equal to the costs;
5. As for scenario 4, but also maintaining the current level of risk for all other properties, regardless of the cost.

Scenario 1 maintains the current total level of annual investment (public and private) of approximately £44m into the future and over the 25 year assessment period.

Scenario 2 also includes an additional £1m year-on-year increase. In this assessment it is assumed that all this additional investment is directed to river and coastal flood defences, rather than other flood risk management activities. The Foresight Report identifies the importance of a wide range of flood risk management actions and not only flood defences.

Scenario 3 considers the investment required to deliver the policies contained in the Catchment Flood Management Plans and Shoreline Management Plans. As above, this assessment assumes that these policies are delivered only by investment in flood defences whereas the Catchment Flood Management Plans advocate a much wider range of actions to complement investment in defences.

Scenario 4 targets the investment to locations of highest flood risk and where the benefits are at least equal to the costs. This represents an economically justified investment.

Scenario 5 is the same as scenario 4 except that further investment is required to maintain the current level of risk for all other properties regardless of cost. These locations may have costs which exceed the benefits. They are more difficult and therefore more costly to defend.

Scenarios 1 to 5 represent progressively increasing levels of investment.

A Do Nothing scenario has also been considered to assess the impact of withdrawing all investment, on properties at risk. Under this scenario all maintenance activity would stop and there would be no further investment in existing or new defences. Over time existing defences would progressively deteriorate through a process of gradual decline and periodic structural failure and breach. This is not an option that would be considered in practice, but is included in the analysis for comparative purposes and for the calculation of the 'net benefits' and 'benefits'.

Results are presented in Section 6, where the costs and outcomes of the scenarios are compared.

Modelling risk and uncertainty

Estimates of both risks and costs are based on assumptions and as with all modelling there are uncertainties that are reflected in the results. Future costs cannot be precisely known and are estimated to a have margin of error of plus or minus 25%. The margin of error for future numbers of properties at risk and the future damages is also at least plus or minus 25%. Hence, the results are not definitive or exact; they are indicative of the possible costs and flood risks.

Investment scenarios: Cumulative spending 2011 to 2035

Figure 5 shows the cumulative spend over 25 years for each scenario and the estimated annual investment in river and coastal flood defence assets in 2035. More detailed expenditure information is included in Appendix 1.

Figure 5: Investment scenarios: cumulative spending 2011 to 2035 (shown in today's prices)

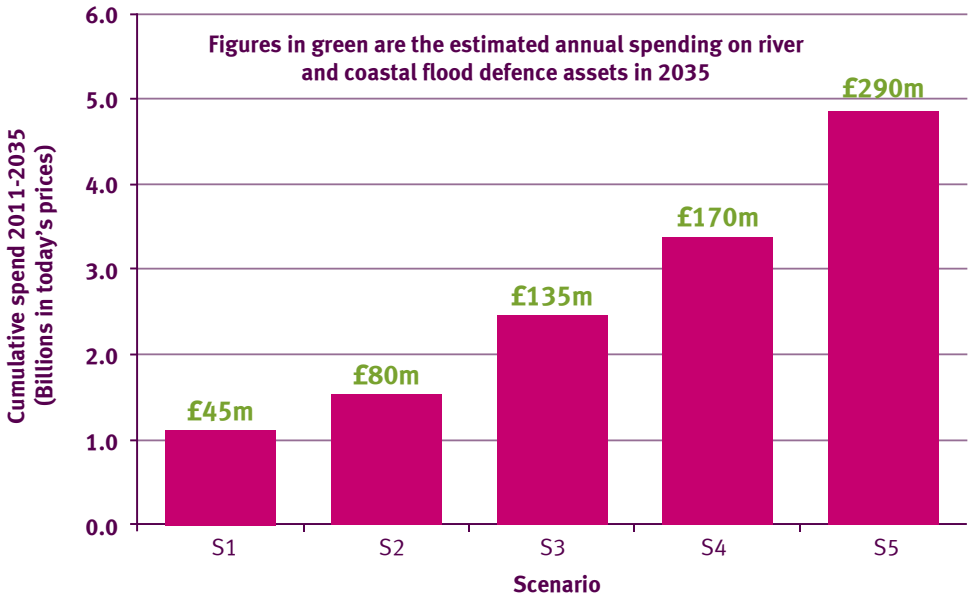


Figure 5 shows that:

- Scenario 1 has a cost in 2035 at around present day levels.
- Scenarios 2 to 5 show significantly increased investment compared with the present day, ranging from £80m to £290m per year by 2035.

6. Consequences for flood risk of different investment scenarios: results from scenario modelling

This section gives a summary of modelled projections of flood risk and benefit for each scenario. More detailed results are included in Appendix 1.

Comparison between scenarios: properties at risk

Figure 6 shows the numbers of properties at significant and moderate flood likelihood in 2035, for each of the scenarios. For clarity, properties with a 'low' likelihood of flooding are not shown. It also shows the results if there was no investment at all, denoted by DN ('Do Nothing'). This is included for comparative purposes.

Figure 6: Investment scenarios - properties at significant and moderate likelihood of flooding in 2035

Figure 6 shows that:

- If no investment at all was made ('Do Nothing'), the increase in properties in the significant likelihood category is very marked, rising from about 65,000 to almost 115,000 in 2035.
- The lower cost scenarios 1 and 2 do reduce the risk relative to the 'Do Nothing' scenario, but in each case the likelihood of flooding increases from the present day, moving the number of properties at significant likelihood from about 65,000 to around 100,000 in 2035. This illustrates that the amount of investment in these scenarios, is insufficient to maintain and replace the flood and coastal defences, therefore the risk (as measured by the number of properties at significant and moderate likelihood) increases relative to the present day.

- Under scenario 3, the number of properties at risk decreases marginally compared to the present day. However, there is an increase in the number of properties in the significant likelihood category.
- The number of properties at significant and moderate risk reduce substantially under scenarios 4 and 5, from about 138,000 to around 107,000. Properties at significant risk decrease under these scenarios.
- However, there is little difference in the numbers of properties at risk between scenarios 4 and 5. This indicates that the increased investment in scenario 5 is not having an additional impact on reducing the numbers of properties at risk within the next 25 years.

Comparison between scenarios: economic indicators

Figure 7 and **Figure 8** show the **'net benefits'** (that is, benefit minus cost) and the **'benefit'** (that is flood damages avoided) of each investment scenario. The costs and benefits of flood defence assets can be added up over the next 100 years to give a long-term view of the investment. This enables a useful comparison of the scenarios. These calculations assume costs and damages in the future have lower value than they do currently, in line with HM Treasury guidance of appraisal of public investment[17]. All of the benefits are calculated relative to the damages from the 'Do Nothing' assumption.

Figure 7: Investment scenarios: the net benefit of investment

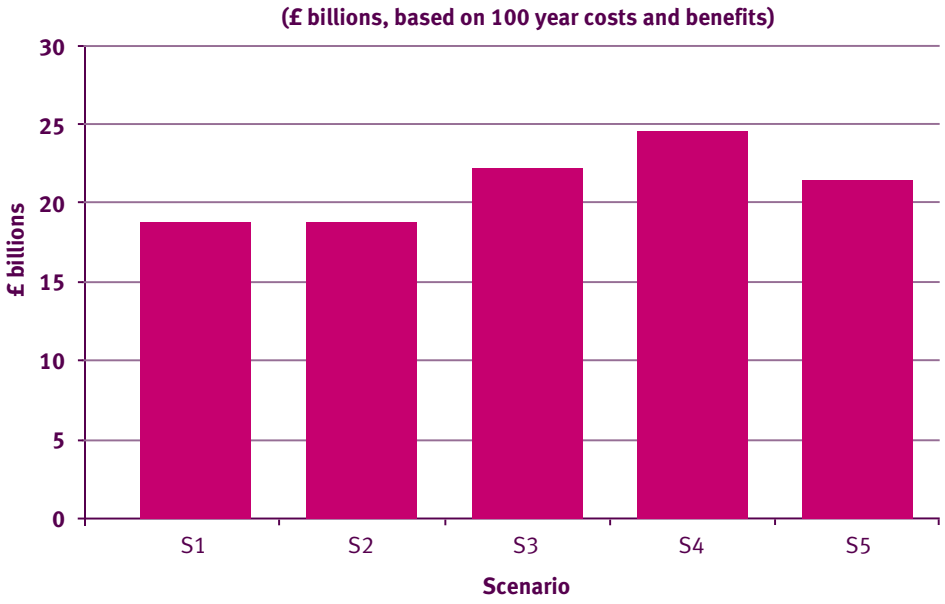


Figure 7 shows that:

- For all of the scenarios tested, the benefits exceed the costs by a large margin – around £20bn over the next 100 years. This demonstrates that these scenarios are all economically justified.
- There is little to choose between scenarios 1 and 2 by the net benefit measure. This is because the additional cost of scenario 2 compared with scenario 1 is matched closely by the additional benefits of the investment in reducing the risk. Therefore the difference between the benefits and costs i.e. the net benefits, remain similar.
- Over the 100 year assessment period the benefit cost ratio is estimated to be nine for scenario 2, and is higher still for scenario 1.

17. The Green Book, Appraisal and Evaluation in Central Government, Treasury Guidance, TSO

- For the scenarios 3 and 4, the net benefits increase, up to about £25bn for scenario 4.
- Over the 100 year assessment period the benefit cost ratio for scenarios 3 and 4 are estimated to be around six, with scenario 3 having a slightly better return than scenario 4 by this measure.
- Scenario 5 is the most costly, and the overall benefits are still very much higher than the costs, at around £20bn over the next 100 years, but the benefit cost ratio falls to around three.

Figure 8: Investment scenarios: the benefit of investment

Figure 8 shows that;

- Increasing investment results in increasing benefit, (that is, flood damages avoided).
- The relatively small increase between scenarios 4 and 5 reflects the fact that the increased investment in scenario 5 is also directed to locations where the costs exceed the benefits. This investment provides a poor economic return in terms of benefits gained.

In summary the results of the scenario modelling show:

- All scenarios are economically positive and justifiable investments in terms of the flood risk benefits gained. For all scenarios there are significant net benefits to Wales of around £20 billion or greater and the benefit cost ratios are all around three or greater, indicating a significant return on investment.
- The net benefits of scenarios 1 and 2 are comparable. However the number of properties in the significant likelihood category increases substantially under both scenarios from the present day 65,000 to almost 100,000 in 2035.
- The additional investment of scenario 2 does generate approximately £1 billion more benefit than scenario 1 over 100 years. However scenario 2 also costs approximately £1 billion more than scenario 1 over the same period. Therefore the net benefits are comparable.
- Substantially increased and high levels of investment are needed to maintain the 2035 risk level, (considering significant and moderate likelihood) to around the current level. Scenario 3 is broadly comparable to the present day, and requires an annual spend of around £135m in 2035. This is around three times the current spend.

- Even higher levels of investment are needed to reduce the numbers of properties in the significant and moderate likelihood categories. Scenario 4 indicates an annual spend of around £170m by 2035 would achieve this. This is around four times the current level of investment.
- Scenario 5 has an estimated annual spend of £290m per year in 2035 – around seven times the current levels. However the number of properties in the significant and moderate likelihood categories are not substantially less than those for scenario 4. This is because scenario 5 also maintains current level of risk for all properties whereas scenario 4 does not. This means that under scenario 5 defences are replaced to keep pace with climate change, and many of the benefits from scenario 5 are not realised until after year 25.

7. Managing flood risk

A risk management approach requires a mix of actions to manage both the likelihood and consequences of flooding. The historic approach has mainly focused on defences and managing the likelihood of flooding. Going forward the balance of investment needs to be considered and even more focus given to actions to manage the consequences as well.

Some of the wider range of actions that could help to manage the **consequences** of flooding include:

- increased coverage and improved **flood warning**;
- increased **awareness** to enable **property owners** to take action before flooding occurs to reduce their damages;
- increased **awareness** amongst the owners of **essential services** and **infrastructure** to enable them to plan for and manage their flood risk;
- increased **resistance** of new and existing property to flooding, for example installing flood gates or covers for air-brick vents;
- increased **resilience** of new and existing property to flooding, for example, raising electrical sockets, using lime-free plaster and tiled or stone surfaces and floors to reduce the time after flooding before the property is habitable or usable.

The wider range of actions could also include **changes in land use or land management** to reduce the **likelihood** of flooding. These have the potential to help reduce the risk of flooding either locally or elsewhere in the catchment. These actions can also provide wider environmental benefits, such as improvements in water quality. Examples of such actions include:

- restoring currently defended floodplains to increase the capacity for storage of flood flows and to reduce the flood risk downstream;
- removing artificial land drainage and restoring more natural and slower rates of surface run-off;
- using tree planting and shelter belts to reduce surface run-off;
- encouraging and supporting good soil management – reducing soil compaction and therefore surface water run off;
- using sustainable urban drainage systems to reduce the rates of run off.

Our current understanding of the effectiveness of these wider actions on flood risk varies. Actions such as raising electrical sockets above flood levels can be readily related to the benefit i.e. it reduces the disruption and time required to recover after flooding. The impact of land management or land use change on flood risk at a local or field scale has been demonstrated by projects such as Pontbren[18]. The flood risk benefits at a wider catchment scale are less readily quantified and are the subject of ongoing research and investigation.

Flood defences will continue to have a key role in reducing the likelihood of flooding to some communities. It is essential that investment in existing or new defences is prioritised according to risk and new defences can be adapted to take account of increasing flood risk.

The most appropriate balance of flood risk management actions will vary between locations and communities. Choices will need to be made about how and where investment in managing flood risk is best directed. Communities and those directly affected should be involved in this debate.

18. Impacts of upland land management on flood risk: multi-scale modelling methodology and results from the Pontbren experiment. Flood risk management research consortium (2008). http://www.floodrisk.org.uk/

8. Additional sources of funding

Nearly all funding for flood and coastal erosion risk management currently comes from the Welsh Assembly Government. The levels of funding that might be needed in the future cannot come entirely from the public sector without significant reallocation of budgets. Alternative sources need to be considered.

European Union funding

Welsh Assembly Government, Environment Agency Wales and Local Authorities have been successful in maximising the use of European Union funds, both under Objective 1 and now under the Convergence and Competitiveness programmes.

Between 2004 and 2008, Environment Agency Wales successfully bid for over £6m of additional European Union funding under the Objective 1 programme. This was match-funded by the Welsh Assembly Government and enabled the completion of ten new schemes which reduced flood risk for over 2,000 homes and businesses across Wales. Locations which benefited from this investment include Aberdare, St Clears, Glynneath, Pwllheli and Bangor.

The current round of EU Funding runs from 2007 – 2013. In December 2008, the Welsh Assembly Government announced an additional £30 million over this time period, from the Convergence fund. This funding will be matched with money from the Welsh Assembly Government, Local Authorities and others to support a programme worth in excess of £65 million over a period of 5 years.

To date, the Environment Agency Wales has had six schemes approved under the Convergence programme including, Conwy Valley, Valley (on Anglesey), Tregaron, Afon Wnion, Afon Gele and the Clwyd Estuary. It is anticipated that more schemes will be approved in the future.

Additional funding of £6 million has also been obtained from the EU Competitiveness fund which covers the East of Wales. This programme will also be match-funded by the Welsh Assembly Government, Local Authorities and others to promote a £13.3 million programme of work. Five schemes have been approved under this programme to date, including the Riverside scheme in Newport, which is a project being developed in partnership between Newport City Council and Environment Agency Wales.

EU structural fund allocations are based on the Gross Domestic Product of EU member states, with only more deprived areas attracting the highest level of funding. With the relative deprivation of Wales being less than that of other countries within the European Union, we expect that the level of funding provided after the 2007-2013 period will be significantly reduced.

Local contributions

Sir Michael Pitt, in his independent review of the Summer 2007 floods in England[19] called for a long-term approach to expenditure on flood risk management. Sir Michael said:

'This long-term approach should not simply assume that the costs of flood risk management will be met centrally. There are direct beneficiaries from flood defence work, and aligning those who benefit with those who pay will bring greater efficiency and greater responsiveness from those carrying out the work'.

A well informed public debate is needed on what further approaches might be explored to supplement central funding by enabling (local) beneficiaries to contribute to reducing flood risk.

19. Sir Michael Pitt (2008). Learning Lessons from the 2007 Floods. Final Report. Cabinet Office, London. http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html

Developers

Developers must consider the flood and coastal erosion risk management costs as they plan and present applications for new building projects and they should pay for the management of any increased risks that they create.

Insurance companies

The insurance industry plays a major role in managing the recovery from flooding. Through the payment of premiums, policyholders pool their risks, gaining access to the funds when they need to replace and repair their property after a flood.

In July 2009 the Welsh Assembly Government and the Association of British Insurers (ABI) reached a new agreement on flooding. Welsh Assembly Government Ministers and the ABI have agreed to work together to improve the management of flood risks and to help people recover more quickly when flooding occurs.

The agreement outlines how Welsh Assembly Government and the ABI will work together to provide a long term solution to enable flood insurance to continue to be made widely available by:

- improving understanding and awareness of flood risk
- putting in place a long-term strategy (of over 25 years) to reduce flood risk and encourage actions to mitigate and minimise the risks and costs of flooding
- ensuring the planning system prevents inappropriate development in flood risk areas and
- raising awareness in areas where flood risk is significant

Actions the ABI have agreed include:

- to continue to make flood insurance available for homes and small businesses and promote access to insurance for low income households and
- to encourage customers to reinstate flood damaged property in ways which make it more resilient to flooding.

This agreement will be reviewed annually.

9. Conclusions

- The current level of spending on flood defences and substantially increased levels of spending, as high as seven times the current level, are all demonstrated to be economically positive and justifiable investments in terms of the flood risk benefits gained.
- Maintaining current levels of spend or increasing them by up to £1m per year results in a substantial increase in the number of properties at significant flood risk in 2035.
- To maintain the numbers of properties at flood risk in 2035 at levels comparable to the present day may require around three times the current level of investment in flood defences.
- To reduce the numbers of properties at flood risk in 2035 relative to the present day, may require around four times the current level of investment in flood defences.
- Flood defences reduce the likelihood of flooding but they cannot stop all floods. Building defences can be technically difficult and may not be affordable in all locations which are at risk of flooding now or in the future.
- It is unlikely that defences alone can be used to manage future flood risk. There should be a focus on a wider range of actions to manage the consequences of flooding, to complement the investment in defences.
- The wider range of actions needed to manage both the likelihood and consequences of flooding will require increased communication, cooperation and partnership working across a range of organisations, as well as with communities and individuals.
- Flood defences will continue to have a key role in reducing the likelihood of flooding to some communities. It is therefore essential that investment in existing or new defences is prioritised according to risk and new defences can be adapted to take account of increasing flood risk.
- The most appropriate balance of flood risk management actions will vary between locations and communities. Choices will need to be made about how and where investment in managing flood risk is best directed. Communities and those directly affected should be involved in this debate.
- Other sources of funding, besides the public sector, should continue to be investigated as part of the ongoing strategy to manage flood risk.

It is intended that this document will help inform a national debate, on the options for investing in and managing the future flood risks to the people, property, infrastructure and environment of Wales.

Appendix 1: Modelling results

Five scenarios were tested in this study (See Box below). These were chosen to cover a wide range of potential future investments and a wide range of future flood and coastal risk management policies. The modelling has not assumed any one scenario is more likely or desirable than another but the results have allowed comparison to be made in the potential costs, outcomes and benefits. All scenarios were modelled with the same starting point and same climate change assumptions

Investment scenarios modelled:

1. 2009/10 allocation with inflation increase going forward;
2. 2009/10 allocation with inflation plus £1m year-on-year increase as suggested in the Future Foresight Flooding report;
3. Allocating and costing the policies contained in Catchment Flood Management Plans[20] and Shoreline Management Plans[21];
4. Target those properties at significant risk of flooding, where the benefits of doing so are at least equal to the costs;
5. As for scenario 4, but also maintaining the current level of risk for all other properties, regardless of the cost.

For scenarios 1 and 2, a set of flood and coastal defence policies were chosen to match the required investment profile. For these lower spend scenarios, i.e. 1 and 2, reduction to building and improving defences provided limited risk reduction except in the most heavily populated areas.

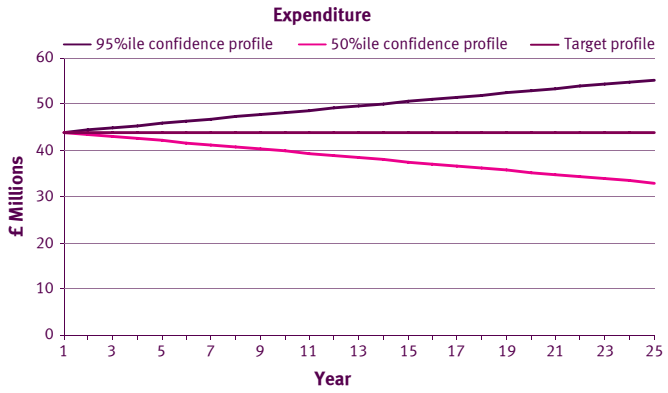
With scenarios 3 to 5, the investment reflects the costs of achieving the scenario aims and is not constrained by budget.

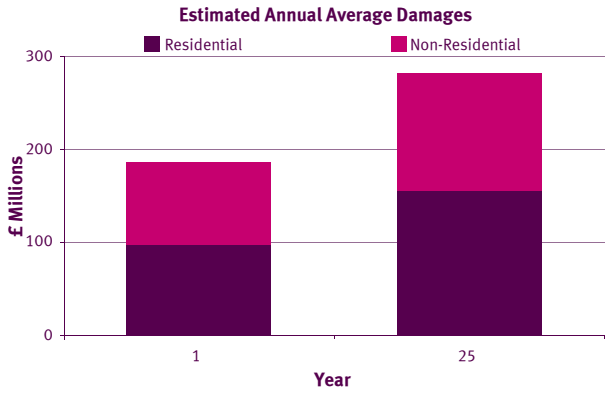
The information for each scenario is displayed in four forms:

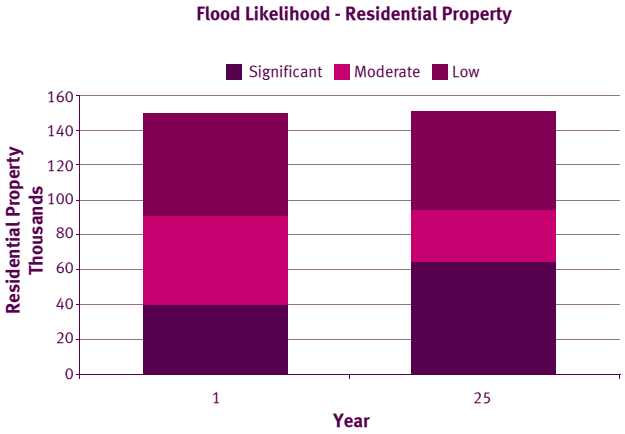
- The investment profile over 25 years. This shows the predicted total amount of investment needed per year, culminating in the amount required in 2035. Two investment profiles are shown that display the 50 percentile and 95 percentile confidence outputs[22].
- The estimated Annual Average Damages at Year 1 and Year 25.
- The total number of residential properties within the three flood likelihood categories at Year 1 and Year 25, (Non-residential properties are not included in these plots).
- The total number of residential properties within the three flood likelihood categories for the Highest 20% of deprived wards (i.e. the most deprived wards) in Wales, at Year 1 and Year 25.

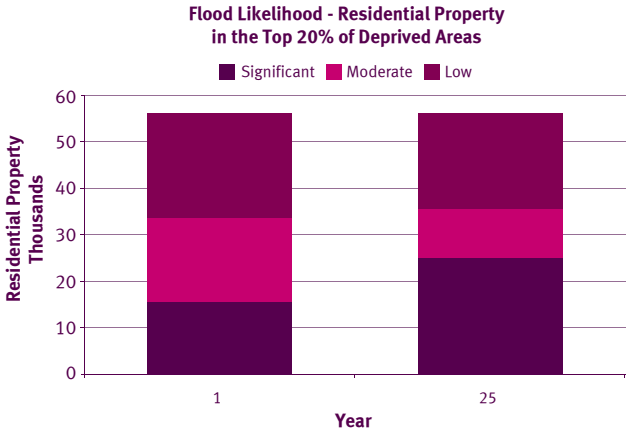
20. CFMPs are high level non statutory plans for inland flood risk produced by the Environment Agency
21. SMPs are high level non statutory plans for coastal erosion and flooding produced by Coastal Groups
22. A 95 percentile output is defined as the expenditure profile with 95 percent confidence that it will provide enough money to meet the policy definition specified. This very high degree of confidence is likely to over-estimate the amount of money needed as it assumes the worst case for most defences (for example, ground conditions make replacement above averagely expensive). However it is a valuable output as it gives an upper bound of what costs could be. The 50 percentile output represents an expenditure profile with 50 percent confidence that it will meet the specified policy. This represents a more likely expenditure need based on what is currently known. However, there are many unknowns that can not be factored into such a high level, national assessment and so care is needed if this number is to be used.

Scenario 1





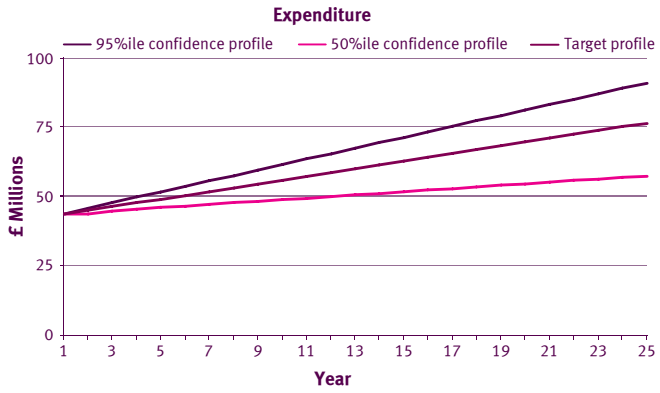


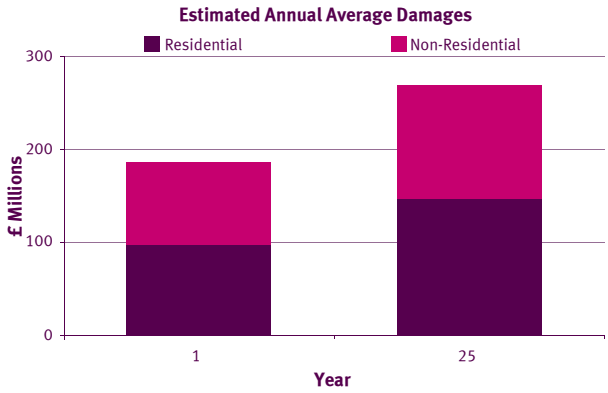


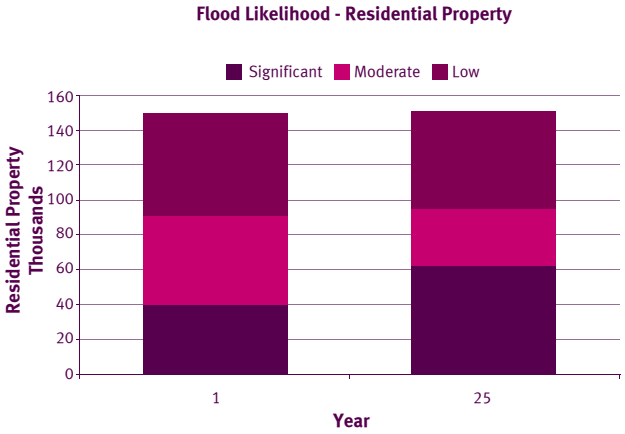
Scenario 1 represents expenditure at 2009-10 levels with increases in-line with inflation year-on-year. Investment is therefore held steady in real terms. The additional money available enables the starting point to be maintained over the 25 year period. This results in:

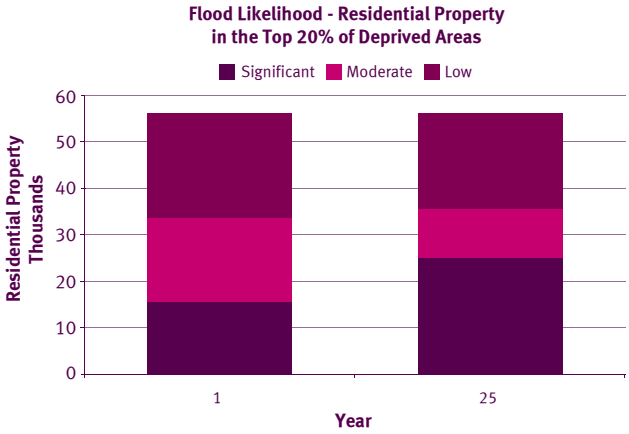
- Replacement of defences in the highest consequence flood risk management systems (but at current crest levels).
- Maintenance only in the remaining flood risk management systems.
- When defences reach the end of their design life they would be allowed to fail and would not be replaced.
- Approximately one-third of flood risk management systems will be able to maintain the current crest level of their defences.
- Increasing water levels result in increased flood risk even to areas where defences are replaced. This is due to defences only being replaced with structures that have crest levels similar to current levels.
- Defences would need to be bigger and more robust to keep pace with climate change.
- The requirement for increased size represents a significant increase in cost, especially for coastal defences which would often need to be built using more robust methods to be able to withstand increased wave power.

Scenario 2





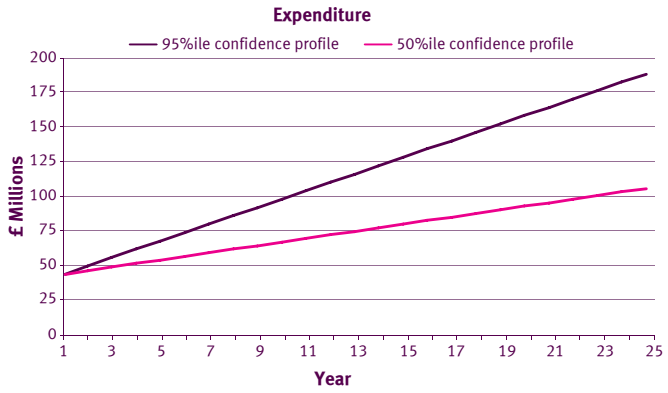


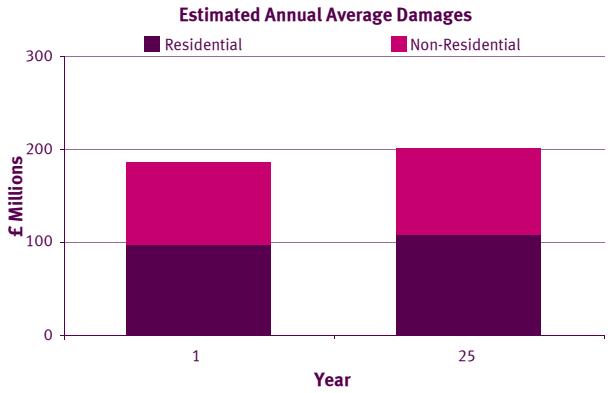


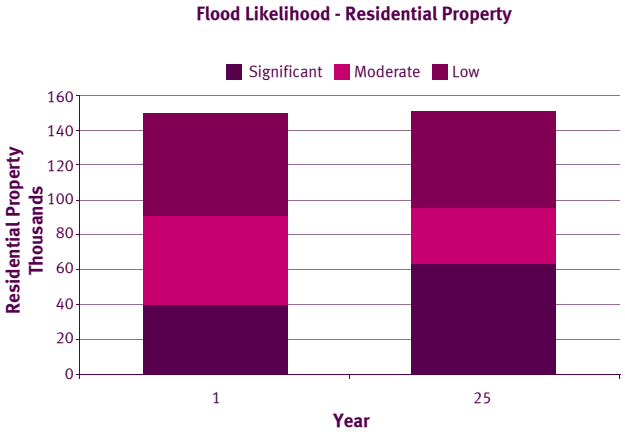
Scenario 2 represents investment increases by inflation plus an extra £1million per year. The additional money enables a slightly more interventional set of policies to be applied.

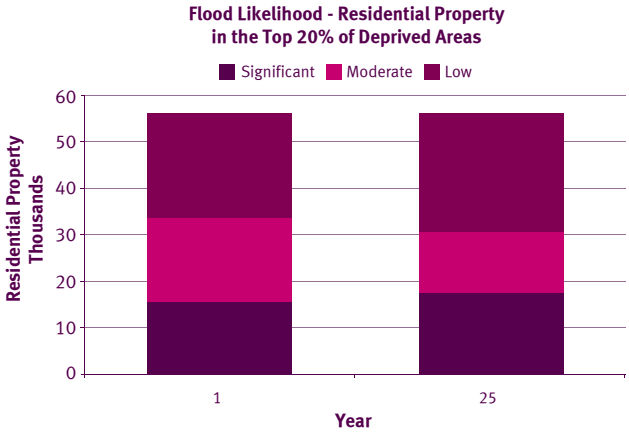
- Most 'high consequence' flood risk management systems receive defence replacement, with crest level maintained.
- Defences in the very highest consequence flood risk management systems band are replaced in line with climate change, keeping the level of risk in those areas at current levels.
- The majority of other flood risk management systems receive a 'maintenance only' investment resulting in increasing levels of flood likelihood over the 25 years.
- These policies reduce flood likelihoods when compared against Scenario 1. However, the reduction in estimated annual average damages and properties in the highest flood likelihood band is small as the increasing spend is still outstripped by the investment required to provide larger and more robust defences to keep pace with climate change, especially around the coastline.

Scenario 3





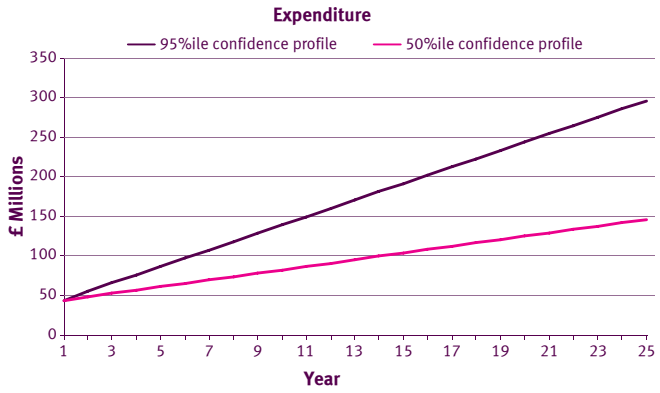


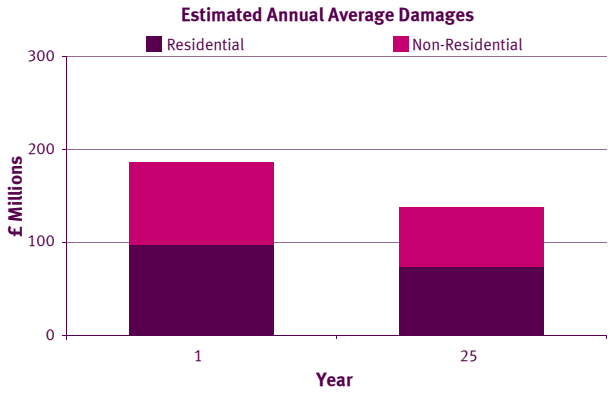


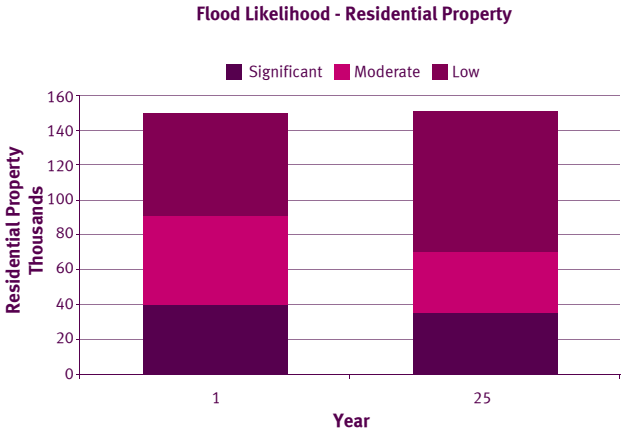
Scenario 3 represents the first of three scenarios where funding is not constrained. The aim of the scenario was to model the investment required to apply the current published Catchment Flood Risk management Plans (CFMP) and Shoreline Management Plans (SMP). These plans look at specific sections of river and coastline and develop a flood risk management policy based on a more detailed understanding of flood risk and other local constraints.

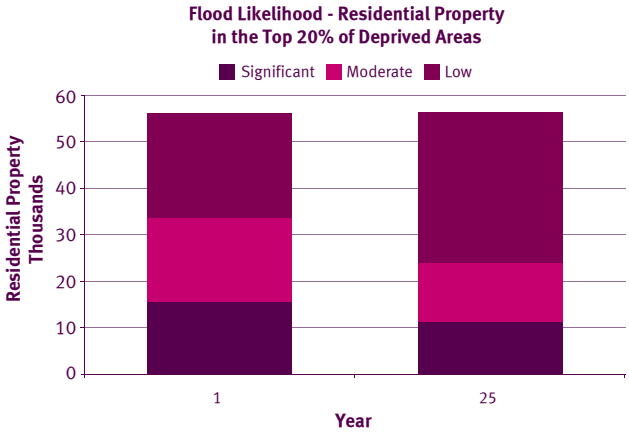
- This scenario indicates that a significant increase in spending is required to implement the defence replacement and upgrade specified in the CFMP and SMPs with required yearly investment increasing by two-four times current levels by 2035. The increasing spend allows the majority of key assets to be replaced with to keep pace with climate change. This helps to hold the flood likelihood at current levels.
- CFMPs and SMPs contain a wide range of non-asset based actions such as controlling development in the floodplain or improved flood warning. Currently the investment model does not include these measures, as the focus is on the costs and benefits of investment in flood and coastal defences.
- For this scenario the estimated Annual Average Damages remain approximately static due to investment in defences. However, this is likely to be further reduced due to other, non-defence, based interventions recommended in the CFMP and SMPs such as flood warnings.

Scenario 4





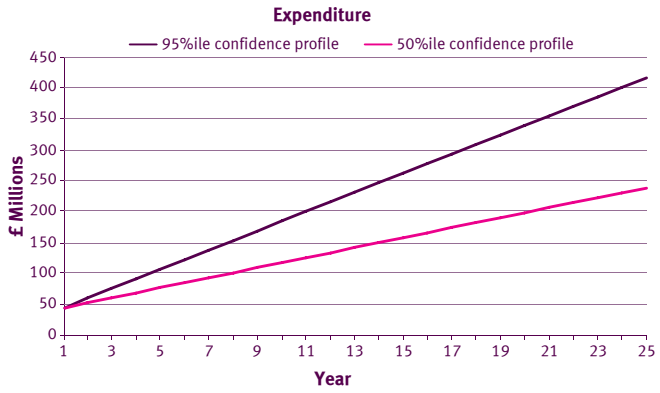


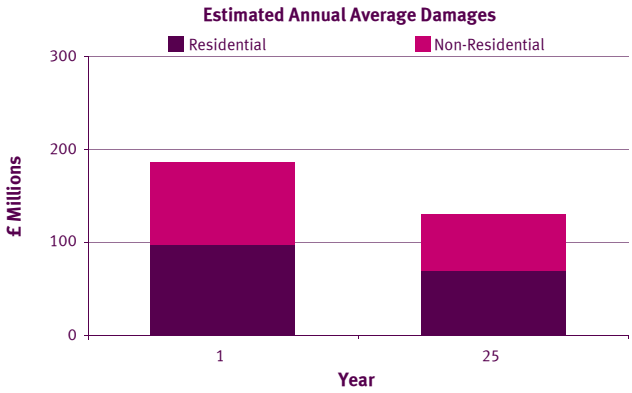


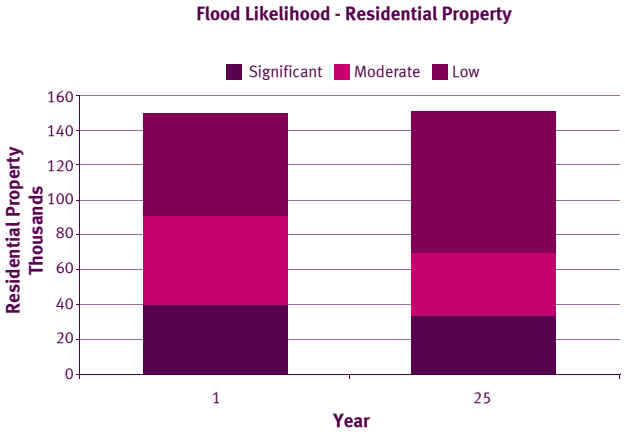
Scenario 4 models a policy to target investment at areas with property in the 'significant' likelihood category. The aim is to improve defence standards to reduce the likelihood in these areas to moderate or low, but this is only done where the benefits exceed the costs. Where the cost of providing defences is estimated to be greater than the benefit, crest levels of defences are only maintained at current levels resulting in gradually increasing flood risk. This is termed the 'fallback' policy.

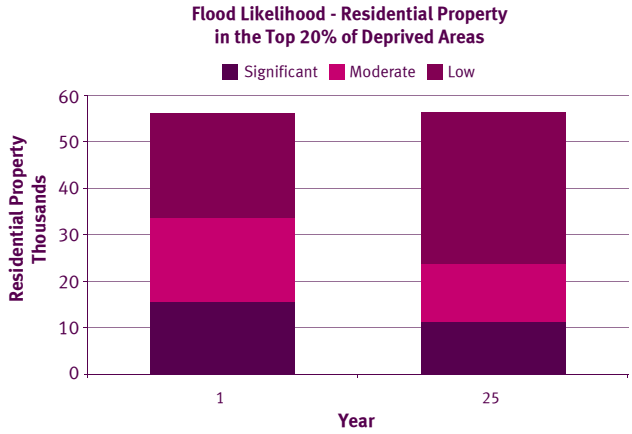
- As can be seen in the graphs above this scenario reduces the number of properties at significant flood risk and the estimated annual average damages. It also helps to reduce flood risk to deprived communities.
- There are still a number of properties in the flood risk band by 2035. This is due to a number of reasons:
  - The less interventional fallback policy can cause flood likelihoods to increase in some areas;
  - Where defence replacement and improvement is not required over the 25 years analysed, properties could be moved out of the significant flood risk category beyond the 25 year assessment period.
- The investment needed to provide this level of flood risk management through defence building is significant, with investment levels in 2035 estimated to be three to six times current levels. This is likely to be a conservative estimate as the benefits assessment only looks at the reduction in direct property damages. When others factors are taken into account such as the cost of managing the flood incidents and relocation of people whilst properties are being repaired the damages are likely to increase by two and a half times.
- This would result in additional areas meeting the benefits cost threshold of one and therefore receiving high cost defences. Currently the modelling has no method of applying these indirect flooding costs as they are hard to assess at a local level. These additional areas passing the benefits cost threshold of one would also reduce the number of properties at significant flood risk in 2035.

Scenario 5









Scenario 5 is similar to Scenario 4 in that it aims to remove properties from the significant flood likelihood category where the benefits outweigh the costs. The difference is in the fallback policy chosen. In Scenario 5 the fallback policy is to replace defences to keep pace with climate change.

- It can be seen from the graphs that this scenario is likely to require an additional £100million per year by 2035 compared to Scenario 4.
- The reduction in the number of properties at significant flood risk is relatively small. This is due to the fact that both scenarios 4 and 5 reduce flood likelihoods in areas where it is cost effective to do to so.
- Scenario 5 has a much more expensive fallback policy which does not provide correspondingly high additional benefits.

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