

(Defra Project Code GA0204)

A climate change risk assessment for Wales

January 2012

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Statement of use

See full statement of use on Page iv.

Keywords:

Wales, climate change, risk assessment

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Document History:

Date	Release	Prepared	Notes
01/02/11	0.1	HR Wallingford	Draft for review
09/02/11	1.0	HR Wallingford	Initial Draft for external review (internal ref: V7)
28/03/11	2.0	HR Wallingford	Revised, updated and improved in response to review comments from Welsh Government
15/04/11	3.0	HR Wallingford	Revised to include further review comments from Welsh Government
07/10/11	4.0	HR Wallingford	Major revision
14/11/11	5.0	HR Wallingford	Revised to include further review comments from Welsh Government
20/01/12	6.0	HR Wallingford	Final release

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This report is available online at:

<http://www.defra.gov.uk/environment/climate/adapting/>

Statement of Use

This report presents the findings of an assessment of climate change risks for Wales, which has been completed as part of the UK Climate Change Risk Assessment (CCRA).

Before reading this report it is important to understand the process of evidence gathering for the CCRA.

The CCRA methodology is novel in that it has compared over 100 risks (prioritised from an initial list of over 700) from a number of disparate sectors based on the magnitude of the consequences and confidence in the evidence base. A key strength of the analysis is the use of a consistent method and set of climate projections to look at current and future threats and opportunities.

The CCRA methodology has been developed through a number of stages involving expert peer review. The approach developed is a tractable, repeatable methodology that is not dependent on changes in long term plans between the 5 year cycles of the CCRA.

The results, **with the exception of population growth where this is relevant, do not include societal change in assessing future risks, either from non-climate related change, for example economic growth, or developments in new technologies; or future responses to climate risks such as future Government policies or private adaptation investment plans.**

Excluding these factors from the analysis provides a more robust 'baseline' against which the effects of different plans and policies can be more easily assessed. However, when utilising the outputs of the CCRA, it is essential to consider that Government and key organisations are already taking action in many areas to minimise climate change risks and these interventions need to be considered when assessing where further action may be best directed or needed.

Initially, eleven 'sectors' from which to **gather** evidence: Agriculture; Biodiversity and Ecosystem services; Built Environment; Business, Industry and Services; Energy; Forestry; Floods and Coastal Erosion; Health; Marine and Fisheries; Transport; and Water.

A review was undertaken to identify the range of climate risks within each sector. The review was followed by a selection process that included sector workshops to identify **the most important** risks (or opportunities) within the sector. Approximately **10%** of the total number of risks (or opportunities) across all sectors were selected for more detailed consideration and analysis as part of the UK-wide assessment.

The risk assessment used UKCP09 climate projections to assess future changes to these selected sector risks. Risks were, in general, analysed using single climate variables, for example temperature.

A final **Evidence Report** draws together information from the eleven sectors (as well as other evidence streams) to provide an overview of risks from climate change to the UK.

This report for Wales provides a similar overview of risks from climate change to Wales. The most important risks (or opportunities) for the UK were reviewed with Welsh stakeholders to determine which were important for Wales. This resulted in some risks being dropped from the list and others being added. Where risks have

been added, these have not been analysed in detail, but are discussed within the broader context of risks from climate change to Wales.

Neither this report nor the Evidence Report aims to provide an in depth, quantitative analysis of risk within any particular 'sector'. Where detailed analysis is presented using large national or regional datasets, the objective is solely to build a consistent picture of risk for the UK, including Wales, and allow for some comparison between disparate risks and regional/national differences. The results presented here should not be used by the reader for re-analysis or interpretation at a local or site-specific scale.

In addition, as most risks were analysed using single climate variables, the analysis may be over-simplified in cases where the consequence of climate change is caused by more than one climate variable (for example, higher summer temperatures combined with reduced summer precipitation).

Executive summary

This climate change risk assessment for Wales has been produced as part of the UK Climate Change Risk Assessment (CCRA). The CCRA is required under Section 56 of the Climate Change Act 2008, and must be laid before Parliament in January 2012.

This report presents a national assessment of potential risks (and opportunities) from climate change facing Wales for the period to 2100. Its findings will inform the development of adaptation work in Wales.

The assessment draws together and presents evidence from individual CCRA UK sector reports and recent research literature. The findings are presented for a range of possible future scenarios and include an indication of confidence in the results and areas where there are evidence gaps.

The assessment is based on the UK Climate Projections which were published in 2009 (UKCP09). This provides projections of climate change for the 2020s, 2050s and 2080s compared with the period 1961-90. For each epoch, a range of climate change scenarios have been considered. For example, projected changes for Wales under the 2050s Medium Emissions scenario include:

- An increase in mean winter temperatures of 2.0°C (very unlikely to be less than 1.1°C and very unlikely to be more than 3.1°C).
- An increase in mean summer temperatures of 2.5°C (very unlikely to be less than 1.2°C and very unlikely to be more than 4.1°C).
- An increase in mean winter precipitation of 14% (very unlikely to be less than 2% and very unlikely to be more than 30%).
- A decrease in mean summer precipitation of 17% (very unlikely to be less than a 36% decrease and very unlikely to be more than a 6% increase).

In addition, sea level rise is projected to increase by between about 0.1m and 0.32m by the 2050s.

These changes have been used to derive projections of changes in bio-physical systems, for example changes in river flows, aridity and water availability. These have been used together with the climate change projections to assess the potential impacts of climate change.

It is important to note that extreme weather events are already a characteristic of the present day climate in Wales and dominate current climate risks. They will also continue to occur in the future, independent of climate change, due to the natural variability of the climate.

A list of the most important climate change impacts and consequences for Wales was developed through a process of consultation with stakeholders. This takes account of the impacts that were considered to be most important for the UK as a whole, together with particular features and issues relevant to Wales.

Particular features of Wales include the following:

- Much of the topography is steep with extensive mountain ranges and upland areas.
- Land use is dominated by grasslands, used for grazing livestock.

- Water sources are mostly surface water with little groundwater.
- The largest cities (Cardiff, Swansea and Newport) and a large proportion of business and industry are on the coast.
- Many of the main transport routes are along the coast or in river valleys.
- About 30% of the land area has environmental designations together with extensive areas of the surrounding sea.
- Tourism is an important element of the Welsh economy, both on the coast and inland.

For each impact, an assessment has been made of the potential consequences that may occur in the future. The results are presented in terms of the magnitude of each impact in the 2020s, 2050s and 2080s. The results are however highly uncertain, as they depend on the UKCP09 projections (which have a high degree of uncertainty), and there is uncertainty associated with the methods of assessment.

Therefore, whilst the assessment provides a range of possible changes in risk, the results must not be considered to be predictions of change. The interpretation and use of the results should be as follows:

1. The results provide a guide to the possibility of a risk occurring, its order of magnitude, direction of change and potential timing.
2. The supporting evidence on specific risks illustrates possible future changes.
3. Adaptation actions should recognise the likely direction of change and the high degree of uncertainty.
4. For the impacts of greatest concern, gaps in evidence should be addressed, including the establishment of monitoring and further research where appropriate.

This report does not attempt to provide a comprehensive discussion of all potential impacts for Wales, nor does it attempt to identify potential adaptation measures or associated policy for Wales. The primary purpose is to provide an overview of the impacts that are considered to be the most important.

Summary of results

From the results of this assessment, the potentially most significant threats for Wales from climate change appear to be:

- Changes in soil conditions, biodiversity and landscape as a result of warmer, drier summers.
- Reductions in river flows and water availability during the summer, affecting water supplies and the natural environment.
- Increases in flooding both on the coast and inland, affecting people, property and infrastructure.
- Changes in coastal evolution including erosion and coastal squeeze, affecting beaches, intertidal areas and other coastal features.
- Changes in species including a decline in native species, changes in migration patterns and increases in invasive species.
- Increases in the risk of pests and diseases affecting agriculture and forestry. The risk to livestock is a particular concern.

The potentially most significant opportunities identified for Wales from climate change appear to be:

- Increases in grass yields, allowing a potential increase in livestock production.
- Increases in tourist numbers and a longer tourist season.

There are close links between the threats and opportunities listed above and others described in this report. They should therefore not be considered in isolation. An integrated approach will be required to mitigate and/or adapt to these threats and opportunities.

Results by theme

The results are presented in the following five themes: natural environment; agriculture and forestry; business; buildings and infrastructure; health and well-being. The main potential threats and opportunities are summarised below by theme.

Natural environment

- Reduction in soil moisture and lower river flows, and an increase in the frequency and magnitude of droughts.
- Changes in soil organic carbon, although the ways in which it might be affected are not adequately understood at present.
- Changes in climate space and species migration patterns, which could result in significant changes to biodiversity.
- Increases in pests and diseases.
- Changes to coastal and estuarine habitats and species, including a reduction in intertidal area.
- Changes to the marine environment, including an increase in disease hosts and pathogens, harmful algal blooms and invasive species. The effects of ocean acidification include adverse impacts on shellfish.

Agriculture and forestry

- Increase in summer aridity and droughts including an increase in fire risk.
- Increase in pests and diseases, affecting livestock, crops and forests.
- Increases in crop yields including grass, which presents a major opportunity although it is not clear to what extent this is constrained by such factors as water availability and nutrients.
- Increase in water stress to crops, grass and forests caused by droughts in the summer and flooding and waterlogging in the winter.

Business

- Increases in flooding which would affect business premises and supply chains, and disrupt business operations.
- Reduction in insurance and mortgage business caused by an increase in flooding, and potential increases in insurance losses resulting from an increase in the occurrence of extreme events.

- Failure of the financial sector to adequately take account of climate change, resulting in poor financial performance which could have widespread consequences for business and other sectors.
- Increase in tourism both on the coast and inland, which presents an important opportunity. However coastal tourist assets including beaches would be affected by sea level rise and coastal erosion.

Buildings and infrastructure

- Increases in flooding of buildings. Flood insurance for some properties may become expensive or difficult to obtain.
- The effects of heat are likely to increase both within buildings and the wider urban environment.
- Reduction in water availability.
- Increases in flooding of critical infrastructure, resulting in more failures of electricity, water and other essential services. Flooding of roads and railways is also projected to increase, resulting in delay, disruption and additional repair costs.
- An additional requirement for energy in the summer for cooling, although this is still likely to be less than the capacity needed for winter heating demand, which is projected to reduce.

Health and well-being

- The effects of increasing temperatures (including heat waves) on people, including increases in summer mortality and morbidity.
- The effects of increases in flooding on people and their homes and work places.
- Improvement of health conditions in the winter, with reduced cold weather mortality and morbidity, and possibly less air pollution.
- Increases in the requirements for emergency response to flooding, heat waves and fires.

Results by type of location

The impacts of climate change have also been considered by type of location (urban, rural, mountains and coasts).

Urban areas are likely to be affected by increases in flooding, a reduction in water availability and an increase in summer heat.

Increases in flooding, including flooding from a combination of different sources, would cause increases in disruption to communities, the economy and employment. It would also affect water supplies, wastewater disposal, energy supplies and health services for areas both inside and outside the floodplains. The potential reduction in water availability in the summer would affect all water users including homes, industry and business.

The effects of climate change are likely to be more severe for vulnerable groups, who may be less able to cope with the effects of flooding and the effects of higher temperatures during the summer.

The potential effects of climate change in rural areas include changes to agriculture, the landscape and the rural economy.

Whilst yields of crops, grass and forests may increase, there are threats to agriculture and forests from droughts, waterlogging, pests and diseases. Increases in drying and wetting could have adverse impacts on soils, including damage and erosion. These changes would also affect biodiversity and the landscape.

The sustainability of agriculture and forestry in some areas could be affected by the combined effects of drier, hotter summers and wetter winters, leading to drying of land and reduced water availability in the summer and increased erosion and flooding in winter.

Extreme weather events could have particularly serious impacts on remote communities including the loss of service connections and flooding of roads. This in turn would affect households and businesses. The effects of climate change would be more severe for vulnerable groups which might include the low paid, unemployed and elderly.

In mountainous areas the drying out of bogs and other habitats in the summer could lead to a loss of biodiversity and carbon storage. An increase in soil erosion in drier summers could also occur, potentially exacerbated by an increase in tourism. These changes would affect the mountain landscape. Biodiversity would also be affected by changes in climatic conditions and habitats, including migration of species to higher altitudes.

The coast could be affected by the loss of designated habitats and protected species as a result of coastal squeeze (caused by sea level rise) and erosion. Erosion and sea level rise could also damage coastal areas including communities and transport links. Fisheries including shellfish could be affected by sea level rise, an increase in water temperature and changes in water quality.

Tourist resorts on the coast could benefit from a potentially longer tourist season although this would increase pressure on natural assets and infrastructure. Threats include the loss of natural assets (particularly beaches) to sea level rise and increases in flooding.

Gaps in evidence

A number of gaps in evidence were identified when undertaking the analysis. These include:

- Consideration of climate extremes and associated uncertainty. This particularly applies to the effects of droughts on water availability and biodiversity.
- Changes in storminess and wind speed. Current guidance from the Met Office indicates that changes are projected to be small, but further research is in progress.
- Consequences of surface water and groundwater flooding.
- Overall impacts of climate change on vulnerable people and communities.
- Understanding the effects of climate change on biodiversity and ecosystems. This reflects the complexity of natural systems and limitations in current knowledge.
- Knowledge of potential changes in pests and diseases and consequences for livestock, crops, forests and ecosystems.
- Overall impacts of climate change on land use and spatial planning.

A more detailed list of gaps in evidence is presented in the report. This can form the basis of the evidence gathering needed to inform the development of adaptation plans, and the next CCRA (due in 2017).

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1 Introduction

1.1 The Climate Change Risk Assessment (CCRA)

It is now widely accepted that the world's climate is being affected by the increasing anthropogenic emissions of greenhouse gases into the atmosphere globally, and that even if efforts to mitigate these emissions are successful, the earth is already committed to significant climatic change (IPCC, 2007).

The UK Government and Welsh Government are committed to actions for both mitigation of and adaptation to climate change.

The Climate Change Act 2008 made the UK the first country in the world to set a legally binding framework for reducing emissions, but also creates a framework for building the UK's ability to adapt to climate change.

The Act requires an assessment of the climate change risks to the UK. The first assessment is due in January 2012 and an updated assessment will be issued every 5 years.

The objective of the UK Climate Change Risk Assessment (CCRA) is to inform adaptation policy across the UK in 2012, by assessing the current and future threats and opportunities posed by the impacts of climate for the UK to the year 2100.

The purpose of this report is to present the findings of the CCRA for Wales.

1.2 Overview of Wales

Wales is one of the four UK countries, with a land area of about 20,800 km² and a population of about 3 million (2008). It is bordered on three sides by the sea and has a very long coastline relative to its size (about 1,500km). The east side of Wales borders England.

The topography is generally steep with extensive mountain ranges. The majority of the land area consists of uplands, and there are relatively small areas of low-lying land. Land use is dominated by grasslands, used for grazing livestock.

The largest cities are on the south coast: Cardiff (population 325,000), Swansea (population 227,000) and Newport (population 116,000). There are other important centres of population on the coast (including tourist resorts in north Wales) and in the valleys of south Wales.

The main transport routes are generally along the coast or river valleys. There are major road and rail routes near the north and south coasts, on the Dee and Severn estuaries respectively.

About 30% of the land area has environmental designations together with extensive areas of the surrounding sea.

Tourism is an important element of the Welsh economy, both on the coast and inland. There are national parks covering the highest mountains in north and south Wales, and the spectacular coastal scenery of south west Wales.

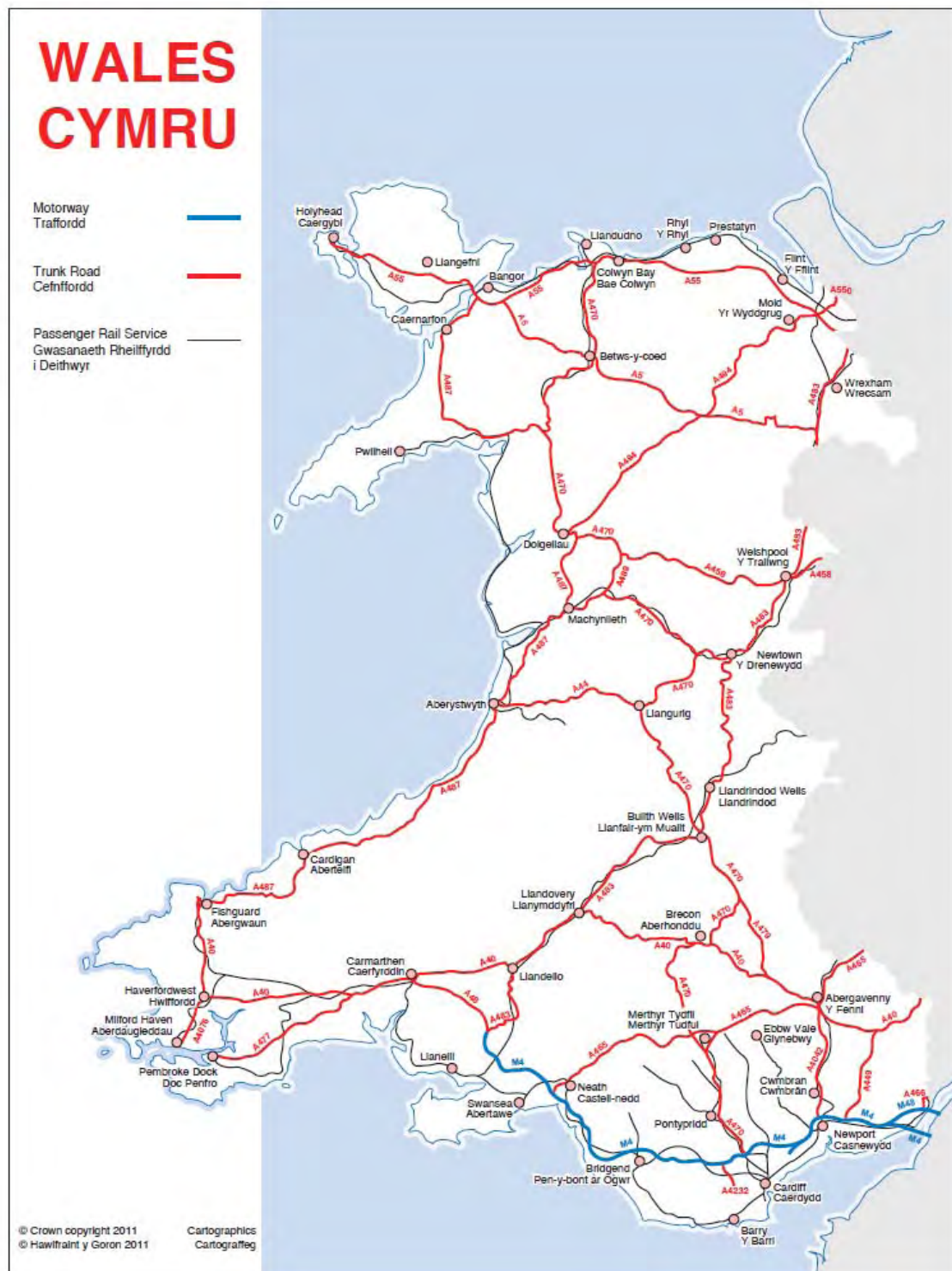
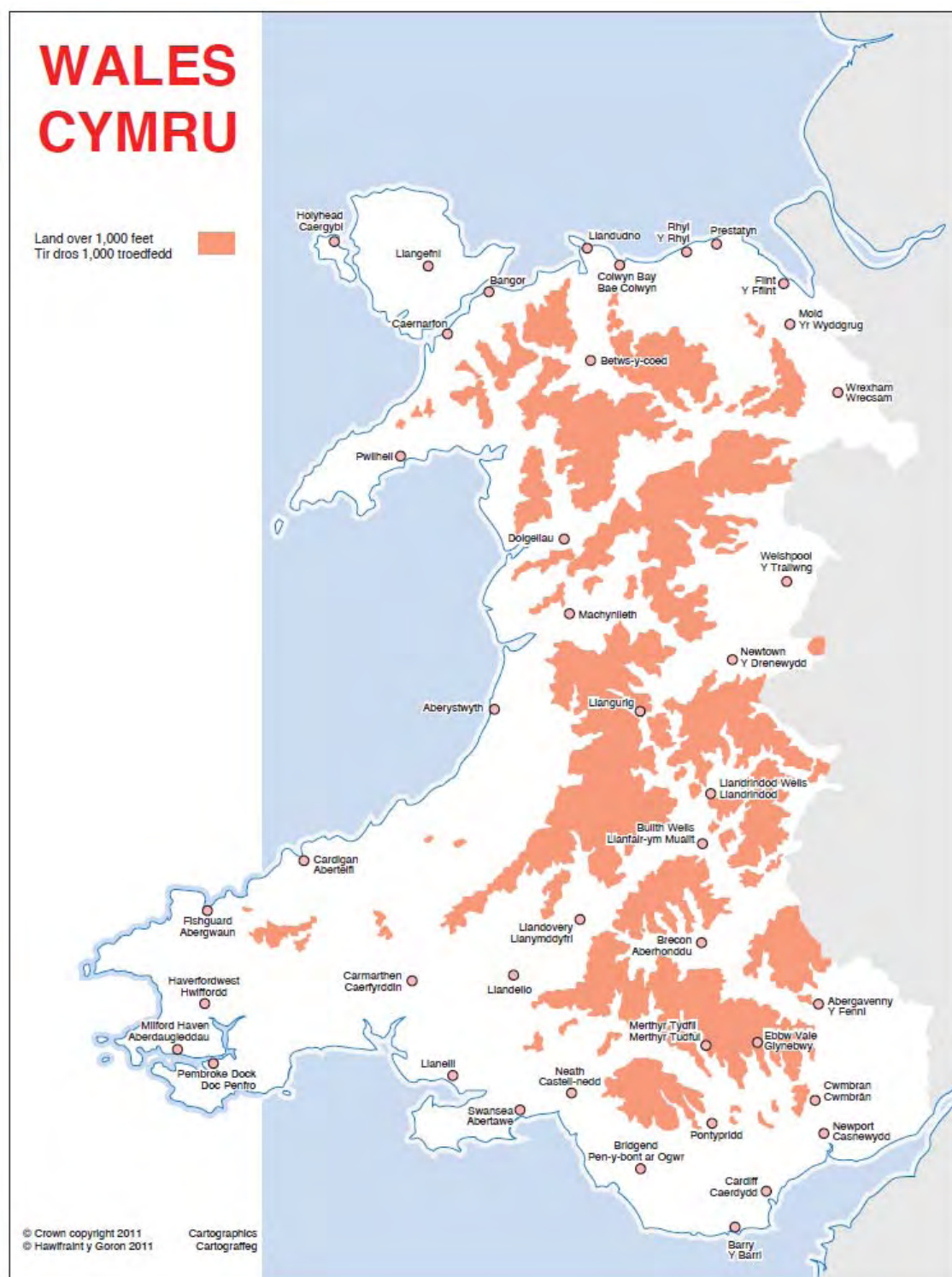


Figure 1.1 Main towns, roads and railways

(Source: Welsh Government)



(Source: Welsh Government)

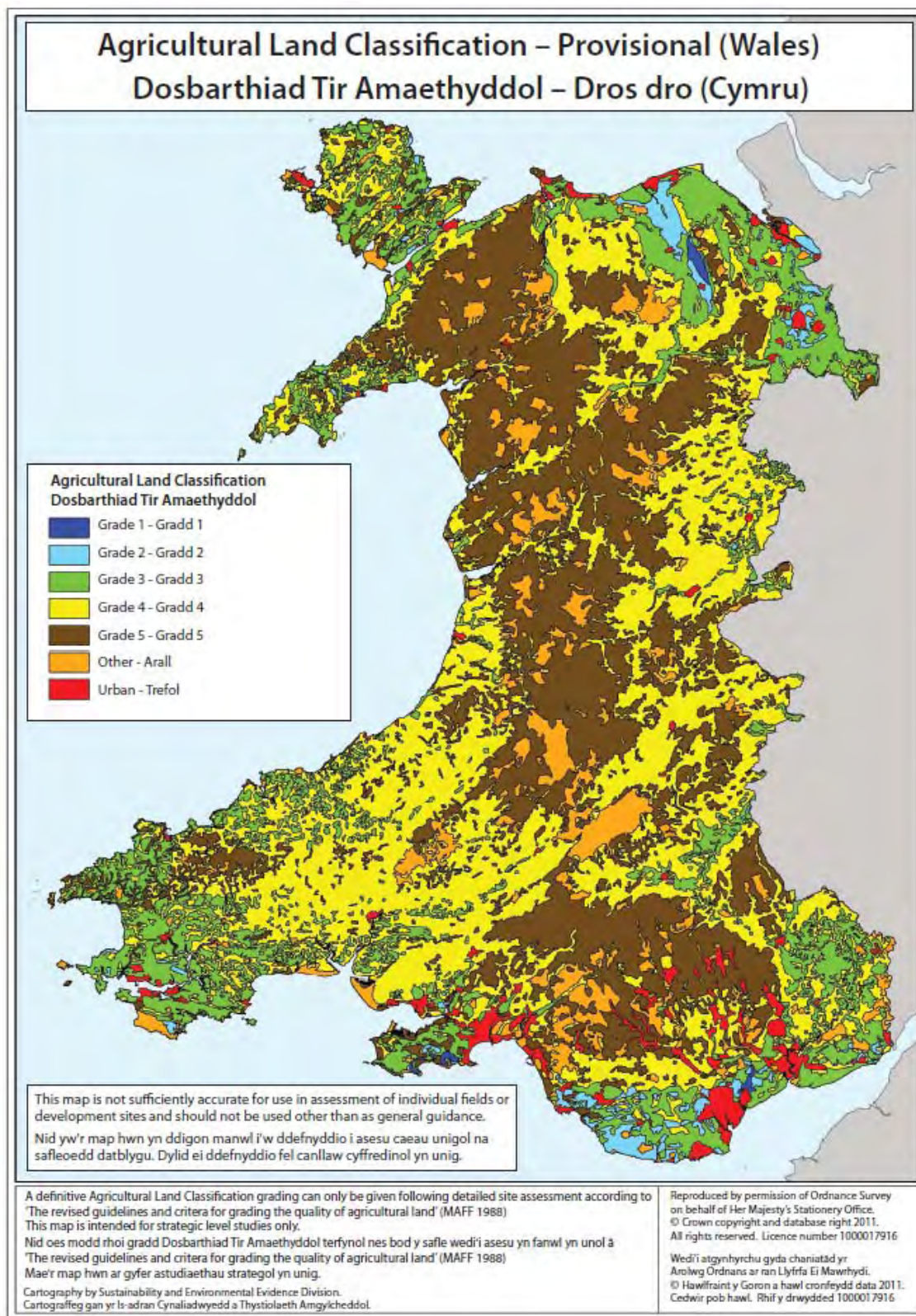


Figure 1.3 Land use

(Source: Welsh Government)

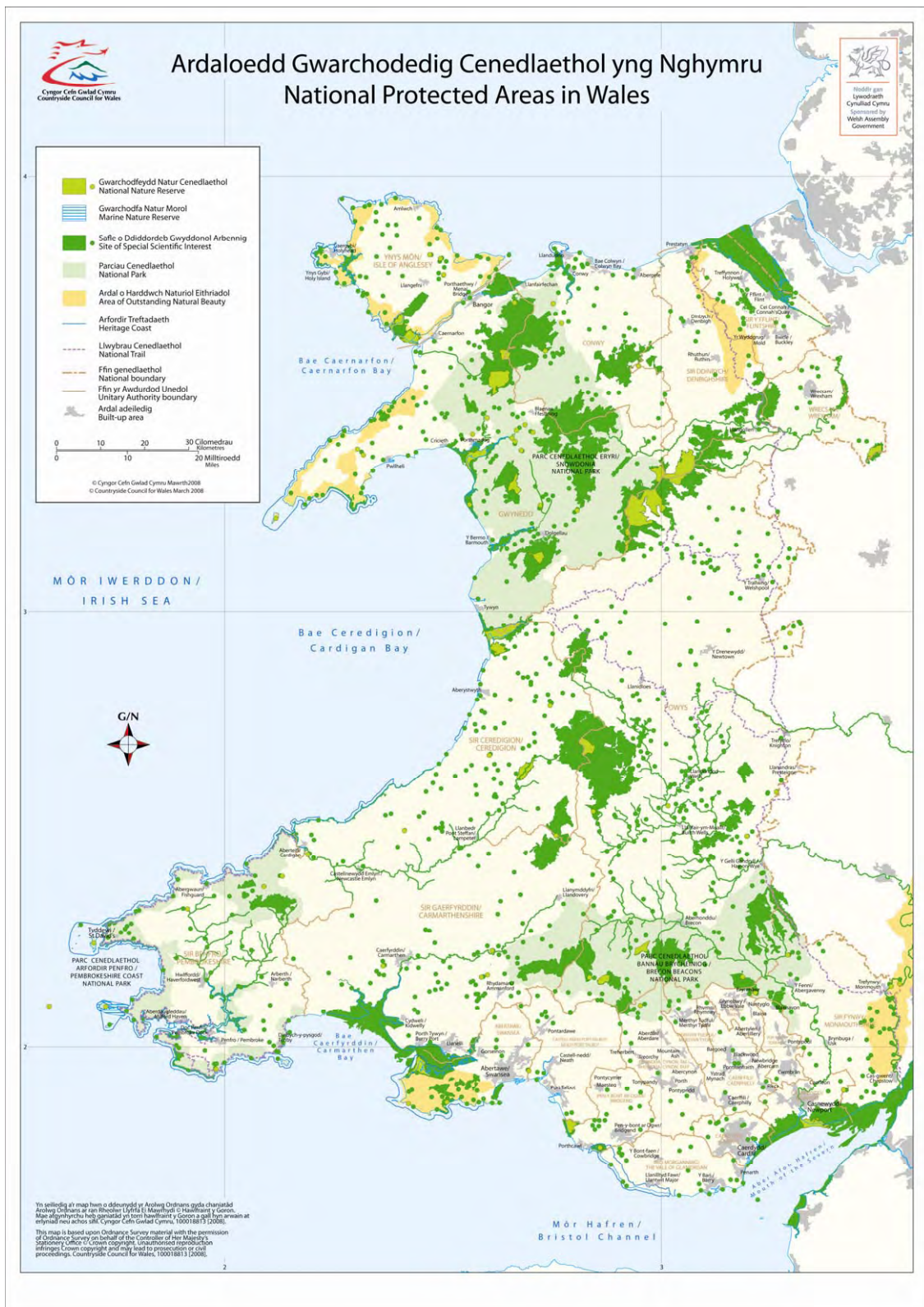


Figure 1.4 **Nationally protected areas**

(Source: Countryside Council for Wales)

1.3 Consultation

This risk assessment has been developed in consultation with the Welsh Government and a wide range of other stakeholders. Following an initial presentation to the Welsh Government in March 2010, meetings were held in August 2010 to discuss particular issues in Wales and plan a workshop.

The workshop was held in Cardiff on 21 September 2010, involving over 40 stakeholders. The workshop identified the main impacts of climate change of concern in Wales, and helped to develop risk metrics to assess the impacts (CCRA, 2010).

The results of the workshop were also used to prepare a list of the most important impacts of climate change for Wales, which was agreed with stakeholders in December 2010. The resulting list of impacts for Wales formed the basis for this risk assessment.

1.4 Climate change impacts

A list of impacts of climate change on the UK was developed in the CCRA. This contains about 700 impacts, and is referred to as the 'Tier 1' list. A procedure was then undertaken to select impacts for more detailed analysis (based on a number of criteria). This involved scoring and expert review of the impacts. The procedure identified about 120 impacts, which are referred to as the 'Tier 2' list.

One of the objectives of the Cardiff workshop was to identify a list of impacts for Wales (i.e. a 'Tier 2' list for Wales). This was prepared in three stages, as follows:

- Workshop participants were asked to comment on the UK Tier 2 list and add potential additional impacts for Wales before the workshop;
- The Tier 2 list was discussed at the workshop itself; and
- After the workshop a Tier 2 list of impacts for Wales was prepared in consultation with the Welsh Government and stakeholders.

This Wales Tier 2 list is contained in [Appendix A](#). The list and associated analysis was developed by sector. The impacts were then mapped onto the five themes used for presentation in [Section 4](#) of this report. The list of impacts by theme is also included in [Appendix A](#).

1.5 Key issues

This section sets out the main climate change concerns to stakeholders and provides the context for the subsequent selection and assessment of climate change impacts. Climate change issues of particular concern to stakeholders include:

- Water quantity. Although Wales has considerable precipitation, there are significant pressures on water resources. Surface water is the main source of water as there is very little groundwater.
- Tidal flooding and sea level rise. Most of the large towns and cities and some of the main transport links are on or near the coast.
- Inland flooding.

- Changes in agriculture and the effects this will have on the rural economy.
- Impacts on wildlife.
- Health and inequality. Particularly vulnerable groups include poorer people in flood risk areas and people in remote communities.
- Overall impacts of climate change on the economy and employment.
- Governance, regulations and planning in relation to climate change.
- Knowledge and data.

Concerns of stakeholders related to different geographical areas are summarised below.

Urban and industrial areas

Most of the major cities and towns are on the coast or in river valleys with many major industrial installations in the floodplain. In addition, many of the main transport links are on the coast.



Figure 1.6 Urban and industrial areas

Specific climate change concerns in urban and industrial areas include:

- A potential increase in tidal flooding and damage to urban areas, industrial areas and transport links.
- A potential increase in occurrences of combined tidal and fluvial flooding.
- A potential increase in disruption to communities, the economy and employment caused by flooding.

- Potential increases in property and other damage caused by flash flooding and landslips as many properties are located on valley sides.
- Potential reduction in water availability.
- The effects of climate change on vulnerable groups and social deprivation.

Rural areas

Much of rural Wales consists of upland areas. The local economies are to a large extent dominated by agriculture with a very high proportion of livestock farming and large areas of forests.



Figure 1.7 Upland areas

Concerns for rural areas include:

- A potential reduction in the sustainability of agriculture (caused by drying of land in summer and increased erosion and flooding in winter) although there are opportunities for increases in crop yields.
- A potential increase in occurrences of pests and diseases in plants, trees and livestock. Livestock disease is a particular concern.
- A potential increase in the impacts of extreme weather events on remote communities, including the loss of service connections and flooding of roads.
- Drying out of land with potential consequences for the landscape and biodiversity. Fire risk may also increase.
- The effects of climate change on vulnerable groups.

- Potentially adverse consequences for rural economies and communities.

Mountainous areas

Wales has extensive mountainous areas which are home to many communities and visited by large numbers of tourists. These include the large Snowdonia National Park in north Wales. Livestock agriculture is also important in these areas, and has an important impact on the landscape.

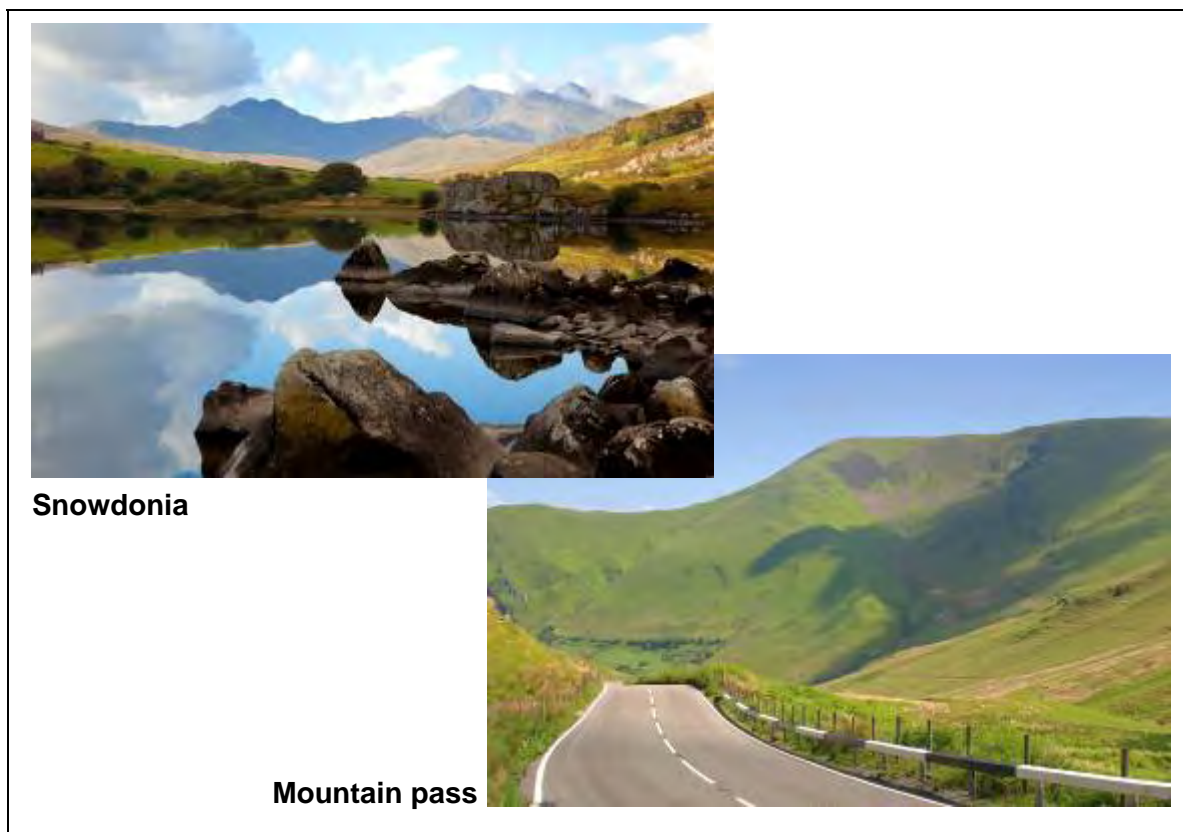


Figure 1.8 Mountain areas

Potential climate change impacts on mountainous areas include:

- Drying out of bogs and other habitats, leading to a loss of biodiversity and carbon storage. This would also affect the mountain landscape.
- Migration of species to higher altitudes. This would affect both biodiversity, including the potential loss of species, and landscape.
- An increase in soil erosion in drier summers, potentially exacerbated by an increase in tourism. Consequences include damage to habitats and footpaths, and sedimentation in watercourses.
- Potential increase in forage growth leading to an increase in livestock numbers.

The coast

The coastline has many environmentally important areas and designated sites that are at risk from sea level rise.



Marloes Sands



Above and top right: Harlech beach

Figure 1.9 The west coast

Potential climate change concerns for coastal areas include:

- Loss of designated habitats as a result of coastal squeeze caused by sea level rise.
- Erosion and damage to coastal areas including communities and transport links, due to coastal erosion and sea level rise.
- Damage to fisheries including shellfish caused by sea level rise, erosion and changes in water quality.
- The uncertain impacts associated with a rise in sea temperature and ocean acidification, which may include loss of local species and an increase in non-native invasive species.
- Water availability for agriculture, as most of the arable and horticulture crops are grown near the coast.

Wales has a large number of coastal tourist resorts. These provide popular holiday destinations for visitors from the UK and beyond.



Figure 1.10 The sea front, Llandudno (Conwy)

The potential impacts for coastal tourist resorts include:

- A longer tourist season and more visitors.
- An increase in pressure on infrastructure.
- Loss of natural assets (including beaches) to sea level rise and erosion.
- An increase in flooding from tidal, fluvial and surface water sources. There is a particular concern that combinations of fluvial and tidal flooding could become more frequent.
- Adverse effects on the marine environment including reduced water quality and increase in invasive species.

1.6 Policy context

Note: Links or references for the key documents referred to in this section are given in a separate section within the report references. These documents are indicated by italics.

1.6.1 The Climate Change Act 2008

The Climate Change Risk Assessment is required under Section 56 of the *Climate Change Act* and applies to the United Kingdom as a whole.

The Act also provides Welsh Ministers with powers to issue guidance on adaptation, and to direct certain organisations to prepare a report outlining their risks from climate change and their plans to address those risks.

The Welsh Government has published Parts 1 and 2 of its adaptation guidance, *Preparing for a changing climate*, and Parts 3, 4 and 5 will follow in 2012. The Welsh Government is also implementing a Knowledge Transfer Programme to support organisations undertaking adaptation work.

It is currently the intention of Welsh Ministers not to issue directions. This position may be reviewed in light of the CCRA and other relevant work. Due to its cross-border nature, the Environment Agency was issued with a joint direction from Welsh Ministers and the Secretary of State and submitted its report in November 2010.

1.6.2 One Wales: One Planet

One Wales: One Planet (2009) is the Welsh Government's Sustainable Development Scheme. It sets out how the Welsh Government intends to promote sustainable development in the exercise of the Welsh Ministers' functions. *One Wales: One Planet*:

- Sets out the Welsh Government's vision of a sustainable Wales.
- Confirms that sustainable development will be the central organising principle of the Welsh Government, and the steps it will take to embed this approach.
- Confirms the two core principles and six supporting principles of sustainable development that the Welsh Government will use to inform all policy and programme development and delivery.
- Sets out an indicative route map of the journey Wales will need to take in order to use only Wales' fair share of the earth's resources.
- Sets out the strategic approach to delivering sustainable development across the Welsh Government.

In its five-year legislative plan, the Welsh Government has announced its intention to bring forward a Sustainable Development Bill that will:

1. Provide for the establishment of an independent body to embed sustainable development as the central organising principle in all Welsh Government actions and in all public bodies in Wales.
2. Continue the work of the Sustainable Development Commission in a way that best reflects the interests and needs of Wales.

1.6.3 The Climate Change Strategy for Wales

The *Climate Change Strategy for Wales* (2010) addresses both emission reduction and adaptation, and includes a framework for progressing adaptation work in Wales. The Adaptation Framework has three pillars:

1. Build the evidence base
2. Mainstream adaptation into decision-making
3. Share information and good practice.

An *Adaptation Delivery Plan* (2010) was published alongside the Strategy and includes 24 specific actions to deliver the Adaptation Framework. Action 2 (Evidence base) is to 'Assess the risks and opportunities presented by climate change through active engagement in UK research programmes'. This report provides evidence to support Action 2.

1.6.4 The Environment Strategy for Wales

The *Environment Strategy for Wales* (2006) provides a framework for managing the environment and aims to provide a thriving, distinctive environment that contributes to the economic and social wellbeing of Wales, and the health of its people, by 2026. The Strategy has five themes of which one, 'Addressing climate change', considers both reducing emissions and developing resilience to climate change.

The Strategy is supported by the *Environment Strategy Action Plan* (2008 – 2011), which sets out the delivery of the Strategy, including actions and participants. 41 actions are identified under 10 themes.

1.6.5 Local Government and planning

The Welsh Government has adopted a partnership approach to working with local government, as set out in the document *A New Understanding between the Welsh Government and Local Government in Wales* (2009). Local actions are set out in Outcome Agreements between the Welsh Government and local authorities that provide a framework of indicators and measures.

Local authorities in Wales are allowed to do anything they consider likely to promote the economic, social and environmental well-being of their area unless explicitly prohibited elsewhere in legislation. All 22 local authorities have signed the *Welsh Commitment to Address Climate Change* (2006) that commits them to work to adapt to the effects of climate change, and to reduce greenhouse gas emissions.

Statutory development planning in Wales includes local development plans, unitary development plans and local plans. Detailed guidance on planning policy is provided in *Planning Policy Wales* and its updates.

Planning Policy Wales (Edition 4, February 2011) includes the need to take account of climate change in development planning and refers specifically to the adaptation requirements set out in the *Climate Change Strategy for Wales*. To support *Planning Policy Wales*, the Welsh Government has published *Technical Advice Notes (TAN)*, including *TAN 14 Coastal Planning* and *TAN 15 Development and Flood risk* that support adaptation to climate change within flood risk and coastal areas.

Whilst not a statutory document, the *Wales Spatial Plan* (2008 update) provides the context and direction of travel for local development planning. This requires climate change to be taken into account in spatial planning.

In its five-year legislative plan, the Welsh Government has announced its intention to bring forward a Planning Bill that will consolidate existing planning legislation, make it more transparent and help deliver economic renewal. A White Paper is expected towards the end of 2012.

1.6.6 Policy within CCRA sectors

In addition to the overarching documents referred to above, some specific policies and strategies exist within the sectors used in the CCRA. When referencing climate change, these often refer back to the key documents, particularly the *Climate Change Strategy for Wales* and the *Environment Strategy for Wales*.

Agriculture

Welsh agriculture is administered and managed within the overall context of the European Union's Common Agricultural Policy (CAP). The current CAP (2007-2013) primarily supports adaptation through Pillar 2 funding, including agri-environment schemes and targeted capital grants. There is scope to include further adaptation to climate change in the next CAP period from 2014.

Set within the *Rural Development Plan for Wales, 2007-2013*, the Glastir agri-environment scheme is a 5-year, whole farm sustainable land management scheme available to farmers and land managers. It is designed to draw together the Welsh Government's commitment to sustainable agricultural development in the context of climate change and is part-funded by the EU. Expected outcomes include better water management, reduced flood risk, and conserved and enhanced biodiversity. Glastir features a grant for woodland creation, which will improve local resilience to the impacts of climate change.

Land managers are expected to be better informed and trained on climate change impacts and possibilities for adaptation thanks to knowledge transfer, advice and skills development through the Farming Connect programme.

Welsh agriculture is also shaped by other EU directives that influence the manner in which land is managed, such as the Water Framework Directive and Nitrates Directive. Environmental aspects of the agricultural sector are regulated by the Environment Agency. The Countryside Council for Wales is a key stakeholder in this sector.

Biodiversity and Ecosystem services

The *Environment Strategy Action Plan* (2008-2011) sets out the Welsh Government's commitment to halting biodiversity loss and to a definite recovery from the losses that have already occurred. This is further supported by the *Biodiversity Framework*, written by the Wales Biodiversity Partnership.

The Welsh Government is also developing a *Natural Environment Framework – A Living Wales*, which adopts an integrated ecosystems approach to management of the natural environment. Climate change is identified as one of the four reasons for developing the new Framework.

Key partner organisations in the biodiversity sector include the Environment Agency, the Countryside Council for Wales, Forestry Commission Wales and the Joint Nature Conservation Committee (JNCC).

Built environment

With the full devolution of Building Regulations from January 2012, the Welsh Government will be able to set new standards for new buildings. A comprehensive programme to gather the evidence to inform any changes to the legislation and support the construction industry in adopting these new standards is underway. These will apply to both domestic and non-domestic buildings. Improvements to the consideration of energy performance and resilience of the built environment to climate change are anticipated. The Welsh Government is already taking steps to improve energy efficiency and reduce fuel poverty.

The majority of executive functions and secondary legislative powers contained in the Acts relevant to land-use planning are devolved. Various *Technical Advice Notes* (TAN) aid in embedding adaptation into the built environment, including *TAN 12 Design*, *TAN 15 Development and Flood risk* and *TAN 22 Sustainable Buildings*.

The Welsh Government's historic environment service, Cadw, works for an accessible and well-protected historic environment for Wales. The Royal Commission on the

Ancient and Historic Monuments of Wales (RCAHMW) and other organisations such as the National Trust Wales play a vital role in achieving this aim. The Historic Environment Group (including Cadw, RCAHMW and other organisations with an interest in the historic environment) are making progress on an action contained in *The Welsh Historic Environment Strategic Statement: Action Plan* (2010) to 'aid understanding of the impacts of climate change on the historic environment and produce priorities for action to mitigate the consequences of climate change'.

Business, Industry and Services

In *Economic Renewal: a new direction* (2010), the Welsh Government sets out its vision for providing the conditions and framework to enable the private sector to grow and flourish. One of the five priorities outlined within *Economic Renewal* is the need for investment in high-quality and sustainable infrastructure. This priority is also recognised in the *Wales Energy Policy Statement*, *Wales Spatial Plan* and *Wales Transport Strategy*.

A prominent sub-sector in Wales is tourism, which relies heavily on the condition of the environment. Consistent with its central organising principle of sustainable development, the Welsh Government's *Sustainable Tourism Framework* (2007) highlights the need to manage and adapt to climate change as being of critical importance to the future of sustainable tourism in Wales.

A study has been carried out into the impacts of climate change on the Welsh visitor economy (ADAS UK, 2010a) that sets out recommendations for the information and research needed to help the tourist industry to adapt to climate change.

Through the *Climate Change Strategy for Wales*, the Welsh Government is implementing an Adaptation Framework, which is designed to incorporate climate change adaptation into decision-making in the private, public and voluntary sectors. The Climate Change Commission for Wales aims to build a consensus with stakeholders on the issues and actions identified in the Climate Change Strategy. The business community is represented on the Commission by the Confederation of British Industries (Wales) and the Federation of Small Businesses. The *Climate Change Strategy* and the *Climate Change Communications and Engagement Strategy* include commitments to engage with private sector organisations, highlighting the need for businesses to understand and plan for the threats and opportunities arising from a changing climate.

Energy

The Welsh Government is committed to achieving the emissions target set out in the UK Climate Change Act 2008 and, in addition, to the headline commitment of a 3% reduction in greenhouse gas emissions per year in areas of devolved responsibility from 2011.

Actions to achieve this that are relevant to the Energy Sector include reducing energy consumption, improving energy efficiency and maximising renewable and low carbon energy generation. This includes encouraging behaviour change, working with private and public sector partners to enable the development of larger scale renewable energy generation, and supporting transport investment which encourages a shift to low carbon modes of transport. *Technical Advice Note (TAN) 8 Renewable Energy* supports *Planning Policy Wales*.

The Energy Policy Statement, *A Low Carbon Revolution* (2010), emphasises the Welsh Government's determination that Wales should be in the forefront of the global transition to a low carbon economy. The Welsh Government recognises that energy policy is largely non-devolved, however, within the broad framework of UK energy

policy the Welsh Government believes there is considerable scope for greater devolution, especially in relation to consenting individual developments.

Floods and Coastal Erosion

The *Flood and Water Management Act* (2010) sets a new framework for flood and coastal erosion risk management, and the Flood Risk Regulations (2009) cover the requirements of the *EU Floods Directive*.

The Act requires the development of a strategy for flood and coastal erosion risk management. Consultation on the *National Strategy for Flood and Coastal Erosion Risk Management* was undertaken in 2010 and the strategy is due to be published by the Welsh Government in 2011. The need to adapt to climate change is recognised both in the legislation and the consultation document.

Policy on development and flood risk is set out in *TAN 15* (referred to in [Section 1.6.5](#)). This provides a precautionary framework for guiding new development on the flood plain and is supplementary guidance to *Planning Policy Wales*. The guidance aims to direct new development away from those areas which are at high risk of flooding, and requires climate change to be taken into account in planning. Guidance on planning in the coastal zone is covered by *TAN 14*.

Forestry

Wales' forestry strategy, *Woodlands for Wales* (2009), has four strategic themes, one of which is 'Responding to climate change'. This focuses on striking a balance between substitution of more carbon-intensive substances with wood (for example in building construction or as fuel) and carbon sequestration and retention in woodlands, through the creation of new woodlands, conforming to the UK Forestry Standard, and maximisation of existing woodland carbon storage capacity. In March 2010, following recommendation from the Land Use and Climate Change Group, the Welsh Government set a target to create 100,000 hectares of new woodland in Wales by 2030 via the Glastir scheme.

Woodlands for Wales moves Wales towards more mixed and native woodland, and reduces reliance on clearfelling regimes. It acknowledges the challenge of how best to adapt woodlands to climate change, whilst at the same time promoting trees, woodlands and timber as part of the solution to reducing greenhouse gas emissions. It also recognises the challenge in rediscovering expertise in managing mixed woodlands for high quality timber products.

The Welsh Government supports the Size of Wales scheme, which aims to promote the conservation of tropical forest in Africa equivalent to 2 million hectares, and the TACC Wales-Mbale Climate Change Partnership, which helps Ugandan coffee farmers build resilience and adapt to climate change by planting trees.

Health

In *Tackling the health effects of climate change* (2009), climate change is recognised as representing a significant and emerging threat to public health and wellbeing. It identifies two ways in which climate change will have an impact on the Health sector:

- Directly, for example as a result of rising mean temperatures and flooding
- Indirectly, as a result of vector, water and food-borne diseases and air pollution.

It also highlights the wider health issues surrounding social welfare and inequality that result from the effects of climate change and provides adaptation priorities and objectives for action.

The *Heatwave Plan for Wales* (2010) provides a framework for preparing and responding to heatwaves. It aims to protect health and to reduce harm from extreme heat and heatwaves, including advice for relevant bodies and organisations on the protection of vulnerable people.

Marine

The *UK Marine Policy Statement* (MPS) was published in March 2011. It references climate change adaptation and the CCRA.

The Welsh Government is responsible for developing a marine plan or plans for the Welsh inshore and offshore area. A public consultation was completed in May 2011 laying out the Welsh Government's intention to develop a National Plan for the Welsh inshore area and a National Plan for the Welsh offshore area by 2012/13.

The Welsh Government is also responsible for marine nature conservation in Welsh inshore waters. In contributing towards a UK network of marine protected areas, the Welsh Government intends to use the new Marine Conservation Zone (MCZs) designation power provided by the Marine Act to supplement the existing marine protected areas with a small number of highly protected MCZs. These sites are expected to contribute towards enhancing marine ecosystem recovery and resilience.

Transport

The Welsh Government is the highway authority for trunk roads (motorways and some A roads), while the 22 County and County Borough Councils are the highway authority for all other roads. With regard to rail, the Welsh Government shares responsibility for the Wales and Borders franchise with the Secretary of State for Transport, and is able to develop and fund rail infrastructure enhancement schemes and new rail passenger services.

The Transport (Wales) Act 2006 required the Welsh Government to publish a strategy, setting out policies for the "safe, integrated, sustainable, efficient and economic transport facilities to, from and within Wales". The objectives of the *Wales Transport Strategy* (WTS) (2008) are delivered at a national level through the *National Transport Plan* (NTP) (2010), and at a regional level through the Regional Transport Plans prepared by the Regional Transport Consortia. A transport system that is adapting to the impacts of climate change is a key long-term outcome of the WTS.

Water

The *EU Water Framework Directive* (WFD) covers management of the water environment, and it is intended that the WFD document *River Basin Management in a changing climate – a guidance document* (2009) will support the incorporation of climate change into the next river basin management cycles.

The effects of climate change in water supply and demand are taken into account in water company Water Resource Management Plans (WRMPs). These are produced by all water companies in the UK. The WRMPs look ahead 25 years and show how the water companies intend to secure a sustainable balance between supply and demand for water, while taking into account the impacts of climate change.

The *Climate Change Act* gives Welsh Ministers the same powers with regard to adaptation reports concerning devolved functions that the UK Government has regarding non-devolved functions. The Welsh Government has identified Dŵr Cymru and Dee Valley Water as being crucial to Wales' preparedness for climate change. Although Welsh Ministers are not issuing directions in the first instance, both companies have produced adaptation reports voluntarily, alongside their counterparts in England.

The *Strategic Policy Position Statement on Water* (2011) sets out the Welsh Government's position on aspects of water policy in response to future pressures and challenges including a range of measures which will help address the impacts of climate change on the availability of water. It confirms the Welsh Government's commitment to managing water resources in a sustainable way.

The Environment Agency (EA) *Water Resources Strategy for Wales* (2009) sets out the EA's view on how water resources should be managed over the coming decades. The EA's *Water Resource Action Plan for Wales* (2010) contains the actions the EA will take forward to deliver the aims and objectives of the Strategy. These documents support policies outlined in the *Strategic Policy Position Statement on Water*, which stresses the importance of building resilience in water management capacity in light of potential disruption to supplies resulting from climate change.

2 Climate variability and change in Wales

2.1 Current climate

Wales has an essentially maritime climate, often with cloudy, wet and windy but mild weather. However, the mountainous landscape and shape of the coastline mean that localised differences in weather conditions occur, with more favourable conditions experienced along the coast and in more sheltered locations in eastern parts of the country and harsher weather experienced in some upland areas.

Some of the main characteristics of Wales' climate and how these compare with other parts of the UK are summarised below:

- **Mean annual temperatures** – At low altitudes these vary from around 9.5°C to 10.5°C. As with other parts of the UK, they decrease by approximately 0.5°C for each 100 m increase in height. Mean annual temperatures for the UK as a whole vary between 7°C in the Shetlands and 11°C in Cornwall and the Channel Islands.
- **Maximum temperatures** – The warmest month in Wales is usually July, with mean daily maximum temperatures ranging from approximately 17°C in higher inland areas to 21°C in the east of Powys and Monmouthshire. In the UK, the highest mean daily maxima for July is in the London area at 22.5°C and the lowest is in the Shetlands at 15°C. In Wales the highest recorded temperature was 35.2°C which was recorded in Flintshire in 1990. Maxima at the coast can sometimes equal those inland, with 31.8°C recorded in Ceredigion in 1995.
- **Minimum temperatures** – The coldest month varies with location in Wales. February is usually the coldest month along the coasts due to the influence of surrounding sea surface temperatures which are lowest in February/March. Inland, January or February is usually the coldest month. Mean daily minimum temperatures in January vary between just under 0°C in upland areas in north and mid-Wales to around 3°C on the coast, with the highest values in Pembrokeshire. These temperatures are generally similar to North West England. The lowest recorded temperature in Wales was -23.3°C, set at Rhayader (Powys) in January 1940.
- **Frost** – The average number of days of frost varies with location in Wales, with altitude and distance from the sea being the main controlling factors. While locations along the west coast have fewer than 25 days of air frost a year, there can be between 45 and 100 days inland. Ground frosts in Wales occur on average from around 40 days each year along the coast to more than 110 days inland. Northern Ireland experiences similar ranges to this, while in Scotland ranges are wider.
- **Precipitation** – This is strongly affected by altitude with central upland areas experiencing the greatest average annual totals. These range from more than 3000 mm in the wettest part of Wales, Snowdonia (similar to the western Highlands of Scotland or the English Lake District), to less than 1000mm close to the border with England and along the coast. The

months of October to January are significantly wetter than February to September, with about 45% of annual rainfall falling in these four months.

- **Snowfall** – Snow is much more frequent in upland areas than near sea level. The average number of days with snow falling each year in Wales ranges from 10 or less in south-western coastal locations to more than 40 in Snowdonia. The average number of days with snow lying also varies, with five or less days each year in coastal areas and more than 30 days a year in Snowdonia. These values are comparable to coastal areas in South West England which have on average less than three days of snow lying a year, and parts of the Scottish Highlands where there are around 60 days with snow lying on average.
- **Wind** – Wales is one of the windiest parts of the UK (western and northern parts of Northern Scotland are on average the windiest). In Wales, the windiest areas are over the highest ground and on the coasts, with south-west Pembrokeshire experiencing around 30 days of gales a year on average.
- **Sunshine** – The amount of cloud cover in Wales varies widely with location, which is influenced by both topography and proximity to the Atlantic. Average annual sunshine totals are highest on the south-western coastal strip of Pembrokeshire at over 1700 hours, which compares favourably to many locations along the south coast of England which get 1750 hours. The mountainous areas are the duller parts of Wales with annual averages of less than 1200 hours of sunshine. This is broadly similar to the Shetland Islands which have an annual average of less than 1100 hours.

More detailed information on Wales' current climate can be found on the Met Office website¹.

2.2 Recent climate trends

The following is mainly a summary of the climate trends as indicated in Jenkins *et al.* (2009).

- **Mean annual temperature** – There has been a fairly steady warming trend since the early 1900s. Decadal variations in mean annual temperature between 1914 and 2006 fluctuated from approximately 8.5°C to 9.6°C.
- **Mean annual minimum temperature** – Mean annual minimum temperatures follow the same trend as mean annual temperature, fluctuating slightly but increasing steadily. Decadal variations between 1914 and 2006 ranged from approximately 5.2°C to 6.2°C.
- **Mean annual maximum temperature** – Mean annual maximum temperatures also follow the same trend, increasing steadily. Decadal variations between 1914 and 2006 fluctuated from just below 12°C to approximately 13.1°C.
- **Annual precipitation** – There is no long-term observed trend in annual precipitation since the records began in 1766.

¹ <http://www.metoffice.gov.uk/climate/uk/wl/>

- **Winter precipitation** – Although there is large year-to-year variability, an increasing trend can be observed. Over the past 50 years however there has been little change.
- **Summer precipitation** – Despite large year-to-year variability, there is a general trend of decreasing precipitation in summer since records began.
- **Extreme precipitation** – Analysis by Osborn *et al.* (2000) indicates that daily precipitation has become more intense during the winter and less intense during the summer. Autumn precipitation intensities were also shown to be increasing slightly in intensity while in spring they were decreasing slightly (Farrar and Vaze, 2000). Jenkins *et al.* (2009) show that from 1961-2006 there has been an increase in the contribution from heavy precipitation events to winter rainfall, while there has been a decrease in the contribution to summer rainfall.
- **Sea-level** - There is clear evidence from the tide gauges and more recently satellite data that eustatic² sea levels have risen considerably since the start of the 20th century. Over the last 100 years, this has averaged out at about 1-2 mm/year (IPCC, 2007), although this rate has increased significantly over the last 20-30 years. Currently it is estimated that they are rising at a rate of approximately 3 mm/year (Jenkins *et al.*, 2009). However, as a result of isostatic rebound this rate is not consistent across Wales. Although the north Wales coastline shows little movement, Cardigan Bay is sinking by about 0.4 mm/year. In addition, the south Wales coastline is sinking by approximately 0.5 mm/year around St. Brides Bay to about 0.8 mm/year around Newport. This means that around Newport, for example, relative sea levels are currently increasing by about 4mm/year.

2.3 Projected climate changes

2.3.1 Introduction

The CCRA analysis of climate change impacts is presented in eleven sector reports (covering: agriculture; biodiversity and ecosystem services; built environment; business, industry and services; energy; floods and coastal erosion; forestry; health; marine and fisheries; transport; water. See [References](#)).

The analysis provides projections of the effects of climate on a range of risk metrics (for example, flood risk) based on the climate projections presented in UKCP09³. The following UKCP09 variables were used in the analysis:

- Change in mean summer, winter and annual temperature, and mean annual maximum temperature (°C).
- Change in mean summer, winter and annual precipitation (%).

For all variables, projections for three thirty year time periods were considered: 2020s, 2050s and 2080s. The thirty year periods are referred to by their central decade, therefore the 2020s represents the period 2010 to 2039.

² Rise in sea levels independent of local factors such as local land movements.

³ <http://ukclimateprojections-ui.defra.gov.uk>

Future UKCP09 projections are available for three emissions scenarios: Low, Medium and High (which correspond to the IPCC B1, A1B and A1FI emission scenarios). In the 2020s only the Medium scenario is used since the projections are relatively insensitive to the choice of emissions scenario (due to the inertia of the climate system), but in the 2050s and 2080s projections from all three scenarios are analysed.

As the projections are probabilistic it is important to explore a range of probability in order to identify the range of potential impacts that could occur. To do this the 10%, 50% and 90 probability levels of the projections are used (labelled p10, p50 and p90 respectively) to provide a range of possible future projections. p50 represents the median value, p10 is at the low end of the range of projections and p90 is at the high end of the range. Taking into consideration all of these possible choices of projections, the following thirteen selected climate scenarios are applied:

- 2020s: p10 Medium, p50 Medium, p90 Medium
- 2050s: p10 Low, p50 Low, p50 Medium, p50 High, p90 High
- 2080s: p10 Low, p50 Low, p50 Medium, p50 High, p90 High.

The results in the assessment generally refer to the p50 Medium Emissions scenario where a single value is given, or the p10 Medium or Low to the p90 Medium or High Emissions scenarios where a range is given.

The main climate change effects are summarised in this section. In addition to temperature and precipitation change, projections of rise in sea level are also included together with discussion of other climate variables. The colours in the tables reflect the increasing magnitude of change (yellow/orange/red for hotter/drier; shades of blue for increases in rainfall and sea level).

In some cases socio-economic change (particularly change in population and residential property numbers) has been included in the projections. The socio-economic scenarios are based on Office of National Statistics projections as shown in the following table.

Socio-economic projections: changes compared with the baseline

	Scenario:	Low projection			'Principal' projection			High projection		
	Baseline	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
People (thousands)	2990	99	-75	-431	256	518	717	418	1155	2047
Residential Property (thousands)	1250	41	-31	-180	107	216	299	174	481	853

The climate change projections provide information on long term future changes in the climate. The outputs, as they are presented as 30-year averages, do not provide projections of climate variability at shorter time scales (e.g. seasonal, annual and decadal). When examined at shorter time scales, the observed changes may differ (larger or smaller) than those suggested by the 30-year averages due to these shorter-term variabilities.

The information presented in this section is a summary of the much more detailed projections given in UKCP09, an example of which is shown in Figure 2.1.

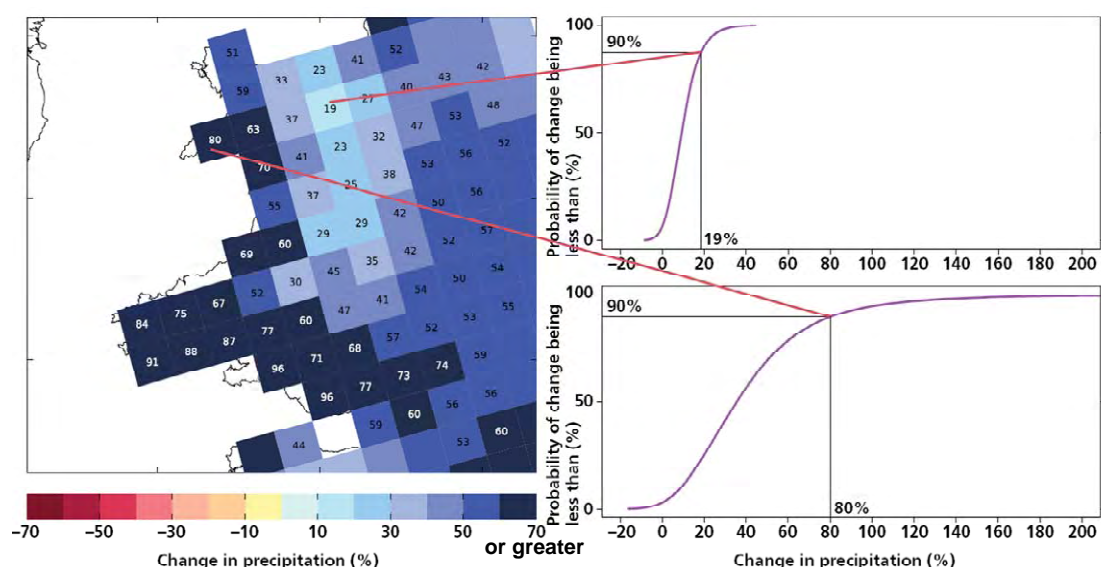


Figure 2.1 UKCP09 Precipitation changes for Wales - 2080s High emissions 90% probability level

(Source:UKCP09)

2.3.2 Projected changes in temperature

Projections for mean temperature change (annual and seasonal) are given in the following tables, which are changes relative to the 1961-1990 baseline.

Temperature change: Mean annual temperature rise (°C)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	P90	p10	p50	p90	p10	p50	p90
Low				1.2	2.0	3.0	1.6	2.6	3.9
Medium	0.7	1.3	2.0	1.4	2.3	3.5	2.1	3.3	4.9
High				1.6	2.6	3.8	2.6	4.1	6.0

Temperature change: Mean Winter (DJF) temperature rise (°C)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				0.8	1.8	2.8	1.3	2.4	3.7
Medium	0.6	1.3	2.0	1.1	2.0	3.2	1.5	2.8	4.3
High				1.2	2.2	3.4	1.9	3.4	5.1

Temperature change: Mean Summer (JJA) temperature rise (°C)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				1.0	2.2	3.7	1.2	2.6	4.5
Medium	0.5	1.4	2.4	1.2	2.5	4.1	1.9	3.6	5.8
High				1.3	2.8	4.6	2.4	4.5	7.1

Temperature change: Max annual temperature rise (°C)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				1.1	2.4	3.9	1.4	3.0	5.0
Medium	0.7	1.6	2.6	1.3	2.7	4.5	1.8	3.8	6.3
High				1.6	3.1	4.8	2.5	4.8	7.6

2.3.3 Projected changes in precipitation

Projections for mean precipitation change (annual and seasonal) are given in the following tables, which are changes (percentage) relative to the 1961-1990 baseline.

Precipitation change: Mean annual change (%)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				-6	-1	5	-5	0	7
Medium	-4	0	4	-5	0	5	-6	0	7
High				-6	0	6	-8	0	10

Precipitation change: Mean Winter (DJF) change (%)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				-2	9	23	4	16	34
Medium	-2	7	16	2	14	31	3	19	43
High				1	13	31	6	26	58

Precipitation change: Mean Summer (JJA) change (%)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				-32	-12	14	-35	-13	11
Medium	-22	-6	11	-36	-17	6	-44	-20	6
High				-39	-17	7	-52	-26	5

Projections for changes in the amount of snow by the 2080s (Medium emission scenario) are as follows:

- Number of snow days projected to reduce.
- The largest reductions (typically >70%) are projected to occur in **spring** and **autumn**, with 40–70% reductions in **winter**.
- The general pattern of heavy snow events shows large reductions but with a high degree of uncertainty in the climate modelling.

2.3.4 Projected relative sea level rise

Relative sea level rise is the rise in sea level compared with the land level. The rise in sea levels varies around the coastline. This variation is taken into account in the CCRA analysis. Sea level rise projections at one location (Cardigan) are presented below. The projections for sea level rise are based on a 2008 baseline. The projected range of relative sea level rise around the Welsh coast is about +/-20mm by the 2050s and +/-30mm by the 2080s compared with the values at Cardigan.

Relative sea level rise (m, based on Cardigan)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				0.096	0.156		0.163	0.269	
Medium	0.044	0.075	0.106		0.186			0.322	
High					0.223	0.323		0.387	0.563

2.3.5 Wind and storminess

There is a perception that wind and storminess will increase as a result of climate change. However the probabilistic projections of future changes in surface wind speed provided in UKCP09 indicate that there is likely to be little change in the frequency or intensity of wind storms.

The most recent guidance from the Met Office (Met Office, 2010) states that by the 2050s:

- Projected changes in summer wind speed covers both positive and negative changes but is generally skewed towards negative changes in the UK, except for slightly positive changes in Scotland. This is consistent with the poleward shift of the storm track in summer.
- Projected changes in winter wind speed are approximately symmetrical around near-zero change.
- The largest uncertainty ranges are over Scotland.

On this basis, it has been assumed for the CCRA that there is not likely to be an increase in average or extreme wind speeds in Wales.

However, this guidance was produced as a result of additional work undertaken subsequent to the main UKCP09 projections. The results (as for all UKCP09 products) are subject to the caveat that the current generation of climate models used to produce them could be missing a key process liable to change the projections. The next set of climate model projections being generated around the world for the IPCC Fifth Assessment Report should improve representation of the effects of the stratosphere on surface climate and assessment of these models will enable modellers to reassess the current results for surface wind speeds (Sexton and Murphy 2010).

It is also assumed that there will not be an increase in deep water wave heights based on current knowledge. Wave heights near the coast may however increase as a result of sea level rise (and therefore deeper water adjacent to coastal structures).

2.3.6 Sunlight and UV exposure

Changes in exposure to UV radiation depend on the amount of radiation that will reach the surface of the earth in the future. This is largely determined by the amount absorbed by the stratospheric ozone layer. It is also affected by levels of cloud cover and temperature changes.

Levels of cloud cover are anticipated to show noticeable changes over the current century. Based on UKCP09 projections for the summer, there could be a reduction in cloud cover of between 10% and 20% in the south of the UK (including Wales) by the 2080s.

Increases in UV radiation are, therefore, projected in the future, although the magnitude of increase is uncertain.

2.3.7 Extreme weather events

Extreme weather events are already a characteristic of the present day climate in Wales and dominate current climate risks. They will continue to occur in the future, independent of climate change, due to the natural variability of the climate. At present, the influence of these natural variations is far greater than the effect of longer term warming and Wales would continue to experience cold as well as heat extremes even under warmer conditions.

Extreme weather events (including heat waves, cold periods and intense rainfall events) are represented using the UKCP09 projections, for example:

- Extreme temperature events are represented in the CCRA analysis by adding the temperature changes in [Section 2.3.2](#) to current extreme temperature data. One way in which the results have been used is to

estimate the number of days that certain threshold temperatures are exceeded.

- Extreme river flood events are represented by using the precipitation data in [Section 2.3.3](#) to predict increases in high river flows. These higher river flows are then used to estimate projected increases in river flooding.
- Extreme tidal flood events are represented by adding the sea level rises in [Section 2.3.4](#) to current extreme sea level predictions obtained from the analysis of historic sea level data. These higher sea levels are then used to estimate projected increases in tidal flooding.

On this basis it is projected that extreme cold weather events are likely to become less frequent. Even so, the cold and snowy weather experienced across the UK between 2009 and 2011 is part of normal climate variability and similar events could still be experienced in the future.

There is also a concern that extremes may become more extreme (i.e. variations from mean values becoming greater, both positive and negative). However, whilst research into the impacts of climate change on extreme events is ongoing, projections that are suitable for application in the CCRA are not yet available.

3 Impacts on bio-physical systems

3.1 Introduction

In order to assess the consequences of climate change, it is first necessary to consider how climate change may affect bio-physical systems, for example the water cycle and soil systems. Some of the main potential impacts of climate change on bio-physical systems are summarised below.

1. Reduction in summer rainfall and higher summer temperatures, leading to:
 - a. Lower runoff and low river flows in summer
 - b. Increase in aridity in summer leading to drying of soils and reduced moisture availability
 - c. Reduction in water availability
 - d. Increase in frequency and severity of summer droughts
 - e. Changes to vegetation and species
 - f. Changes to the landscape
2. Increase in winter rainfall (and intense summer storms), leading to:
 - a. Higher runoff and higher river flows in winter
 - b. Increase in wetness in winter leading to increased water logging
 - c. Increase in flooding in winter and from summer storms in summer
 - d. Increase in erosion of soils and sediment movement in rivers
3. Sea level rise, leading to:
 - a. Loss of beaches and coastal features
 - b. Increase in tidal flooding
 - c. Increase in coastal erosion
4. Combined effects of all climate drivers, leading to:
 - a. Changes to vegetation and species
 - b. Changes to the landscape
 - c. Changes to the built environment and society.

3.2 Drivers of change

Drivers of change include the climate effects referred to in [Section 2](#) and direct impacts on bio-physical systems. Estimates are presented in this section of the potential magnitude of the direct impacts on bio-physical systems, based on UKCP09 projections and results from the CCRA analysis.

The consequences of these bio-physical impacts for the natural environment, agriculture and forestry, business, buildings and infrastructure, and human health and wellbeing are discussed in [Section 4](#).

3.2.1 Lower runoff and low river flows in summer

Summer rainfall is projected to reduce by an average of about 17% by the 2050s compared with the baseline for the p50 Medium Emissions scenario (see [Section 2.3.3](#)). This would result in lower river flows and less available moisture.

Low flows in watercourses are projected to become lower in warmer drier summers. It is projected that Q95 flows⁴ for rivers could reduce by between 5 and 40% by the 2050s, and between 10 and 50% by the 2080s (Figure 3.1) compared with the 1961-90 baseline.

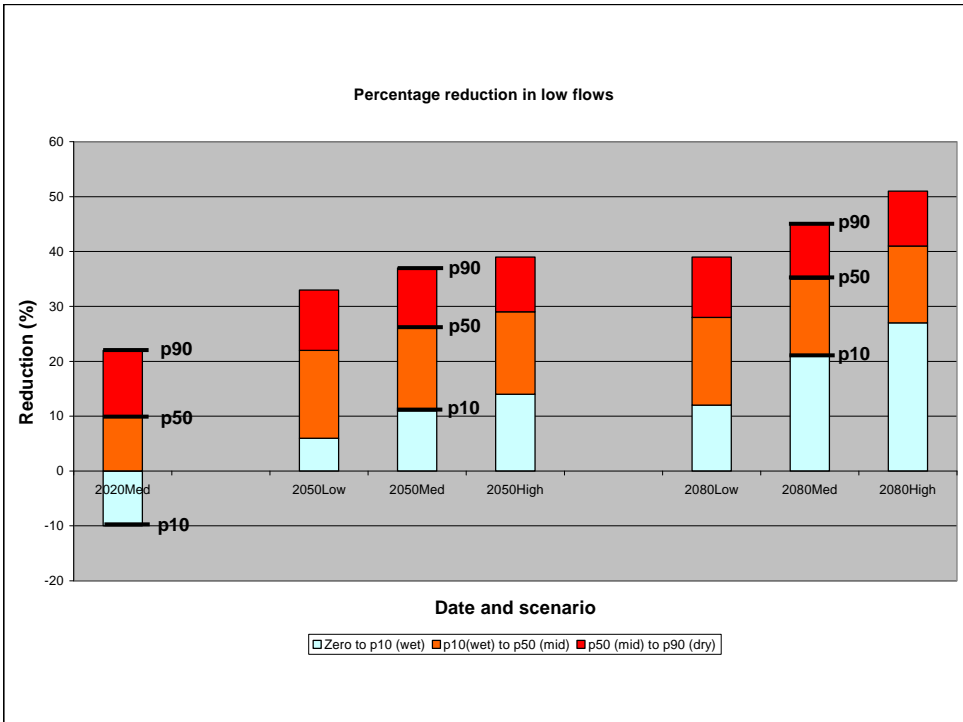


Figure 3.1 Projected reductions in low flows (from 1961-90 baseline)

3.2.2 Increase in aridity in summer

Increases in aridity in the summer would cause drying of soils and reduced moisture availability, with consequences for the natural environment, agriculture, forestry and water use. The projected change in relative aridity is shown in Figure 3.2. Relative aridity is an indicator of dryness based on temperature and rainfall. It is projected to increase from a current average value of about 0.5 to nearly 2.0 by the 2050s under the p50 Medium Emissions scenario.

⁴ The flow exceeded for 95% of the time.

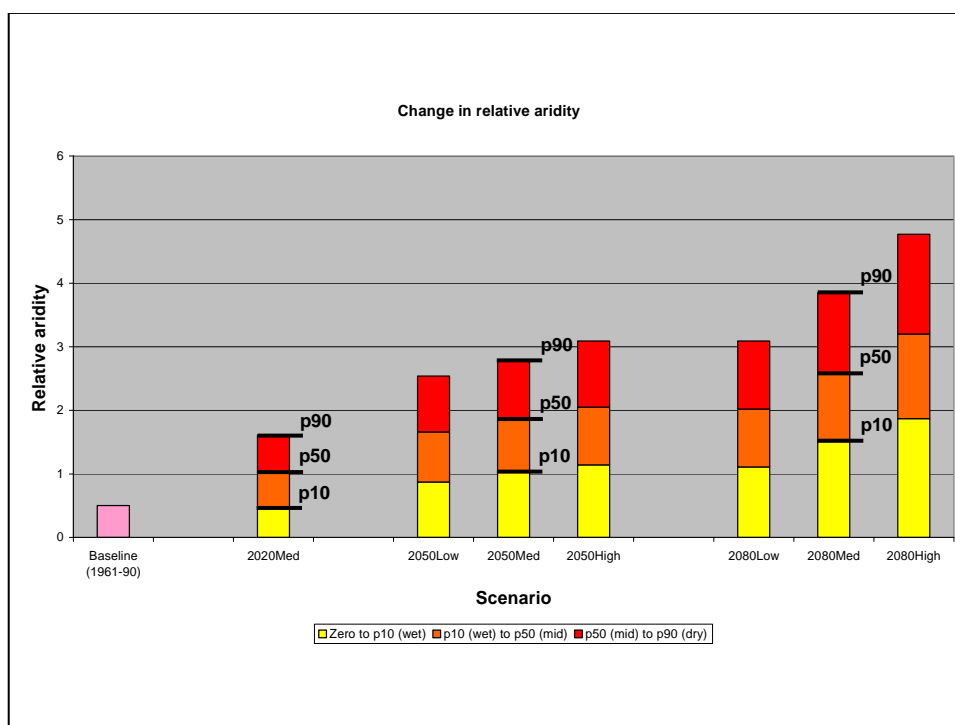


Figure 3.2 Projected changes in relative aridity

3.2.3 Increase in frequency and severity of summer droughts

Detailed projections for the frequency and severity of summer droughts have not been made in the CCRA. However an initial assessment of the potential increase in drought conditions can be made based on changes in relative aridity.

The relative aridity projections indicate that the average relative aridity may increase to between 0.5 and 1.5 by the 2020s, between 1 and 3 by the 2050s and between 1 and 5 by the 2080s. Whilst values of 0.5 to 1.5 lie within the present range of normal climate variability, the projected values for the 2050s and 2080s represent extreme conditions compared with present day. For example, the figures indicate that an average year in the 2050s might be similar to the dry summer of 2003, and that an average year in the 2080s might be similar to the major drought year of 1921.

The projections for a p90 High emissions scenario in the 2080s is an average relative aridity of about 4.7 in England and Wales (compared with a 1921 value of 2.59). This indicates that future major droughts could be very severe events, far more so than droughts experienced to date.

3.2.4 Reduction in water availability

Despite having considerable precipitation, supply-demand deficits already occur in parts of Wales during dry summers. The availability of water in the summer is projected to reduce as a result of rising temperatures and less precipitation.

Whilst little change is projected in overall annual precipitation, changes in seasonal precipitation combined with increased temperatures and changes in demand mean that the overall availability of water is projected to reduce. Wales currently exports water to England, which means that changes in water availability in Wales would affect both Wales and England.

Estimates of potential changes in water availability based on Deployable Output (the amount of water that can be pumped from a water company's sources, constrained by licence, hydrology or hydrogeological factors and works capacity), supply demand deficits and population affected by shortage of supply are summarised below (Rance *et al.*, 2011). The figures are based on the three River Basin Districts covering Wales (Dee, Western Wales and part of the Severn).

- Deployable outputs are projected to change from a surplus of about 160 Megalitres per day (MI/day) to a deficit of about 600MI/day by the 2080s if adaptation measures are not implemented.
- About 90% of the population could potentially be affected by supply-demand deficits by the 2080s if adaptation measures are not implemented.

In addition the number of sites with sustainable water abstractions is projected to reduce by about 55% by the 2050s from a 1961-90 baseline.

3.2.5 Higher runoff and higher river flows in winter

Whilst annual rainfall is not projected to change significantly in the future, winter rainfall is projected to increase, by an average of about 14% by the 2050s compared with the baseline for the p50 Medium Emissions scenario (see [Section 2.3.3](#)). This may lead to higher river flows and increased flooding from rivers and surface water.

Projected increases in river flows are shown in Figure 3.3 compared with the 1961-90 baseline. Note that the increase is zero for the Low projection in the 2050s.

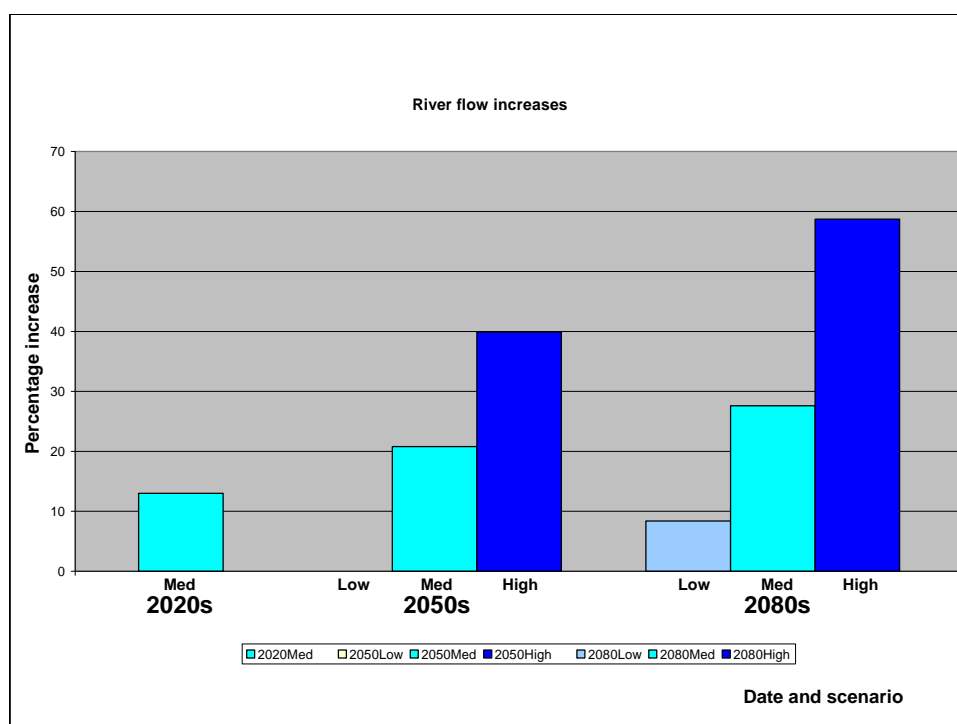


Figure 3.3 Projected changes in river flood flows (from 1961-90 baseline)

3.2.6 Increase in flooding from rainfall

Changes in rainfall quantity and intensity are likely to cause an increase in flooding, both from rivers and surface water. The projected increase in frequency of the present

day '1% flood' from rivers is shown on Figure 3.4. This is the flood with an annual probability of occurrence of 1% (sometimes referred to as the '1 in 100-year flood'). This shows that the chance of occurrence of the estimated 1% flood based on the 1961-90 baseline may be about 2% per annum by the 2020s and 4% per annum by the 2080s for a Medium Emissions scenario. The range of increase by the 2080s is between 2 and 10 times for the five selected scenarios described in [Section 2.3.1](#).

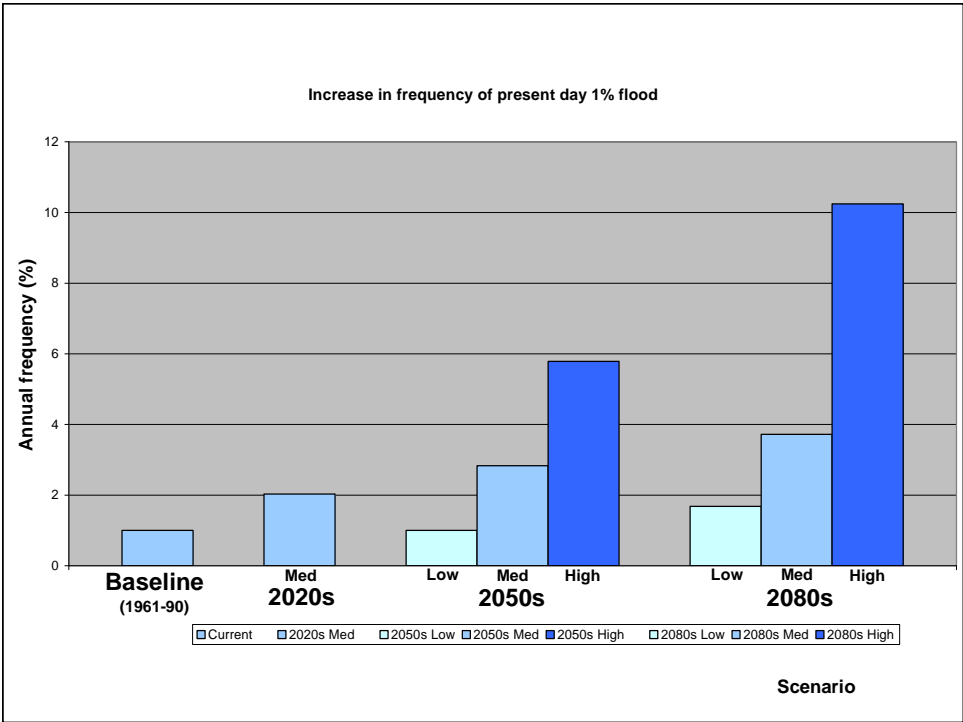


Figure 3.4 **Projected increase in flood frequency: river floods**

3.2.7 Increase in tidal flooding

The projected increases in sea level mean that the annual probability of occurrence of present day high sea levels is likely to increase. For example, the tidal water level with an estimated present day annual probability of occurrence of 1% (1 in 100 years) is projected to have an annual probability of occurrence of 7% (1 in 14 years) by the 2080s.

Figure 3.5 shows projected changes in the frequency of extreme tidal water levels compared with the 2008 baseline for the p50 Medium Emissions scenario at Cardigan. The y-axis is annual probability, which has no units (i.e. 0.02 means a 2% annual probability).

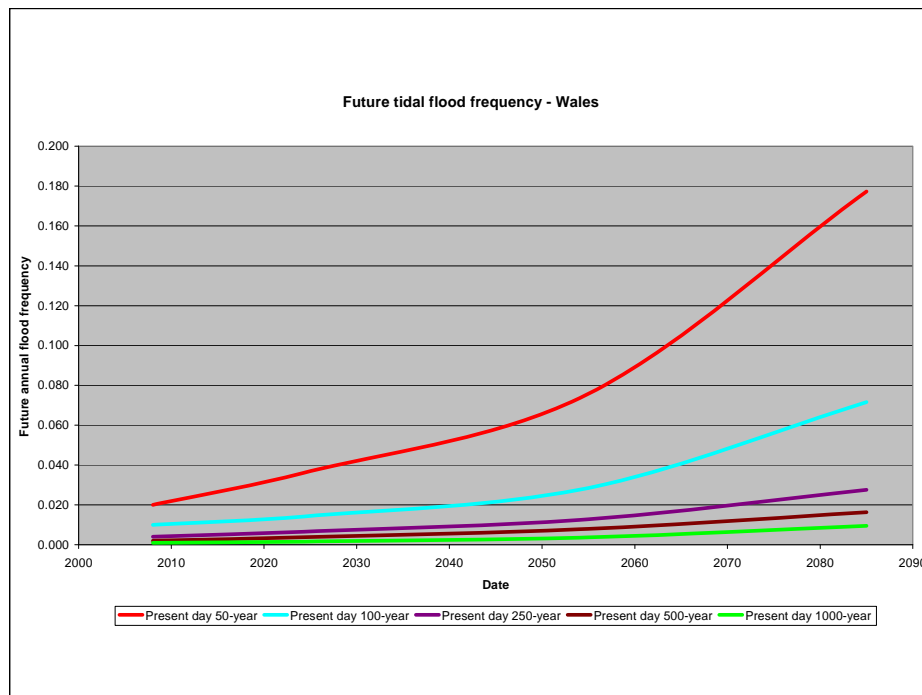


Figure 3.5 Projected increase in flood frequency: tidal floods

3.2.8 Approach to flood analysis

The flood analysis was based on national flood modelling for Wales undertaken by the Environment Agency (Environment Agency 2009).

The modelling and other analysis are high level and provide indicative projections that are appropriate for a national risk assessment. The results should not be used for re-analysis or interpretation at a regional, local or site-specific scale.

It was assumed for the analysis that the existing fixed flood defences are maintained in their present condition over the long term for tidal and river flooding. Crest levels of the defences remain unchanged from present day. Flood control gates are assumed to operate under present day rules. Because the flood defences do not change, the results of the analysis reflect the impacts of climate change effects only (i.e. increases in river flows and sea level).

This baseline does not, however, take account of current measures to reduce flood risk or the ongoing deterioration of defences. Flood risk reduction and climate change adaptation measures will, if/when implemented, reduce the level of risk. Deterioration of defences would lead to an increase in flood risk if maintenance and repairs are not carried out.

The baseline dates are 2008 for tidal flooding and 1961-90 for river flooding. Further details of the baseline, analysis approach and the assumptions made are given in the Floods and Coastal Erosion Sector Report (Ramsbottom *et al.*, 2011).

3.2.9 Coastal erosion

The coast is subject to both erosion and accretion. It is estimated that about 23% of the Welsh coastline is eroding (346km of a total of 1,498km). The combination of sea

level rise and erosion is likely to reduce the area of beaches and affect other coastal features. It has been assumed in the CCRA analysis that urban areas will continue to be protected against sea level rise and coastal erosion. This is likely to require significant future investment and, in some cases, may not be sustainable.

3.2.10 CO₂ levels

The balance between carbon in the atmosphere and in storage (in soils and the oceans) may have significant impacts both on the consequences of climate change and the mechanisms that are causing it. For example, more carbon dioxide in the atmosphere would lead to an increase in plant productivity (affecting agriculture and forestry) but would also contribute to increases in global temperatures and acidification of the oceans.

Whilst no quantified estimates have been made in this report on the climate change impacts of CO₂ levels in the atmosphere and in storage, this is recognised as an important issue with potentially significant consequences for primary productivity.

3.3 How Wales may change

A summary of the way in which projected changes to the climate would impact on Wales is summarised in this section. The impacts are considered in more detail in [Section 4](#) based on the findings of the CCRA analysis.

The analysis includes not only climate change but also socio-economic change. Three scenarios have been used for increases in population and property numbers (Low, 'Principal' and High, see [Section 2.3.1](#)). Changes by the 2050s are projected to be in the range of -3% to +40% for the scenarios considered (2.9 million to 4.1 million people compared with a baseline of 3 million, and 1.2 million to 1.7 million residential properties compared with a baseline of 1.25 million).

3.3.1 Changes to vegetation and species

Warmer and drier summers would affect both natural biodiversity and human interventions including agriculture and forestry. Wetter winters would result in wetter soils and increased waterlogging. This would affect biodiversity, agriculture and forestry.

Marine species are likely to be affected by increases in water temperature and other consequences of climate change, for example increased acidification of seawater.

These impacts are discussed in Sections 4.2 (The Natural Environment) and 4.3 (Agriculture and Forestry).

3.3.2 Changes to the landscape

The landscape may change significantly if summers become warmer and drier. The landscape may become more arid and drought resistant species are more likely to prevail. Soil erosion may increase as soils dry out in the summer and are then eroded by increasingly intense summer and winter rainfall.

Impacts on the landscape have not specifically been addressed in the CCRA although inferences on the likely effects can be made from the analysis and discussion

presented in [Section 4](#), particularly Sections [4.2](#) (The Natural Environment) and [4.3](#) (Agriculture and Forestry).

3.3.3 Loss of beaches and coastal features

Sea level rise is likely to cause changes to the shoreline including a loss of beach and intertidal area. Coastal erosion may increase as a result of sea level rise, causing an increasing loss of coastal land including intertidal habitats. These impacts are discussed in [Section 4](#), particularly Sections [4.2](#) (The Natural Environment) and [4.4](#) (Business).

3.3.4 Changes to the built environment and society

Changes to the physical built environment as a result of climate change may include adaptation actions to mitigate adverse consequences and take advantage of the opportunities presented, for example, by warmer summers.

However the direct impacts of climate change on society are projected to include increases in heat waves, droughts and floods. The consequences of these impacts would be wide ranging and include health effects on people, damage to business and disruption to society.

These impacts are discussed in Sections [4.4](#) (Business), [4.5](#) (Buildings and Infrastructure) and [4.6](#) (Health and Well-being).

4 Risk assessment

4.1 Summary of approach

The approach to risk analysis is described in the CCRA Method Reports (Defra, 2010a and 2010b). The method has been applied to the Tier 2 impacts referred to in [Section 1.4](#). The results of the CCRA analysis are described in the eleven UK Sector Reports (see [References](#)). The CCRA Evidence Report provides an overview of the analysis (CCRA, 2012a).

The impacts of climate change have been assessed for each of the threats and opportunities on the Wales Tier 2 list based on the results of the CCRA analysis. The Tier 2 list grouped by sector is contained in [Appendix A.1](#). A summary of the assessment of the individual impacts is presented in [Appendix B](#).

The following sections discuss the consequences of climate change under the following themes:

- The Natural Environment
- Agriculture and Forestry
- Business
- Buildings and Infrastructure
- Health and Well-being.

[Appendix A.2](#) includes a list of impacts by theme in the order in which they are discussed in this report. The sector impacts have all been allocated to one or more themes. For example, there is no specific theme for 'water', but water sector impacts appear in all of the themes.

Risk metric numbers (e.g. BD1) are also listed. Risk metrics are measures of the consequences of climate change. Where metrics have not been developed or analysed, impacts have been given a number for reference purposes (e.g. BDr1, etc).

At the end of each theme there is a summary figure similar to the one shown below.

The figure presents the estimated scale of the consequences for Wales (both threats and opportunities) of each impact ranging from low to high. By presenting these for the three time slices of the 2020s, 2050s and 2080s, this gives an indication of how the risk may change over time.

Where the magnitude of the consequences has been quantified, the scaling is based on the p50 Medium Emissions scenario for the 2020s, 2050s and 2080s which is referred to as the 'central estimate'. These impacts are identified by a Q for quantified. The majority of impacts, however, have had to be assessed using informed judgement and these are identified by an IJ.

Some impacts are too difficult to assess at the present time, either because the science is not sufficiently well advanced yet to understand the scale of the consequences or the inherent uncertainty is too great. In addition, some impacts were identified on the Tier 2 list for Wales but not assessed. These are included in the figure for completeness, but have a grey bar.

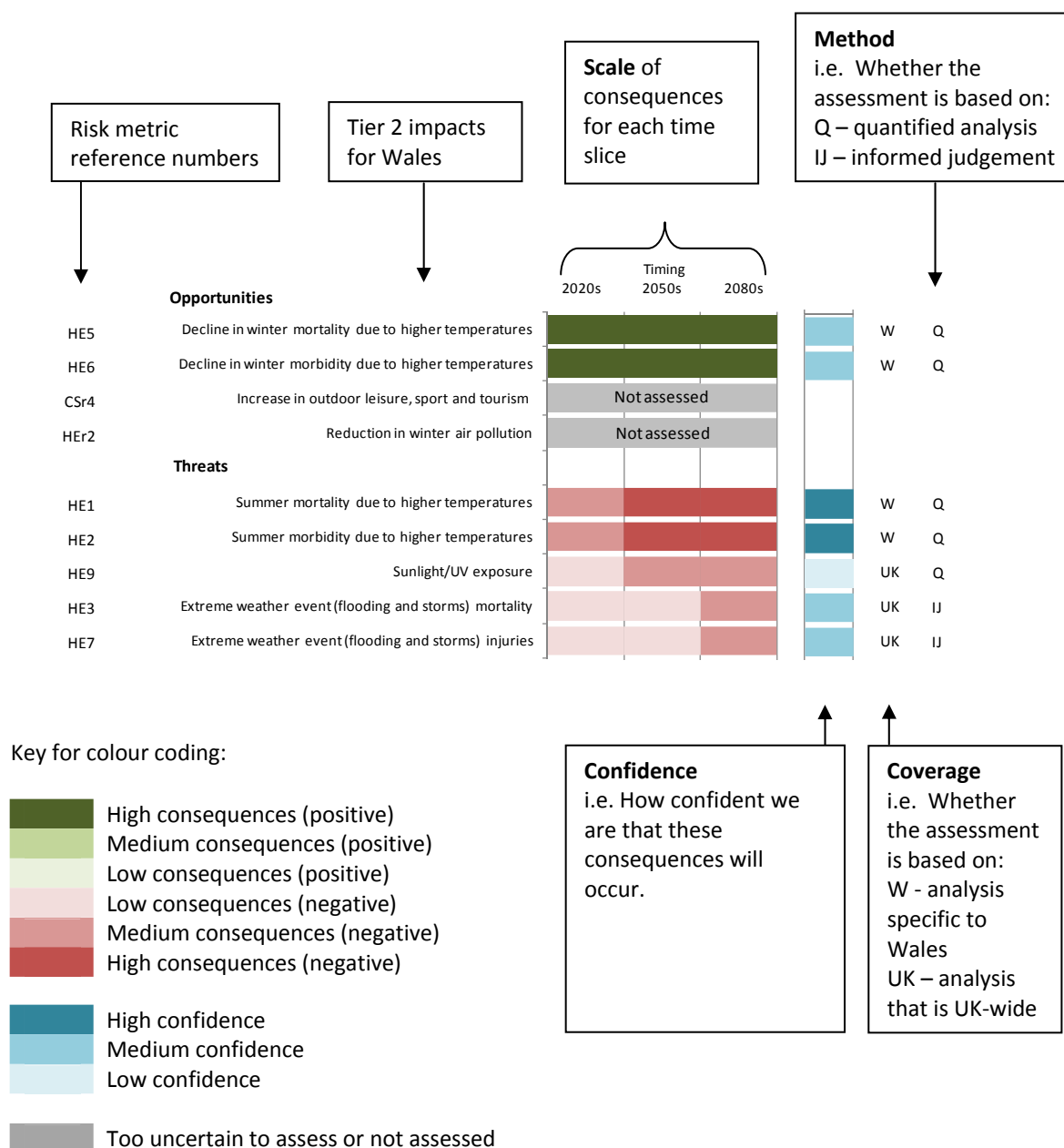
As discussed earlier, this assessment for Wales is based on the UK-wide analysis undertaken for the CCRA. As part of this analysis, some impacts were assessed at the

Wales scale but others were assessed at the UK scale. These are identified by 'W' and 'UK' respectively in the coverage column.

It is important to stress that all projections presented in these figures are simply best estimates based on current understanding and some impacts are understood better than others. Therefore, there is a further column provided that gives an indication of how much confidence there is in whether the consequences will actually occur, ranging from low to high.

Consequences can be considered as high, medium or low depending on four different criteria, as listed below. The cost per year has been estimated based on a monetisation exercise, which is described in [Appendix C](#). However, this alone does not determine whether the consequence is high or not. If any one of these four criteria scores high, then the consequences are shown as high in the figure.

Criterion	High	Medium	Low
People affected (number)	> 100,000	100,000 – 10,000	<10,000
Deaths per year (number: increase or decrease)	> 1,000 / year	1,000 – 100	<100
Cost per year (increase or decrease)	> £100 million	£100 – 10 million	< £10 million
Environmental impact (positive or negative)	Widespread and potentially large	Locally large, or widespread but not large	Local



4.2 The Natural Environment

Wales has a dramatic and beautiful landscape. Much of the country consists of uplands including mountainous areas. Much of the coast is unspoilt and includes cliffs, extensive beaches and estuaries. About 30% of Wales is designated including international and domestic site designations, and there is an impressive range of National Parks, Areas of Outstanding Natural Beauty and lengths of Heritage Coast.

The natural environment is therefore intrinsically important as a home for a wide variety of species. It also provides services to the public including tourist attractions and public amenity. Climate change could have serious and far reaching impacts on the natural environment. These impacts are considered below under terrestrial, coastal and marine headings.

Ecosystems are complex and are affected by a wide range of factors. There are also limited data and modelling capability. As a result the amount of quantification of impacts on the natural environment is very limited. The impacts have been assessed using available literature. In some cases the assessment is based on case studies of particular species or local areas.

4.2.1 Terrestrial

Climate change could lead to changes in terrestrial biodiversity which would not only affect the environment but would also have knock-on impacts for society and the economy.

Soil organic carbon

One of the potentially most important impacts of climate change is on soil organic carbon. The organic content of soil is a key regulator of plant nutrient cycling and water availability. Soil contains more than 90% of species biodiversity and forms the basis for both effective ecosystem functioning and associated services including crop production. However the potential impacts of climate change on soil organic carbon are currently not well understood and projections of future change are very tentative.

Seasonal precipitation

Whilst little change is projected in annual precipitation, the distribution between summer and winter is likely to change. The availability of water in the summer is projected to reduce as a result of reduced precipitation and rising temperatures. Whilst little change is projected in overall annual precipitation, increases in temperature and demand would mean that the overall availability of water is projected to reduce.

Under the p50 Medium Emissions scenario, winter rainfall could increase by an average of about 7% by the 2020s, rising to 19% by the 2080s compared with the 1961-90 baseline. Summer rainfall is projected to reduce by about 6% on average in the 2020s, increasing to a reduction of about 20% by the 2080s compared with the baseline.

A reduction in summer rainfall is likely to cause reductions in soil moisture and river flows. An increase in winter rainfall is likely to result in increases in waterlogging and flooding, which provide both threats and opportunities for biodiversity.

Low flows in watercourses are projected to become more frequent and more severe in warmer drier summers, leading to a decline in ecological status. It is projected that

Q95 flows⁵ for rivers could reduce by up to 20% by the 2020s, and between 20 and 40% by the 2080s compared with the 1961-90 baseline (see Figure 3.1). Water availability for biodiversity may therefore be reduced. This pressure is likely to be increased by a projected increase in societal water demand.

Reductions in river flows may cause a decline in water quality as a result of reduced dilution of pollutants. This may have significant impacts on rivers in warmer drier summers, with adverse implications for biodiversity.

The number of river sites that meet Water Framework Directive (WFD) Environmental Flow Indicators (EFIs) is projected to reduce, largely as a result of reduced summer flows. The reduction could be of the order of 40% on average by the 2020s rising to 90% by the 2080s compared with the 1961-90 baseline. The EFIs show whether or not a site has the physical habitat required to meet Good Ecological Status, and these figures therefore indicate that climate change could have large adverse impacts on in-stream ecology.

The ecological impacts of reductions in river flows are therefore potentially a major threat to biodiversity.

Increasing air temperatures could lead to stratification of water bodies including rivers and lakes, with adverse impacts on aquatic habitats. Some species would also be directly affected by temperature increases. For example, there is a risk to salmon growth from increased water temperatures and any negative changes in water quality.

Warmer drier summers

Reductions in summer rainfall and increasing temperatures are projected to cause an increase in the risk of drought. In addition, future droughts may be more severe than those experienced to date.

Whilst UKCP09 does not provide guidance on the magnitude of future droughts, a review of relative aridity information for Wales and England suggests that an average year by the 2050s could be similar to the dry summer of 2003, and by the 2080s an average year could be similar to the extreme drought of 1921. This means that the baseline (i.e. an 'average year') for future droughts could be more severe than at present. The consequences for biodiversity could be severe.

Increased soil moisture deficits and drying could have severe adverse effects on key habitats including for example blanket bog. There are about 70,000ha of blanket bog in Wales. Blanket bog not only provides an important habitat but is also a major store of organic carbon. Loss of this habitat could therefore affect both biodiversity and the storage of soil organic carbon.

The risk of wildfire could increase in hotter, drier conditions. Assuming that the number of other fires does not change, grassland and heath land fires could represent about 30% of all fires attended by the Fire and Rescue Service in the UK by the 2080s compared with 15% at present.

It is also estimated that the risk of wildfires in Welsh National Parks could increase by the order of 30 to 50% by the 2080s. Some key habitats are sensitive to fire including woodlands, grassland, peat soils (including blanket bog) and heathlands. Fires could therefore lead to a significant loss of biodiversity.

Impacts on species and habitats

Climate change could lead to a spread of pests and diseases. Whilst the CCRA analysis indicates that conditions for sample pests and diseases may become more favourable with climate change, potentially leading to an increase in the threat to

⁵ The flow exceeded for 95% of the time.

biodiversity, pests and diseases need to be understood on an individual level before reliable projections can be made. This is because of the wide variety of factors that affect the spread of pests and diseases.

As temperatures and precipitation patterns change, the locations where different species are able to survive may also change. Barriers to movement include fragmentation of habitat caused by agriculture and other land uses. Some species may not be able to track their changing climate space and may, therefore, be threatened by climate change. However the CCRA analysis also shows that other species could gain additional climate space and could therefore benefit.

One of the main potential adverse impacts of changing climate space could be loss or damage to species that could affect the integrity of a whole ecosystem. Beech woodland is an example of a species in the UK that could be threatened by climate change. A study of an area of Beech woodland in Wales demonstrated the severe effects that the 1975/76 drought caused, including tree death and damage (Peterken and Mountford 1996).

As temperatures rise, some species may migrate upwards to higher altitudes. This could lead to significant changes in biodiversity and landscape in the Welsh uplands. Observations in Wales suggest that certain species such as western gorse and bracken are already moving to higher ground.



Figure 4.1 Gorse and heather on the Llŷn peninsular

The CCRA analysis of upward migration of species has shown that some species may migrate but others may not. One example from the analysis is *Ulex gallii* (western gorse), where upward migration is projected. However, for some species, other factors such as the water balance or wind exposure dominate. In these cases species may not migrate upwards and in some cases may even migrate downwards. Furthermore, summer rainfall is projected to decrease. This could also affect the ability of some species to survive in their present locations.

Species migration patterns are likely to change as a result of climate change in Wales and elsewhere in the world. This has potentially serious implications for the designated

site network, as these are fixed physical locations with particular habitats that may not be available elsewhere. However there may also be opportunities for new species using Wales as part of their migration pattern in the future.

Asynchrony between the breeding cycle of species and their food supplies could lead to ecological disruption as a result of climate change although this has not been investigated in the CCRA.

Agricultural intensification may occur in the future for a number of reasons, some of which could be related to climate change. For example, the impacts of climate change overseas could affect food imports, requiring additional food to be produced locally.

Agricultural intensification has had adverse impacts on biodiversity in the past (for example, during the post World War II period) and this could threaten biodiversity in the future because of the additional pressures it would place on the environment. In particular, nutrients could become depleted and marginal land could be brought in to agricultural production.

Flood defence structures create barriers between floodplains and rivers, estuaries and coastal waters. This loss of connectivity has adverse impacts on biodiversity: floodplains do not benefit from inundation and sedimentation, and species are unable to utilise floodplains and intertidal areas that are cut off by the defences.

Whilst not specifically covered in the Wales Tier 2 list, the climate change impacts on designated sites for inland habitats are potentially significant. Impacts on the future sustainability of these sites include drying of soils, changes in species migration patterns, and changes in climate space for different species. A study on behalf of the Countryside Council of Wales indicated that more than two-thirds of habitats and species in the conservation network of Wales are at a medium or high risk from climate change (ADAS UK, 2010b).

Summary of results

The results of the analysis are shown in Table 4.1. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA 2012a) but have been adjusted for Wales where appropriate.

Table 4.1 Climate change impacts on the Natural Environment (Terrestrial)



#Coverage of analysis		##Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on the terrestrial natural environment

Some of the main threats from climate change to the terrestrial natural environment include:

- Reduction in soil moisture and lower river flows, and a potential increase in the frequency and magnitude of droughts.
- Impacts on habitats and species including changing climate space, increases in pests and diseases, and changes in migration patterns. Migratory birds in Wales have already reduced in number. This is potentially due, in part, to changes in the climate worldwide.

Soil organic carbon is important, but the ways in which it might be affected by climate change are not adequately understood at present. Conservation of carbon is linked to soil moisture and land use.

MIGRATION PATTERNS

A key impact of climate change on biodiversity is the effect on migration patterns in birds. Climate change can lead to changes in birds' migration distance, the sites they choose and the timing of their departure and arrival at wintering and summering sites.

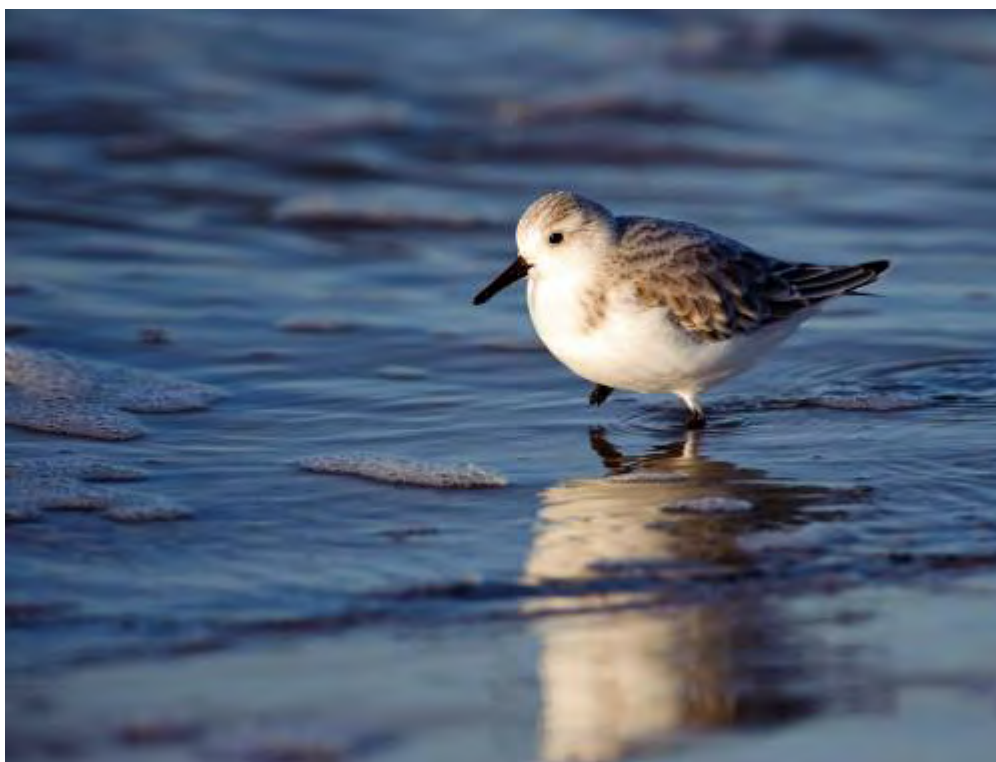
Evidence presented by the RSPB (Johnson *et al.*, 2010) indicates that warmer winters have allowed certain species, such as the sanderling and bar-tailed godwit, to winter on muddy food-rich estuaries further east and north of the UK than usual. This potentially has a positive impact on the birds, as they may have to fly less distance to reach suitable wintering grounds and so benefit from the reduced effort that takes. Shorter distance may also allow those species to better predict the onset of spring at their breeding sites and so enable them to cope with the phenological changes that may occur with climate change (Visser *et al.*, 2009).

Long distance migrants may encounter the opposite problem. As climate change leads to hotter spring and summer temperatures, breeding ranges may shift further north and wintering grounds may shift southwards, increasing the journey (Moss, 2009). Increasing the migration distance, although only a small percentage of the total distance travelled, may make species more dependent upon vulnerable pit-stop habitats used for re-fuelling. This could pose a significant extinction risk to some species.

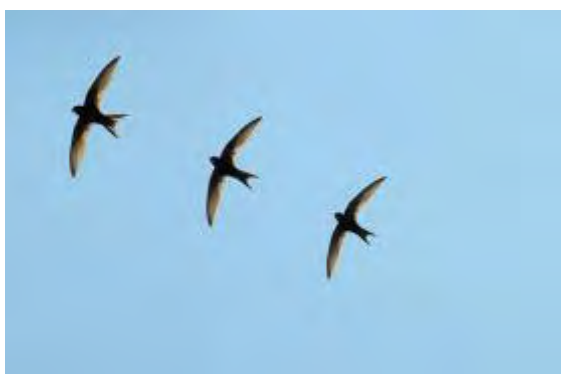
In conjunction with this, whilst warmer summer weather may increase insect activity and so improve bird breeding performance and weight gain in preparation for migration, a reduction in summer rainfall could reduce insect populations and thus put further pressure on long distance migratory birds (West Wales ECO Centre, 2011).

Overall, migratory birds are already decreasing in number in Wales. This could in part be due to the changes that have already happened in the UK climate. It could also be due to the impact of climate change, or other factors, in their habitats elsewhere in the world. Swallows for example, listed by the RSPB as a species in decline, are directly affected by winter rainfall in their African wintering grounds; reduced rainfall leads to increased mortality.

MIGRATION PATTERNS (Continued)



Sanderling



Swallows

Given the uncertainty of the effects of climate change and the possibility that cold winters may still occur, coupled with sea-level rise which is expected to be greatest along the North Sea coasts, Welsh estuaries are still very likely to play an important part of securing migratory birds' ability to adapt to climate change.

4.2.2 Coastal

Wales has a long and varied coastline with many areas of outstanding beauty and important habitats. There is a wide range of habitats on the coast including extensive lengths of cliff, coastal freshwater habitats and areas of intertidal habitats.

Coastal and offshore areas in south east Wales (the Severn Estuary), south west Wales (the Pembrokeshire Coast) and west Wales are designated as Special Areas of Conservation (SACs). Much of the north Wales coast is designated as Special Protection Areas (SPAs).

The coast is threatened by climate change. The sea level is projected to increase by about 0.05m by the 2020s, 0.15m by the 2050s and 0.30m by the 2080s. About 350km of the coast is eroding (nearly a quarter of the overall length of about 1,500km).

In addition, some of the main transport links are on the coast because of the steep inland topography. Roads, railways, coast defences and other man-made structures limit the scope for allowing the coast to retreat naturally in many areas. This causes the foreshore to narrow with a consequent loss of intertidal habitats in parts of Wales. This process is often referred to as coastal squeeze.

Coastal habitats could therefore be affected by sea level rise and consequent coastal squeeze, and coastal erosion. It is also projected that tidal flooding is likely to increase with adverse consequences for coastal freshwater habitats, for example those on estuaries on the west coast.



Figure 4.2 Coastal habitat: sand dunes near Harlech

The potential loss of coastal habitats has not been quantified in the CCRA analysis owing to a lack of suitable data. The analysis indicates that these losses could be significant in some areas, but that there could also be gains in other areas.

Species migration patterns are likely to change as a result of climate change in Wales and elsewhere in the world. This has potentially serious implications for the designated site network as these are fixed locations.

There is already concern that reductions in wintering wildfowl on coastal estuaries have been caused by climate change. Previous studies have identified a move of overwintering migratory birds from the South-West of the UK to the east coast during warmer winters (Brown *et al.*, 2011). However, there may also be opportunities for new species using Wales as part of their migration pattern in the future.

There could be increased pressure on the coastal environment from increased tourism as a result of warmer and drier summers. This could lead to greater disturbance and damage to coastal areas, and a greater need for conservation and protection.

Summary of results

The results of the analysis are shown in Table 4.2. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA, 2012a) but have been adjusted for Wales where appropriate.

Table 4.2 Climate change impacts on the Natural Environment (Coastal)

		Central estimate			Confidence	Coverage [#]	Method ^{##}
Threats		2020s	2050s	2080s			
MAR1	Impacts on protected habitats and species	Medium consequences (negative)	High consequences (negative)	High consequences (negative)	High confidence	UK	IJ
BD2/7	Risks to species and habitats due to coastal evolution and flooding	Medium consequences (negative)	High consequences (negative)	High consequences (negative)	High confidence	UK	IJ
BD9	Changes in species migration patterns	Medium consequences (negative)	High consequences (negative)	High consequences (negative)	High confidence	UK	IJ
BU8	Expansion of tourist destinations in Wales	Medium consequences (negative)	Medium consequences (negative)	Medium consequences (negative)	Low confidence	W	IJ

High consequences (positive)	High confidence
Medium consequences (positive)	Medium confidence
Low consequences (positive)	Low confidence
Low consequences (negative)	Too uncertain
Medium consequences (negative)	
High consequences (negative)	

#Coverage of analysis		##Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on the coastal environment

Climate change presents major threats to coastal and estuarine habitats and species. Whilst there may be opportunities for new species, a possible reduction in intertidal area would mean that there may be an overall loss of biodiversity.

Changes in species migration patterns could affect the numbers and types of species using coastal and estuary sites, for example wintering birds.

COASTAL BIODIVERSITY

Wales is bordered on three sides by the sea. One sixth of the coastline is owned by the National Trust. The coastline is extremely important for both heritage and biodiversity. Climate change and sea-level rise are expected to increase the scale and pace of coastal change. This in turn may have a huge impact on coastal habitats, species, heritage areas and livelihoods along the coast.

Erosion and flooding are the primary concerns for National Trust coastal sites (National Trust 2007). The Trust estimates that 72% of its sites (which equates to 167km of the coastline) could lose land through erosion. The maximum loss is estimated to be about 200m over the next 100 years. In terms of flooding, 1,572 hectares of National Trust sites are currently at risk from tidal flooding, and this risk is likely to increase in the future. Key areas at risk include:

From coastal erosion:

- Dinas Dinlle
- Rhossili
- Nicholaston Burrows

From tidal flooding:

- Stackpole Estate
- Porthdinllaen

From tidal flooding and coastal erosion:

- Cemlyn Estate
- Llanrhidian Marsh



(Base map source: www.wales.com)

Sites such as these are already losing land usually given over to recreation. In addition, paths and access roads have already been moved inland to cope with the current changes.

Small much-loved beaches, such as Marloes Sands are being lost; their movement inland prevented by cliff faces. Many historic buildings face a similar fate; the church at Llandanwg is already close to the current high tide line. Many local communities also face considerable encroachment from the sea. Communities along the Llŷn Peninsula such as Porthdinllaen village are already at the high tide line and stormy weather causes buildings to flood. Furthermore, erosion in nearby areas has led to landslips that leave communities isolated.

COASTAL BIODIVERSITY (continued)



Horseshoe Bay in the summer, where rising sea levels threaten the community

Local biodiversity and conservation activities would also be affected by the changes to the coastline. There is the opportunity that changing water levels and flows would create new habitats and encourage the recruitment of new species to different areas. However, current coastal habitats are potentially subject to adverse changes. Saltmarsh in particular is vulnerable to squeeze with rising sea levels, especially where cliffs block the retreating habitats.



Wreck on a sandy beach (Rhossili). Erosion can expose buried relics

4.2.3 Marine

Climate change could lead to changes in the marine environment, which in turn could have impacts on human health, tourism, fisheries, shell fisheries and the natural environment.

Projected future changes in rainfall could cause greater pollution in the marine environment as a result of lower dilution of pollutants in summer and an increase in sewer overflows in winter. This, combined with increasing temperatures, could lead to a decline in marine water quality and an increase in the occurrence of microbial pathogens.

There may also be an increase in harmful algal blooms which could affect people and wildlife. This is difficult to predict because of the complexity of the processes. The CCRA analysis indicates that some blooms may increase their prevalence generally whereas others may shift their distribution.

Changes in coastal water quality could lead to an increase in the incidence of human disease via bathing and also the consumption of seafood, particularly shellfish. Changes in water quality could also adversely affect marine habitats and species.

Coastal shell fisheries could be adversely affected by a number of climate change effects. Sea level rise could reduce the extent of shellfish beds, reducing the overall area and affecting the quality of those that remain. However whilst some cold water species may decline, potential benefits include faster growth rates for some species, and the introduction of new species that thrive in warmer conditions.

Acidification of the sea could have a direct effect on the quality of shellfish: it is estimated that the economic losses in the UK to the shellfish, mollusc and aquaculture fisheries could be of the order of £15 million to £120 million. Whilst the effect on cultured aquatic species has not been assessed in detail in the CCRA, it is likely that there would be an adverse impact based on the UK estimate. This is assessed as a medium threat by the 2080s owing to the limited size of the Welsh aquaculture industry.

Shifting of marine species is projected to occur as a result of changes in sea temperature. Commonly fished species might move about 20 to 150km by the 2080s relative to their 1961-1990 baseline fishing grounds. Whilst this would require longer fishing trips, there would also be opportunities for the fishing industry as new species enter existing fishing grounds. A northward shift in the distribution of plankton would have impacts through the food chain, affecting seabirds and other species.

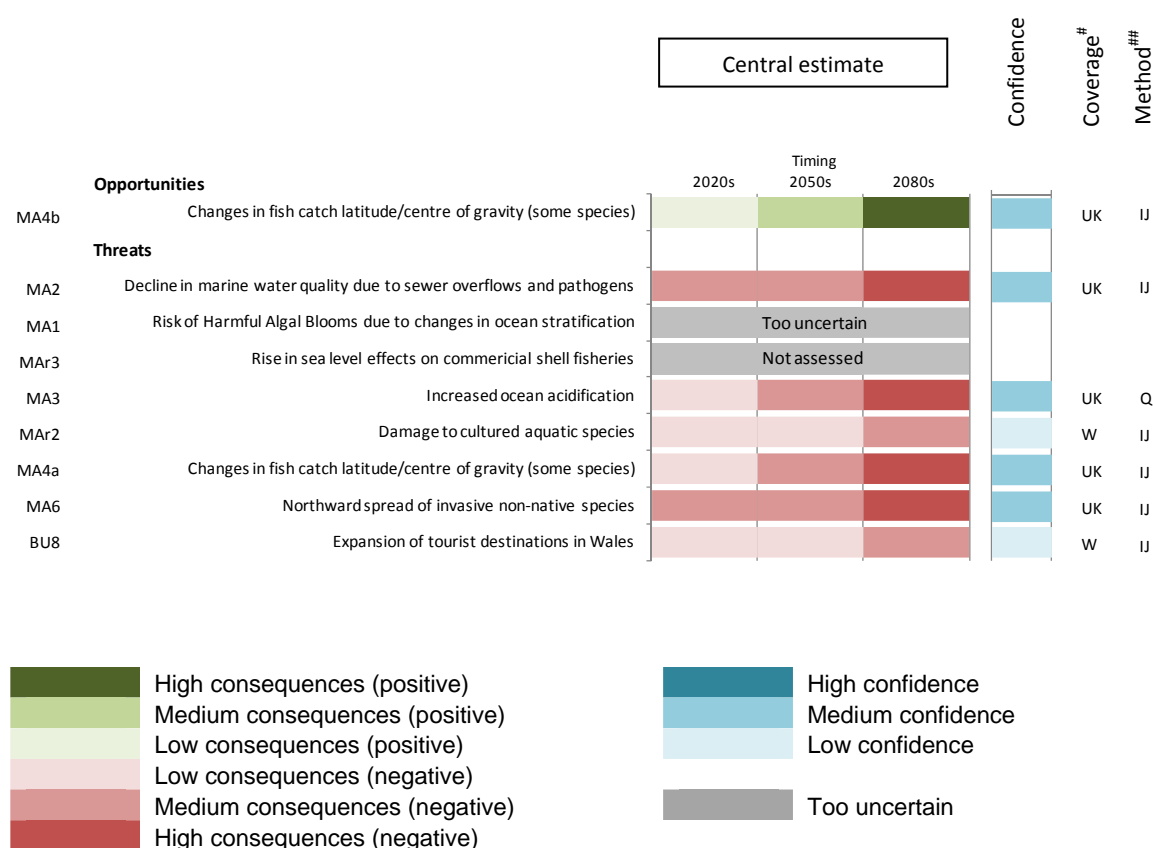
The coastal marine environment could also be seriously affected by non-native invasive species. These could potentially affect all areas of the Welsh marine environment during the 21st century as sea temperatures increase. Whilst the potential impacts of invasive species have not been assessed in detail, they could have significant economic and environmental implications, particularly where they occupy the same niche as native or commercial species.

Increasing coastal tourism as a result of warmer and drier summers could increase pressure on the marine environment. Potential impacts include increases in waste water (and therefore a decline in water quality), increasing demand for seafood and greater disturbance of coastal waters.

Summary of results

The results of the analysis are shown in Table 4.3. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA 2012a) but have been adjusted for Wales where appropriate.

Table 4.3 Climate change impacts on the Natural Environment (Marine)



# Coverage of analysis		## Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on the marine environment

There is a high degree of uncertainty regarding the impacts of climate change on the marine environment owing to the complexity of processes and the difficulty of predicting future change.

Non-native invasive species could potentially have a large impact on marine ecosystems. Other potential threats include a decline in marine water quality and increases in harmful algal blooms and ocean acidification.

CHANGES IN THE MARINE ENVIRONMENT

Changes occurring in the marine environment may have a significant impact upon the livelihoods of Welsh fishermen and women, potentially in both positive and negative ways.

Jerry Percy, Chief Executive of the Welsh Federation of Fishermen's Associations (WFFA), highlights in a testimonial to WWF Cymru the effects that Welsh fishermen and women are already experiencing from climate change (Percy, 2009).

Black bream, spider crab and sea bass are three examples of species that are now found in Welsh waters that would not have been expected to be present 20 years ago.

CHANGES IN THE MARINE ENVIRONMENT (Continued)

The common spider crab in particular is very noticeable in Welsh waters. Fishermen potting for the native brown crab⁶ and lobster are increasingly finding their catch full of spider crab.

The same is true for scallopers, who find their dredgers packed with spider crabs rather than scallops. Spider crabs have been seen to be breeding off UK waters and it is thought that the combination of warmer waters and milder winters has allowed their spread up to Wales and now beyond.



Spider crab (Source: <http://www.porthgainshellfish.com/?p=544>)

Black bream used to be confined to a few individuals in high summer, but now they are present in larger numbers throughout the summer period. Similarly, sea bass also used to be found in Welsh waters only in the height of summer, but is now found all year round. Other species, usually expected to be found in Mediterranean waters, are also now increasingly spotted in Welsh waters, including Atlantic triggerfish, sun fish and turtles.

Conversely, cod numbers have fallen and it seems that their juvenile food source, small plankton, have moved further north to cooler waters and are being followed by the cod. Of particular concern to fishermen is the impact of climate change upon species such as plankton that occur at the bottom of the food chain, as this can have a huge impact upon commercially valuable species.

⁶ Also known as the Edible crab.

4.3 Agriculture and Forestry

Agriculture is dominated by livestock production. Of the 17,100km² of agricultural land in Wales, 12,700km² (75%) is permanent grass and 1,800km² (10%) is rough grazing. 2,100km² (12%) is land with potential to grow arable crops (about half of this is short-term grassland), with the remainder of land on agricultural holdings being predominantly woodland⁷.

In addition, there are about 2,900km² of forests and woodland, representing about 14% of the total land area.

Agriculture and forestry are very sensitive to the climate. Any changes in climate are likely to lead to changes in agriculture and forestry, both positive and negative. Opportunities include increases in crop yield, new cropping opportunities and carbon storage. The main potential adverse impacts include declining water availability and the potential for new pests and diseases.

The CCRA analysis was carried out under the headings of arable, horticulture, livestock and forestry. Livestock is heavily dependent on the availability of pasture and feed crops, and both arable and horticulture are concerned with crops. The impacts of climate change are therefore discussed under the headings of agriculture and forestry.

4.3.1 Agriculture

Crop yields

Based on projections of higher temperatures and CO₂ concentrations, crop yields would be maintained or improved in future. The impact of climate change on grass growth is of particular importance in view of the importance of livestock in Wales. Higher temperatures could lead to higher yields and therefore provide a benefit. A study for west Wales (where yields are already high) indicated projected increases of 6% to 20% by the 2020s compared with a 1961-90 baseline, rising to 14% to 35% (the maximum potential yield) by the 2080s. However this benefit could be offset by increasing aridity caused by lower summer rainfall in combination with higher temperatures.

Although not grown on a large scale in Wales, wheat yields might increase by about 40% by the 2020s, 70% by the 2050s and 100% by the 2080s relative to a 1961-1990 baseline providing that water or nutrients (or pests and diseases) do not become constraints to final yield (see Figure 4.3). However, water availability may be a constraint in summer months, particularly for higher value horticultural production.

Even where water availability and other constraints occur, there is scope to change the types and locations of crops in order to maximise yield under changing climatic conditions, although the availability of suitable land is limited. Examples of crops identified in the Agriculture Sector Report that could potentially be grown commercially in Wales in the future include Elder, Garlic, Juniper, Lupin and Rocket. There is already a trend for growing maize as a forage crop. However, it is understood (from consultees) that this is causing problems with soil erosion and diffuse pollution that could be exacerbated by climate change.

In addition to increases in mean growing season temperature, yields are likely to increase even further with improvements in varieties and some gains due to higher CO₂ concentrations.

⁷ <http://www.defra.gov.uk/statistics/foodfarm/landuselivestock/junesurvey/>

There is a temperature related problem with soft and top fruit in that, if the temperature is not low enough for long enough in winter, vernalisation would not occur, which in turn would severely reduce the fruit crop.

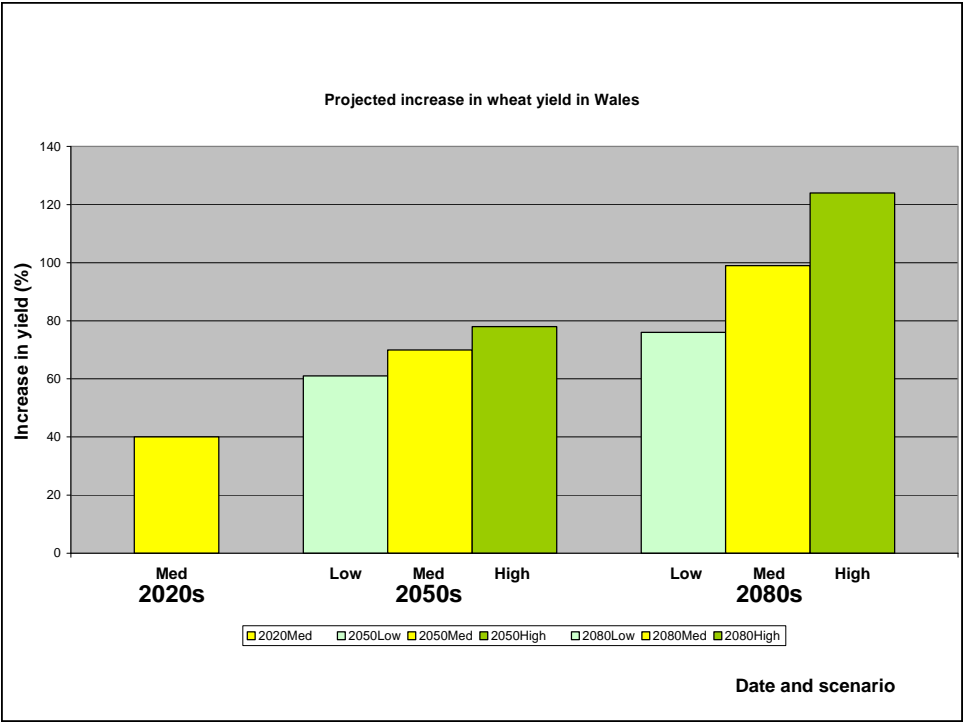


Figure 4.3 **Projected increase in wheat yield (no constraints) from 1961-90 baseline**

Crop yields could be affected by a number of other factors that have been identified in the CCRA, but not included in the analysis. These include:

Factor	Potential impact on crop yield
Increases in CO ₂ concentrations	Increase
Technological changes (e.g. plant breeding and pest control)	Increase
Crop stress factors, including lack of moisture, waterlogging and frost damage	Reduce
Pollination	Unclear
Increase in countryside recreation	Reduce

Summer water availability

Projected changes in rainfall could lead to an increase in water stress in the summer and increased waterlogging in the winter, both of which are likely to impact on agricultural production.

The Potential Soil Moisture Deficit is projected to double by the 2080s and the moisture available for crops may significantly reduce. Supplementary irrigation may be required for high value horticultural crops.

Whilst crop water use is currently modest compared to water availability, large increases may be required during periods of greatest water stress during the summer. In the CCRA analysis, crop water use is projected to approximately double by the 2050s. Livestock water use is also likely to increase.

Whilst Wales is often regarded as having a plentiful supply of water, there is a very high dependence on surface water with little groundwater reserve during dry periods. Water availability could reduce significantly in summer months, which may be exacerbated by increased domestic demand.

Overall it is projected that the supply demand balance in the three UKCP09 river basin regions in Wales (Dee, Severn and West Wales) would change from the present surplus to a deficit within about 20 years. There is therefore likely to be pressure on water resources that could affect agriculture.

The sustainability of water supplies could also be threatened if they are not well managed. For example, agricultural abstractions from sustainable sources in the UK as a whole are projected to reduce by about 5% by the 2020s and 10% by the 2050s, indicating that future increased demand might not be sustainable unless new sources are identified or step changes in water demand are achieved. In west Wales (an area of high agricultural activity) the level of agricultural abstractions from sustainable sources could reduce by between 30% and 60% by the 2050s.

The risk of summer droughts is also projected to increase and future droughts could be more severe than those experienced to date. These events could cause severe damage to agricultural production and the frequency and severity is likely to increase. In addition, warmer drier summers could lead to drying of soils and an increase in soil erosion.

A further impact of reduced water availability is the potential for reduced water quality. A particular concern is the spread of *Cryptosporidium* in water. This affects both animals and people, and is understood to be on the increase. Heavy rainfall is an important contributory factor.

Flooding and waterlogging

Flooding and waterlogging are both projected to increase as a result of increased winter precipitation and sea level rise. The overall area of agricultural land at risk of river and tidal flooding has been assessed for an annual flood probability of 10% (1 in 10 years) and a flood depth of 0.5m or greater. The area is projected to increase by about 50% by the 2080s, from a baseline area of about 500km² (3% of agricultural land) to more than 750km² (about 5% of agricultural land).⁸

This increase can be broken down by Agricultural Land Classification grades, as follows:

- Grades 1, 2 and 3 (mainly arable and horticulture): from 180km² to 260km².
- Grades 4 and 5 (mainly pasture): from 340km² to over 500km².

The area of land that floods very frequently (an average of once in 3 years or more frequently) could increase by a factor of between 3 and 4 by the 2080s, from the baseline of about 130km² to over 400km².

The total area with a flood depth of 0m or greater and an annual flood probability of 10% is projected to be about 1,300km² by the 2080s (about 8% of agricultural land) compared with the current baseline of about 750km² (about 5% of agricultural land).

⁸ The baseline is 1961-90 for river flooding and 2008 for tidal flooding.

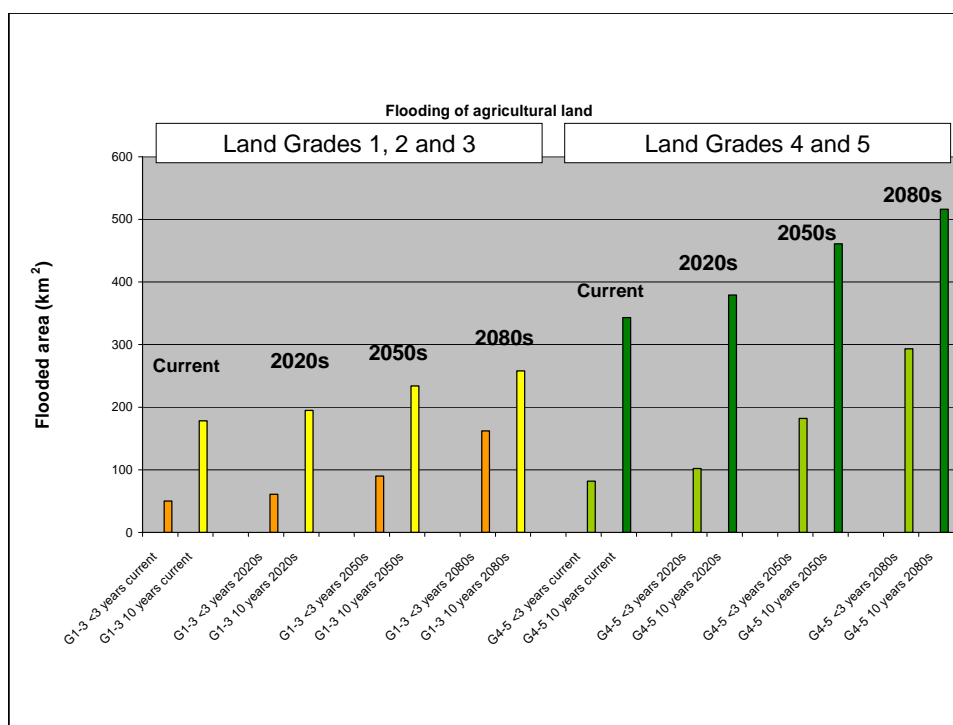


Figure 4.4 Flooding of agricultural land

Figure 4.4 shows changes in the frequency of flooding of the two types of agricultural land referred to above (i.e. Grades 1 to 3 and Grades 4 and 5) under a p50 Medium Emissions scenario as follows:

- Land flooded on average once in 3 years or more frequently
- Land flooded on average once in 10 years or more frequently (which includes the land flooded once in 3 years or more frequently).

Land that is flooded regularly (particularly from the sea) may become untenable for higher value agricultural use. There is therefore a risk of loss or downgrading of some agricultural land as a result of increased flooding.

It is also projected that between 0.1% and 0.2% of agricultural land in Wales could be lost to coastal erosion by the 2080s, although this is an indicative estimate based on limited data.

There is likely to be a change in the overall suitability of some agricultural land as a result of a combination of climate change effects (including warming, drying and flooding). This may lead to the adoption of new types of crops that are more suited to the new conditions.

Pests, diseases and heat stress

Warmer summers and milder wetter winters could cause an increase in plant pests and pathogens as a result of climate change. The processes involved in spreading pests and diseases are currently poorly understood and, therefore, projections of the consequences are difficult to make. However, there is little doubt that pests and pathogens would exploit opportunities resulting from climate change.

Livestock pests and diseases are also of particular concern as they could affect livestock welfare and product quality. The CCRA analysis has identified studies that show a northward spread of the Bluetongue virus leading to large numbers of affected animals on the continent (a few of which were transported to the UK in 2008). This is

believed to be related (at least in part) to climate change. The foot and mouth outbreak has shown just how serious disease in livestock can be.

Livestock pests and diseases are therefore assessed as an important potential threat given the dominance of livestock farming in Wales.

Other factors that could affect livestock as a result of climate change include heat stress. This is unlikely to be a major issue for dairy production although the impacts on meat production have not been assessed in detail. The impacts of heat stress on livestock and, in particular, the potential number of deaths from this cause appears to be negligible.

A particular problem related to meat production is the effect of increases in precipitation and waterlogging on pasture. Not only would this put pressure on grazing land, but could also lead to an increase in soil erosion, diffuse pollution and breakdown of soil structures.

PESTS AND DISEASES TO ANIMALS: Bluetongue



Bluetongue is a vector-borne disease that affects livestock. It is transmitted by *Culicoides* biting midges and in 1998 it was reported in Europe for the first time in 20 years. The disease was first recorded in Europe 75 years ago, and only in an area that also had the old world vector, *Culicoides imicola*. The range of *C. imicola* has extended northwards considerably in that time. Other *Culicoides* species, that inhabit more northerly ranges now overlap in range with the old world vector and are also thought to be carriers of the disease. Between 1998 and 2005, bluetongue was responsible for the death of over 1.5 million sheep in Europe. In 2008, the disease reached Wales.

Cattle imported from France were found to test positive for Bluetongue in September 2008. The existence of bluetongue in France was well-known at the time, and the instance of bluetongue in imports to Wales highlights the importance of carefully considering all factors before importing animals from infected areas. Bluetongue is considered one of the most deadly of animal diseases. The consequences of an outbreak could be as severe as the foot-and-mouth outbreaks in 2001 that saw many animals killed and livelihoods disrupted (Miloudi 2008).

It has been suggested that the northward spread of this disease is partly driven by climate change, particularly milder winters. This has not only allowed the principal vector to extend its range northwards but also to persist during winter months.

Summary of results

The results of the analysis are shown in Table 4.4. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA 2012a) but have been adjusted for Wales where appropriate. In particular, the scores relating to grassland productivity, crop yield and new crop opportunities reflect the dominance of grassland in Welsh agriculture.

Table 4.4 Climate change impacts on Agriculture

		Central estimate			Confidence	Coverage [#]	Method ^{##}
		2020s	Timing 2050s	2080s			
Opportunities							
AG1	Changes in crop yield (due to warmer conditions)					W	Q
AG9	Opportunities to grow new crops					UK	IJ
AG10	Changes in grassland productivity					W	Q
Threats							
AGr1	Change in crop stress factors	Not assessed					
AGr3	Impacts on pollination (crop yield)	Not assessed					
AGr4	Increased countryside recreation	Not assessed					
AG5	Increases in water demand for irrigation of crops					W	IJ
AG6	Increases in water demand for livestock	Not assessed					
AG4	Drier soils (due to warmer and drier summer conditions)					W	IJ
WAr4	Increase in cryptosporidium	Not assessed					
AG2/FL4	Flood risk to agricultural land					W	Q
FL14a	Agricultural land lost due to coastal erosion					W	Q
AG3	Risk of crop pests and diseases	Too uncertain					
AGr2	Change in livestock pests and diseases	Not assessed					
AG7a	Reduction in milk production due to heat stress					UK	IJ
AG7b	Reduction in dairy herd fertility due to heat stress					UK	IJ
AG8a	Increased duration of heat stress in dairy cows					UK	IJ
AG8b	Dairy livestock deaths due to heat stress					UK	IJ

	High consequences (positive)		High confidence
	Medium consequences (positive)		Medium confidence
	Low consequences (positive)		Low confidence
	Low consequences (negative)		
	Medium consequences (negative)		Too uncertain
	High consequences (negative)		

#Coverage of analysis		##Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on agriculture

Potential major threats to agriculture include drought, flooding of agricultural land, and pests and diseases, particularly those affecting livestock. Increases in crop yields including grass present major opportunities although it is not clear to what extent this is constrained by such factors as water availability and nutrients. Reduction in livestock meat product quality as a result of climate change has not been assessed.

4.3.2 Forestry

Pests and diseases

Pests or pathogens could cause a reduction in timber yield and quality, and possibly result in changes in forest management practices. It is widely recognised that climate is a major controlling influence on the spread of pests and pathogens. An assessment based on sample pests and diseases has shown that large proportions of different woodland types could be affected as climatic conditions change.

Drought and fire risk

Drought could seriously affect tree productivity in warmer drier summers. It is estimated that there could be a 10% loss of yield caused by droughts under present day conditions. It is projected that this could rise to about 20% by the 2080s under the p50 Medium Emissions scenario (range 10% to 30% for the five selected scenarios in the 2080s).

The risk of wildfires is also likely to increase in warmer drier summers, with adverse consequences for timber production and biodiversity. It has been estimated that the risk of wildfires might increase by 30% to 50% in National Parks (Snowdonia, Brecon Beacons and Pembrokeshire Coast) during the 100-year period from the 1980s to the 2080s.

Forest productivity

The potential yield of forests has been assessed using information from Forestry Commission managed public forestry estate in Wales. Results indicate a potential increase in productivity for some species in Wales, but a decline in other species. The rate of change is projected to be greatest after 2050 for most species.

Sitka spruce represents about 70% of the total timber yield in the assessment for Wales. Estimated changes in yield for Sitka spruce are an increase of about 20% by 2050 and an overall increase of about 10% by 2080 (thus a decline between 2050 and 2080).

Twelve species make up the remaining 30% of the yield. The overall change in yield for these species is projected to be an increase of about 4% by 2050, but an overall decline of about 25% by 2080.

Waterlogging and landslips

Increased waterlogging may occur during wetter winters, reducing timber yields and affecting access in woodland areas. It may also weaken tree roots, leaving the trees more vulnerable to wind throw. This is regarded by stakeholders as an important impact.

Landslips may increase in forests as a result of a reduction in slope stability caused by wetter winters. This is a particular concern in Wales as many forests are in areas of steep topography. Landslips may be exacerbated by increases in tree growth rates and increased vulnerability to wind throw. The consequences of landslips include damage, to transport infrastructure for example, and soil loss.

Impacts associated with phenology

Growing seasons including that of nursery stock may change as the temperature rises and rainfall patterns change. For example, changes in the timing of frosts would affect the growing season. However, this impact has not been assessed in detail in the CCRA.

TREE DISEASES

Phytophthora ramorum (*P. ramorum*)



P. ramorum is a fungus-like pathogen that causes “Sudden-oak death”. Most trees that become infected are killed. The pathogen favours warm and moist conditions. However certain stages of the life cycle can also survive extremes in temperature and humidity.

The future projected climate in Wales is expected to be very favourable for *P. ramorum*. In May 2010, *P. ramorum* was confirmed to be in Welsh Government woodland. Tree disease caused by *P. ramorum* was first found in the south west of England and then spread to areas in the Afan Valley, near Port Talbot, the Garw Valley, near Bridgend and the Vale of Glamorgan. Outbreaks have also occurred in other parts of Wales. The outbreak has been found on both public and privately owned woodlands (Forestry Commission 2010a, b and c).

Rhododendron species act as a host for the pathogen. It is thought that the pathogen spread from Rhododendron to Japanese Larch. The UK is the only place in the world where *P. ramorum* has infected large numbers of commercially important conifer species. The three larch species grown in Wales cover an area of 23,000ha, 8% of the total woodland cover. Foliage of Japanese Larch allows *P. ramorum* to produce five times the number of spores (the spreading agent in the pathogen’s life cycle) than are found on Rhododendron.

Control efforts in the UK have focused on the removal of Rhododendron and infected Larch. The most commonly grown commercial species in the UK, Sitika spruce, *Picea sitchensis*, is also susceptible. *P. ramorum* can also infect plants such as *Viburnum spp.* and *Vaccinium myrtillus*, winberry (bilberry in English) and as such, there is concern about the pathogen’s impact on other habitats, such as heathland.

Source of photographs:

<http://www.forestresearch.gov.uk/fr/INFD-6YUJRD>

<http://www.aberdareonline.co.uk/content/fatal-disease-spreads-larch-trees-wales>

Summary of results

The results of the analysis are shown in Table 4.5. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA 2012a) but have been adjusted for Wales where appropriate.

Table 4.5 Climate change impacts on Forestry

		Central estimate			Confidence	Coverage [#]	Method ^{##}
		2020s	Timing 2050s	2080s			
Opportunities							
FO4b	Increase of potential yield of Sitka spruce					W	IJ
Threats							
FO1a	Forest extent affected by red band needle blight					UK	Q
FO1b	Forest extent affected by green spruce aphid					UK	Q
FO2	Loss of forest productivity due to drought					UK	Q
BD12	Wildfires due to warmer and drier conditions					W	Q
FO4a	Decline in potential yield					W	Q
FOr3	Increase in waterlogging	Not assessed					
FOr1	Increase in erosion and landslips	Not assessed					
FOr2	Impacts associated with phenology	Not assessed					

	High consequences (positive)		High confidence
	Medium consequences (positive)		Medium confidence
	Low consequences (positive)		Low confidence
	Low consequences (negative)		
	Medium consequences (negative)		Too uncertain
	High consequences (negative)		

[#] Coverage of analysis		^{##} Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on forestry

The most serious impact of climate change on forestry appears to be pests and diseases, as large proportions of different woodland types could be adversely affected as climatic conditions change. Water stress including drought and waterlogging are also important concerns together with an increase in fire risk in the summer.

4.4 Business

Businesses in Wales range from large industrial and commercial undertakings that employ a large number of people to small businesses. The range of businesses and services includes:

- Major iron and steel industries in south Wales, which are of international importance.
- Oil, gas and chemical installations including the major gas and oil port at Milford Haven.
- Businesses reliant on tourism, particularly in seaside resorts.
- Businesses in relatively remote rural locations, that are vulnerable to being cut-off during bad weather; many of these are related to agriculture.
- A wide range of industrial and commercial businesses and services, particularly in the urbanised areas of south Wales.

Climate change impacts on business include direct damage caused by extreme events, impacts from gradual changes (such as temperature increases), losses due to business disruption and adverse impacts on financial investments. The single greatest climate change concern for business is flooding.

There is a particular concern that many of the smaller businesses are vulnerable to extreme weather events, either because of inadequate insurance or inadequate resources to recover quickly. For example Small and Medium Enterprises (SMEs), which have 250 employees or less, provide about 60% of private sector employment in the UK and contribute over 50% of total business turnover (about £1,500 billion per year). SMEs are of particular importance to the Welsh economy, employing over 300,000 people (32% of all employment) and having a turnover of around £15 billion (based on 2006 figures).⁹

Businesses will also be affected by climate change impacts on transport, energy supply, water supply and other services. These impacts are discussed in Section 4.5.

Impacts of increased flooding

Flood risk in Wales is higher than in other UK countries in terms of the proportion of people, property and infrastructure at risk of flooding. This reflects the fact that most of the population is either near the coast or in river valleys.

The risk of flooding is projected to increase as the sea level rises and winter rainfall increases. Businesses in Wales are at relatively high risk from tidal flooding because most of the population (and associated businesses) are near the coast.

It is estimated that about 357,000 properties (1 in 6 of all properties in Wales) are at risk of some form of flooding (Environment Agency, 2009) including both residential and non-residential properties. It is also estimated that about 65,000 properties are at significant likelihood¹⁰ of river and tidal flooding of which 24,000 are non-residential. The number of non-residential properties is projected to increase to between 30,000 and 45,000 by the 2020s and to between 30,000 and 65,000 by the 2050s.

Expected Annual Damages (EAD) corresponds to the average amount of damage that could occur each year to buildings as a result of flooding. The EAD caused by river

⁹ <http://www.statswales.wales.gov.uk/index.htm>

¹⁰ Annual probability of flooding of 1.3% (once in 75 years on average) or greater.

and tidal flooding for all non-residential properties is projected to increase from a baseline value of about £90 million to between £100 million and £200 million by the 2020s. By the 2050s, EAD is projected to reach between £100 million and £300 million. Figure 4.5 shows changes in EAD for selected climate change scenarios.

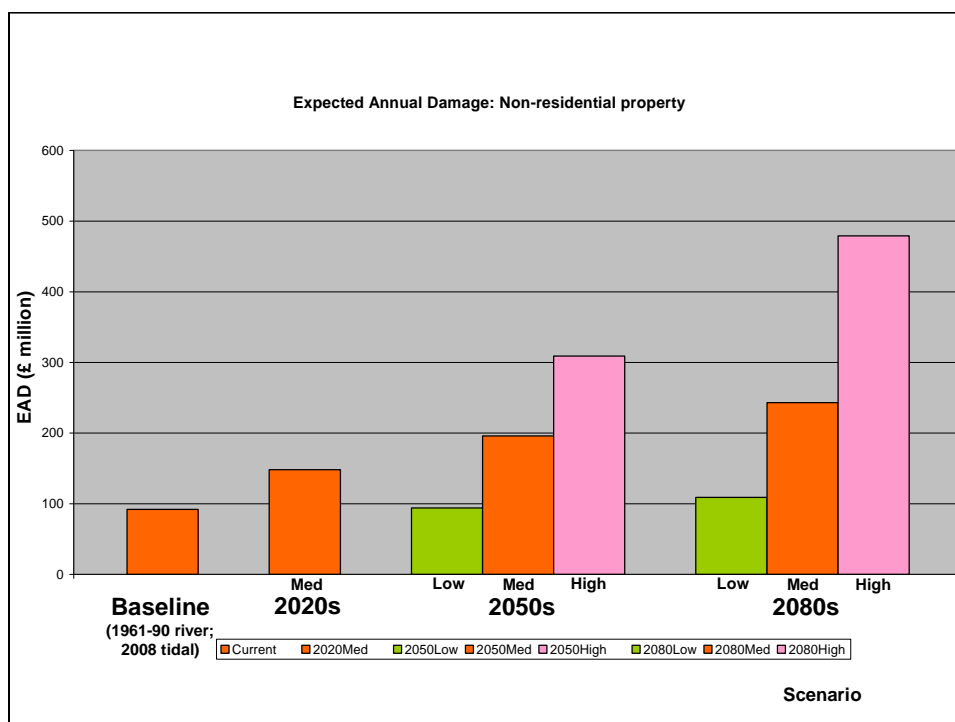


Figure 4.5 EAD for non-residential properties

It may therefore be concluded that a large increase in flood risk to businesses may occur assuming that no adaptation measures take place. However the range of uncertainty is large as shown by Figure 4.5, from minimal increase to five times the baseline value by the 2080s. In addition to damage caused by river and tidal flooding, other sources of flooding including surface and ground water are not covered by the analysis. Therefore the overall impacts are likely to be larger than those quoted above.

Flood damage to buildings is only part of the overall cost of floods to businesses, and some of the other business consequences are discussed further below. The overall impact of flooding on business can be estimated from the summer 2007 floods in Wales and England, where about 8,000 business premises were affected at an overall economic cost of about £740 million (Environment Agency, 2010b). This corresponds to an average of nearly £100,000 per business.

One aspect of business disruption that is likely to increase with climate change is the effect on supply chains, where transport links are flooded and businesses that supply other businesses are affected by floods. Some supply chains are international, for example where agricultural produce and other raw materials come from overseas.

The effect of disruption on supply chains has been exacerbated in recent years by the development of leaner supply chains which have less flexibility when something goes wrong. Supply chain disruptions are costly to business. Evidence shows that disruptions negatively affect company stock price, return on assets, and return on sales. Businesses do not tend to recover quickly from supply chain disruptions and share prices can be adversely affected (Baglee *et al.*, 2011).

Increased flooding as a consequence of climate change could adversely affect the mortgage and insurance markets and businesses, for the following reasons:

- Properties at risk of frequent flooding may have difficulty obtaining insurance.
- Mortgages would not be offered on properties that are unable to obtain insurance. This loss of business would affect mortgage lenders.
- Insurance losses from flooding could increase, thus affecting insurance providers.

As discussed above, there are estimated to be about 41,000 residential properties and 24,000 non-residential properties at significant likelihood of river and tidal flooding, representing about 3% of all properties. This provides an indication of the number of properties where there could be difficulties obtaining insurance (and therefore mortgages) in the short to medium term.

The actual number of properties affected would depend on the position taken by the insurance industry on the provision of insurance to properties in flood risk areas. There is a statement of principles between the Welsh Government and the Association of British Insurers (ABI) which sets out the current approach to flood insurance provision. In this agreement, significant likelihood of flooding is identified as the threshold that insurers use to consider their approach to the provision of insurance cover. The agreement expires in 2013.

The number of properties (both residential and non-residential) at significant likelihood of flooding could rise to between 80,000 and 130,000 by the 2020s and between 80,000 and 180,000 by the 2050s. From a business perspective, difficulties providing mortgages for a sizable proportion of these properties would have a significant adverse impact on mortgage lenders.

Increased flooding could lead to increased annual insurance pay out costs. It is estimated that these could potentially increase for the UK by a factor of 3 to 5 by the 2080s. However this depends on future policies adopted by the insurance industry regarding the provision of flood insurance, and policies adopted by the Welsh Government regarding flood risk management.

Climate change impacts on infrastructure

Business relies on a range of infrastructure and associated services including water supplies, waste disposal, energy supplies and Information and Communications Technology (ICT). Disruption to any of these services has a direct impact on business.

The impact of failures of essential services on businesses was demonstrated in the 2007 floods, where both water supplies and electricity supplies were cut off because of the threat of flooding to infrastructure on the River Severn. Such failures can lead to serious business disruption including premises outside flood risk areas.

Water availability for all uses is projected to reduce during warmer drier summers in the future. For example, the number of river sites with sustainable abstraction is projected to change by between plus 10% (increase) and minus 65% (decrease) by the 2020s. By the 2080s, a reduction of between 50% and 80% is projected compared with the 1961-90 baseline.

However, whilst climate change could affect the access of industrial plants and other businesses to water, industrial demand is a relatively small proportion of overall water demand. It is more likely that adaptive measures or regulation would have a greater impact on water supplies for industry.

A particular concern is the need for increased cooling requirements for industrial machinery. Not only would this require greater water abstraction and more energy, but the resultant waste water could cause additional environmental impacts on biodiversity.

There are also concerns regarding the disposal of solid and liquid wastes due to lower river flows, and the potential effects of infrastructure disruptions including gas and electricity outages.

It is estimated that about 80% of businesses are 'heavily dependent' on ICT, and therefore any disruption would have immediate effects. The risk of major ICT disruption due to climate change is considered to be relatively low for large businesses, as backup systems are often in place.

However smaller companies (including SMEs) and remote workers are more vulnerable to ICT disruption and the risks are therefore greater. This is because they are often dependent on a single link which, if it fails, causes a complete loss of service. The collapse of a bridge carrying communications cables during the 2009 Cumbria floods caused a breakdown in service that was difficult to repair (Figure 4.6).

At present it may not be possible to foresee some of the potential future impacts of climate change on ICT. For example, increased fire risk or intense storms could cause unforeseen damage to ICT infrastructure and equipment.



**Figure 4.6 Loss of service connections caused by bridge collapse
Cumbria (2007)**

(Source: Mark Tozer/Chris Clarke)

Climate change impacts on tourism

Coastal tourism forms an important part of the economy. Adverse effects caused by climate change are likely to include the loss of beach area and other natural assets due to increased flooding, coastal erosion and sea level rise. It is projected that about 2% to 8% of the total beach area of Wales could be lost by the 2080s. The number of tourist facilities at risk of flooding is also projected to increase, and floods could become more frequent.

Increased tidal flooding and coastal erosion is therefore likely to cause losses to the tourist industry although the magnitude of losses would depend on how the tourist industry changes in the future. There are also opportunities for increased tourism as a result of warmer summers, therefore the net effect of climate change could be positive.

Potential opportunities for the tourism industry include changing holiday trends and the potential for new markets. There is scope to further promote outdoor activities given the physical beauty and variety of the Welsh landscape. The changing climate is likely to affect the tourist potential of different areas and different types of activities.

Climate change impacts on financial services

The financial services sector accounts for less than 5% of Gross Domestic Product in Wales and employs about 2.6% of the workforce. However, climate change can have a major impact on investment performance with severe potential consequences for the financial sector. This would be exacerbated if risk management processes are inadequate or climate change risks are underestimated.

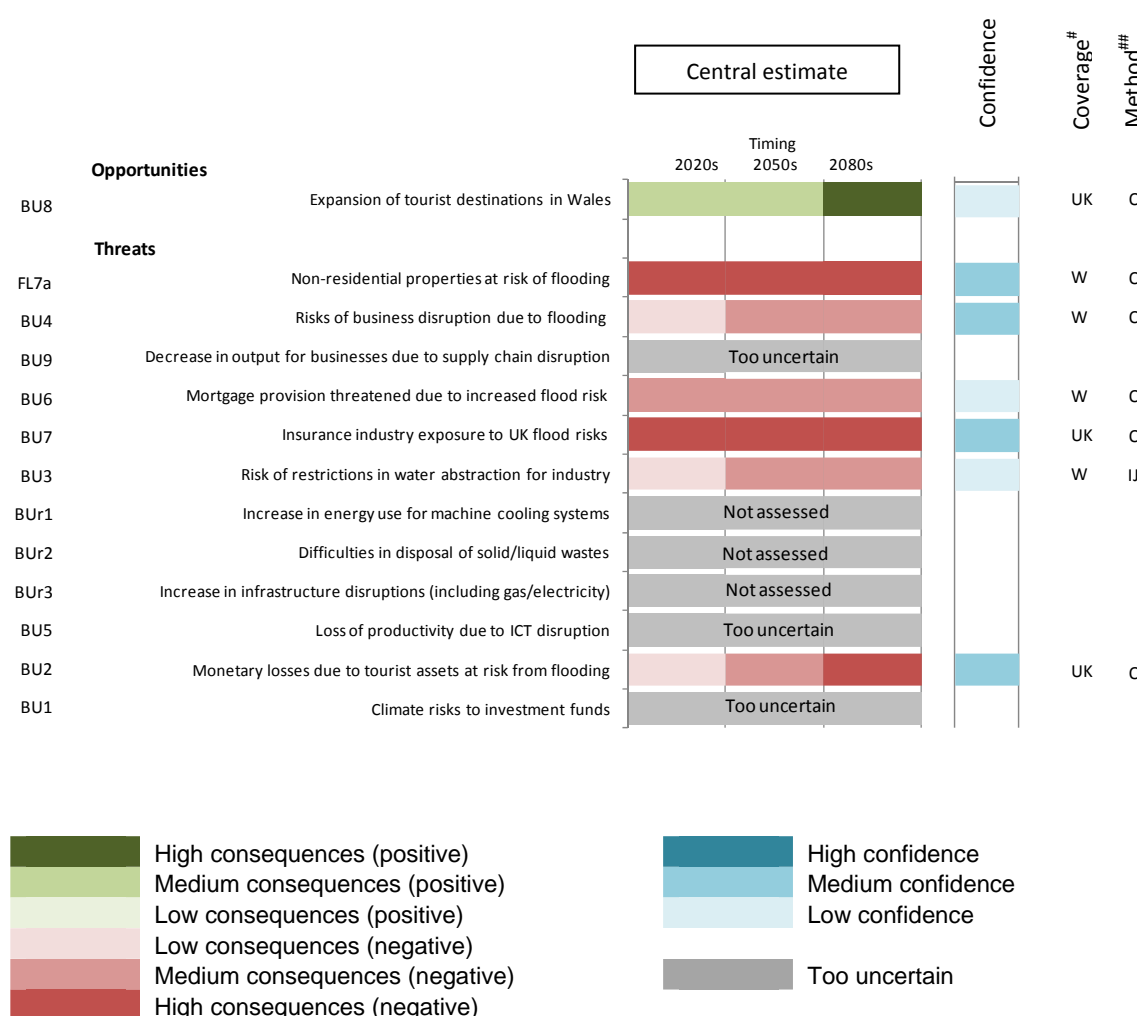
Particular issues on investment performance might include, for example, the actual benefits of an investment being lower than the expected benefits because of climate change impacts. The international insurance market would also be affected by climate change impacts. The potential effects on the UK mortgage and insurance markets are discussed above.

Whilst there was insufficient evidence to quantify the magnitude of these impacts in the CCRA analysis, it is clear that they could be very important with knock-on effects across business and society.

Summary of results

The results of the analysis are shown in Table 4.6. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA 2012a) but have been adjusted for Wales where appropriate.

Table 4.6 Climate change impacts on Business



#Coverage of analysis		##Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on Business

The potential for future increases in flooding is a major risk to business, affecting business premises and supply chains, and disrupting operations. Some smaller companies may not have the resilience to recover. The business sector is also vulnerable to infrastructure failure and disruption that may become more likely because of climate change.

A potentially large but unquantified risk is the failure of the financial sector to adequately take account of climate change, resulting in poor financial performance which could have widespread consequences for business and other sectors.

Coastal tourism could be adversely affected by the impacts of sea level rise and erosion on beaches and coastal features. However there are opportunities for an increase in tourism both on the coast and inland.

4.5 Buildings and Infrastructure

Buildings range from modern residential properties and offices to relatively old houses associated with industry and agriculture.

Infrastructure provides the physical framework for society including transport, water supply, drainage and waste water disposal, energy supply and communications (ICT). In the urban environment, infrastructure includes local roads, paths, parks and other green space.

The main potential climate change effects on buildings and infrastructure include:

- Flooding, that can affect a significant proportion of all buildings and infrastructure.
- Subsidence and landslips, that could potentially affect buildings and sections of the transport network in some areas.
- Increased summer heat, that particularly affects conditions in buildings and the urban environment, although the 'Urban Heat Island' effect is not regarded as a major concern, partly because the large cities are on the coast and because they are smaller in scale and density than the larger cities elsewhere in the UK.
- Changes in energy demand, with more cooling required in summer but less heating in winter.
- Changes in water availability, particularly reductions in the summer.

The impacts of climate change on infrastructure and buildings are covered under the following headings: buildings and the urban environment; urban space; transport; water supply; and energy supply. ICT is discussed under Business.

4.5.1 Buildings and the urban environment

There are estimated to be about 2 million buildings in Wales including 1.26 million residential properties. Climate change impacts that could affect buildings include floods, overheating and soil instability (subsidence and landslips).

Flood risk

Flood risk in Wales is higher than in other UK countries in terms of the proportion of people, property and infrastructure at risk of flooding. This reflects the fact that most of the population is either near the coast or in river valleys.

It is estimated that about 357,000 properties (including residential and non-residential) are at risk of some form of flooding, approximately one property in six. It is likely that the number of existing properties at risk would increase as a result of climate change.

There are currently about 220,000 properties at risk of river and tidal flooding, about 11% of all properties. It is also estimated that about 230,000 properties (about 12% of all properties) are currently at risk of surface water flooding. These numbers of properties both include about 97,000 properties that are at risk from surface water flooding and river and tidal flooding. This overlap explains why the sum of 220,000 plus 230,000 properties exceeds the overall total of 357,000 properties.

There are about 65,000 properties at significant likelihood¹¹ of river and tidal flooding. This number is projected to increase to between 85,000 and 135,000 by the 2020s, rising to between 90,000 and 230,000 by the 2080s. The number of residential properties at significant likelihood of river and tidal flooding is projected to rise from about 41,000 (1961-90 baseline) to between 60,000 and 150,000 by the 2080s, affecting between 150,000 and 350,000 people (4% to 10% of the projected population). Properties at significant likelihood of river and tidal flooding are shown in Figure 4.7 for selected climate change scenarios.

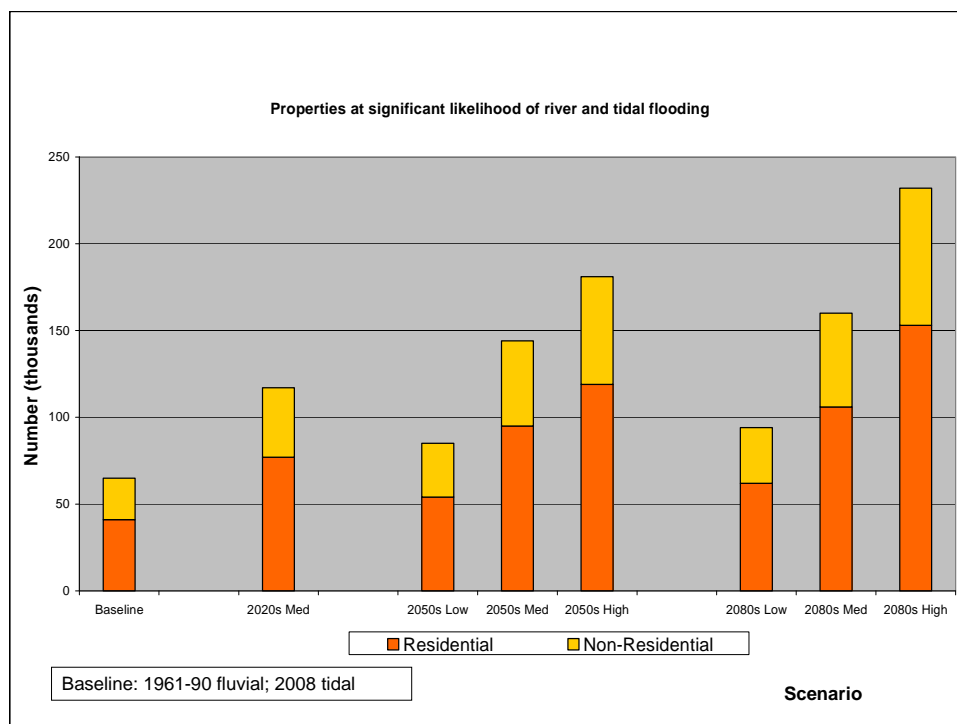


Figure 4.7 Properties at risk of river and tidal flooding

The projections include both existing and new properties (based on the socio-economic projections). However it is expected that planning controls and policy on flood risk will reduce flood risk to new developments by ensuring that high risk areas are avoided and suitable mitigation measures are incorporated into layouts and design.

No projections are currently available on how surface water flood risk might change in the future. However it is likely to increase given the projected increases in mean and extreme rainfall, as discussed in [Appendix B](#), Section [B.4](#).

The Expected Annual Damages (EAD) of residential and non-residential properties at risk from tidal and river flooding is projected to be between £200 million and £400 million by the 2020s, rising to between £250 million and £900 million in the 2080s (at today's prices). This provides an indication of the potential increase in the annual cost of flood damage assuming that flood defences remain exactly as they are today. In practice flood risk will be reduced by flood risk management measures and increased by defence deterioration.

The 65,000 residential and non-residential properties at significant likelihood of river and tidal flooding are below the flood probability threshold used by the Welsh Government and the Association of British Insurers (of 1.3% chance of flooding per annum or greater), about 3.5% of all properties in Wales. This provides an indication of the number of properties where the provision of insurance could be affected by flood risk. By the 2020s this number could rise to between 85,000 and 135,000 properties.

¹¹ 1.3% annual probability or greater (1 in 75 years on average or greater).

Experience to date suggests that the number of properties unable to obtain insurance may be less than these figures indicate, but this would depend on future change in flood risk and the ability and willingness of the insurance industry to cover any increase in risk.

There are over 600ha of Scheduled Ancient Monument sites at significant likelihood of flooding. This could rise to between 700 and 900ha by the 2080s. The impacts of flooding on other aspects of cultural heritage, for example listed buildings, has not been quantified in the CCRA analysis.

Flooding from a combination of different sources could increase with climate change, particularly in coastal areas where rising sea levels would make the discharge of the increasing fluvial flood flows more difficult. This is a particular concern as most of the largest cities and towns are on the coast. The potential increasing incidence of tide-locking (i.e. the closure of drainage outfalls caused by high tidal water levels) would contribute to this problem.

Climate projections suggest that the amount of rainfall that falls during heavy rainfall events may increase in the future, which may increase the frequency of spills from combined sewer overflows (CSOs).

Sewer flooding has not been assessed as part of the CCRA. However, a previous study has estimated that there may be a 27% increase in sewer flooding by the middle of the century due to climate change (Ofwat, 2011).

Increases in CSO spills and sewer flooding would lead to increases in damage and clean-up costs. In addition to climate, CSO spills and sewer flooding are heavily influenced by socio-economic drivers (e.g. population change, which affects sewer flows, and the extent of impermeable ground surfaces in any given location, which influences rainwater runoff).

Heat impacts

The risk of overheating in buildings is currently relatively low. However overheating may become a problem within the lifetime of buildings constructed today and should be taken into account in building design.

Damage from heat and the consequent drying of buildings is expected to increase as the temperature rises although no robust evidence was identified to assess this impact.

Soil impacts

The number of claims for subsidence damage to buildings is likely to rise in the UK as a result of changes to the shrink swell pattern of clay soils. Projected increases in subsidence claims of about 7% for the UK are projected by the 2020s, rising to 20% in the 2080s. Subsidence is generally not a serious problem in Wales. The main area of risk is in the clay soils of south east Wales.

The incidence of soil erosion and landslips causing damage to buildings is likely to increase. This is a particular concern in Wales as there are a relatively large number of settlements in valleys or on hillsides.

4.5.2 Urban space

There are both opportunities and threats to urban space as a result of climate change. Increasing temperatures could lead to higher temperatures in cities caused by the 'Urban Heat Island' effect, although this is not regarded as a major issue for Wales, as cities in Wales are not as large as many elsewhere in the UK and are located on the

coast. Increasing temperatures and reduced summer rainfall could also lead to changes in lifestyles with more outdoor living, for example more street cafes.



Figure 4.8 Urban green space: Cardiff

The main adverse impact identified in the CCRA analysis is the effect of higher summer temperatures and reduced rainfall on urban green space. The capacity of green space to provide cooling benefits within urban environments may reduce, both as a result of temperature rise and a reduction in cooling from evapotranspiration of moisture. The landscape would also be affected as vegetation dries out.

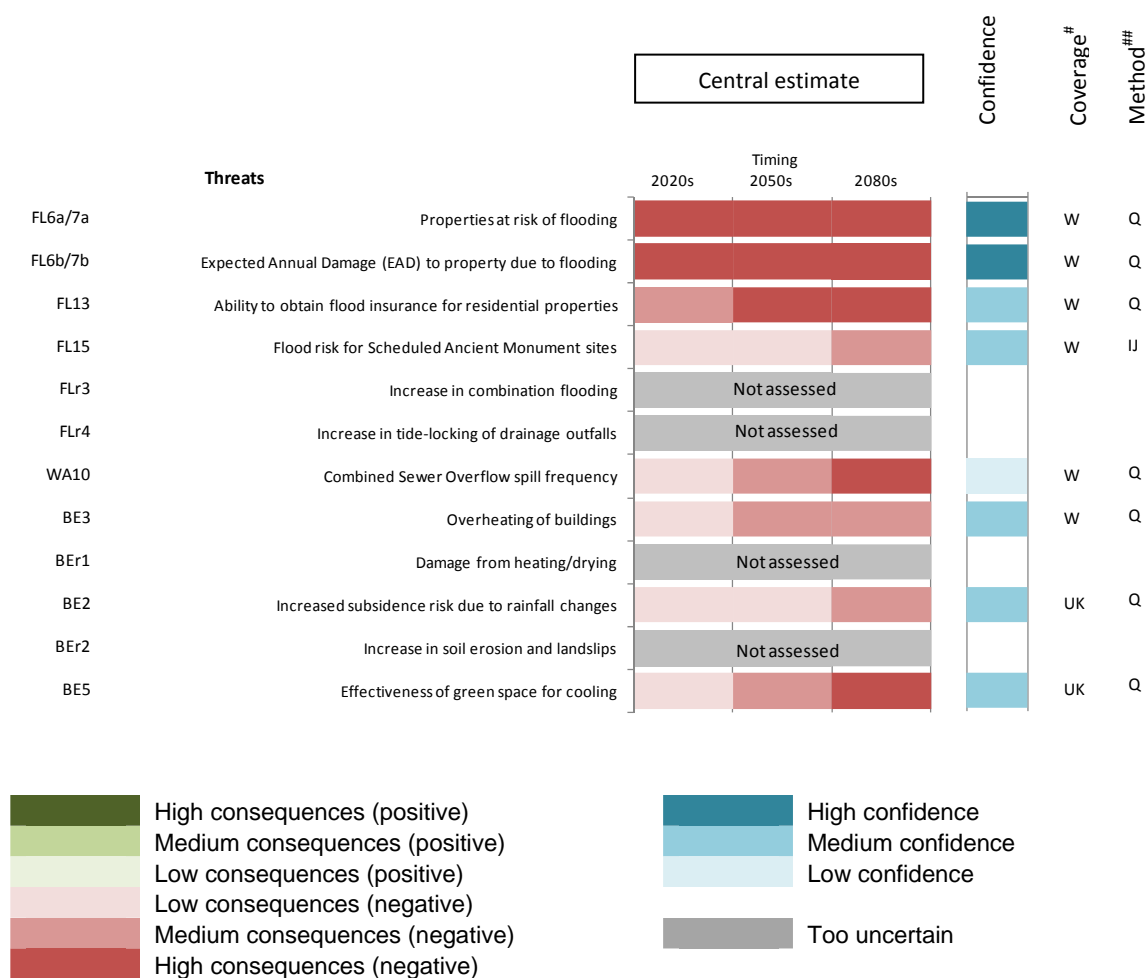
The effect of climate change on the cooling benefit of urban green space was represented in the CCRA by a reduction in the effective area of green space. It is projected that the reduction for the UK as a whole could be about 15% by the 2050s rising to over 30% by the 2080s.

4.5.3 Buildings: summary

Summary of results

The results of the analysis are shown in Table 4.7. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA 2012a) but have been adjusted for Wales where appropriate. In particular, overheating of buildings and building subsidence are considered to be less significant in Wales than the UK as a whole.

Table 4.7 Climate change impacts on Buildings and the urban environment



#Coverage of analysis		##Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on buildings and the urban environment

Impacts of the projected increases in flooding on buildings are potentially a major consequence of climate change. The number of properties at significant likelihood of flooding could increase by between 40% and 250% by the 2080s. Flood insurance for some properties may become expensive or difficult to obtain.

The effects of heat in the urban environment are likely to become increasingly important as temperatures rise, including both the environment within buildings and the wider urban environment. Green spaces may become less effective at providing cooling, and lifestyles may change to more outdoor living.

4.5.4 Transport

The vast majority of transport within Wales is by road and rail. Water and air transport includes ferry services between Wales and Ireland, and internal and international air services. As most transport needs are provided by roads, and are projected to do so in the future, most of the CCRA analysis has concentrated on road transport (UKCIP/BESEECH, 2005).

Flooding of transport infrastructure

Flooding of roads and railways, and the associated disruption, is projected to increase. Not only does this affect some of the main roads including motorways, but many rural communities can be cut off if their access roads flood. Some of the main railway lines are particularly vulnerable to flooding including those on the west and north coasts.

Currently it is estimated that about 22km of motorways, over 2,300km of A-roads and other roads and over 400km of railway lines are at significant likelihood of flooding¹². It is projected that these figures would gradually increase as flood risk increases, with an overall increase of about 20% by the 2080s.

Disruption and delay to road and rail traffic and the associated consequences for society and business is likely to increase if flooding increases. Some detailed analysis of costs has been carried out for the 2007 flood, which affected large parts of England and Wales. The estimated cost of transport disruption was about £100 million.

The annual frequency of occurrence of the 2007 flood varies from location to location, but was about 0.5% (1 in 200 years) on the River Severn at Gloucester. An equivalent flood of this magnitude might have an annual probability of 1.3% (1 in 75 years) or greater by the 2080s.

Landslips, coastal erosion and bridge scour

The incidence of landslips affecting transport may increase. The main cause of this is increased winter rainfall leading to greater slope instabilities. This is a particular concern as there is a relatively large number of transport corridors in valleys. The number of roads and railways at risk of landslides may double by the 2080s.

Coastal erosion is likely to be an increasing threat to infrastructure either on or close to the coast. Some major transport links run along the coast and are therefore vulnerable. These include main road and rail links along the north Wales coast. A further threat to roads and railways is bridge scour which could potentially increase as a result of increases in flood flows in rivers.

¹² Annual probability of flooding of 1.3% (once in 75 years on average) or greater.



Figure 4.9 Transport links on the coast: the A55 in north Wales

Impacts of temperature change

Temperature rise would affect the comfort of travellers and transport staff on all forms of transport including roads and railways. This has not been analysed in the CCRA.

Increased temperatures would affect transport infrastructure including road surfaces and rail. Rail buckles were identified as a potentially serious problem, and the number of rail buckles could increase by a factor of 3 to 5 by the 2080s due to rising temperatures. There are currently about 2 rail buckles a year in Wales (6 occurred in the hot summer of 2006).

Higher winter temperatures may benefit transport as disruption and delay caused by snow and ice may become less frequent. This may also lead to a reduction in maintenance and repair requirements. This would however increase the risk of being less well prepared for occasional severe winters. The capability to respond to severe winters is still likely to be required.

A particular problem with warmer winters is a potential increase in the freeze/thaw cycle (i.e. the number of times the temperature passes 0°C). This contributes to damage to paved surfaces (including roads, runways and ports) and also creates dangerous driving conditions.

Demand for transport may increase for a number of reasons including consequences of climate change, for example increased tourism. It may be difficult to provide the required infrastructure in some areas for topographic reasons, as the land is steep and the available space for transport links is limited. Other changes that could affect transport in the future include social and economic change, technology change and shifts in transport modes (for example, from cars to mass transport systems).

IMPACTS OF TIDAL FLOODING AND EROSION ON TRANSPORT



Railway line adjacent to the coast (Tywyn, Gwynedd)

Erosion and extreme storm events can cause damage and disruption to transport and communications infrastructure on the coast. Erosion and flooding can undermine structures, increase the chances of landslips, cause damage to railway tracks and roads, and disrupt signalling.

A fifth of Wales' artificially defended coastline is the responsibility of Conwy County Borough Council (Redfern, 2010). Despite the current defences, the County Borough considers tidal flooding and erosion to be a high risk.

Given the topography and the fact that many transport links are along the coast, this can create large problems for social and economic activity. Some of the main links affected by flooding and coastal erosion are:

- The railway on the west coast
- The Conwy Valley railway to Blaenau Ffestiniog and the Dyfi estuary
- The M4 near the Severn crossing
- Road and rail links along the north Wales coast including the A55 and the main railway line along the Dee estuary.

Towyn Flooding 1990

On 26th February 1990, a combination of storm-force winds, a high tide with a 1.3 m surge and extreme wave conditions (4.5 m) caused the breach of more than 400m of the railway-owned sea wall and the flooding of thousands of properties along the coastline of Conwy, including those in Towyn and Kinmel Bay. More than 2,500 properties were affected, 38% of which had no contents insurance; more than 5,000 people were evacuated and housed in temporary accommodation. The total cost of this flood was estimated at £35 million.

4.5.5 Water supply

Water supply is likely to become increasingly stressed in the future. Whilst overall rainfall is not projected to change significantly, summer rainfall is projected to reduce and winter rainfall increase. In addition, domestic water demand is projected to increase as a result of increases in aridity and population.

Wales largely depends on surface water for its water supply, as groundwater resources are very limited. There are already a number of large storage reservoirs, although some of these are used to provide water to parts of England.



Figure 4.10 Craig Goch reservoir, Powys

Overall it is estimated that the supply demand balance in the three UKCP09 river basin regions in Wales (Dee, Severn and West Wales) could change from a surplus of about 160MI/day at present to a deficit of about 200MI/day by the 2050s and a deficit of over 400MI/day by the 2080s under the p50 Medium Emissions scenario with no population growth and assuming that no adaptation is carried out. Some water resources zones are already in deficit as a result of recent changes in temperature and precipitation.

The time of greatest water stress is expected to be in the summer, when there would be a reduction in the availability of water. It is provisionally estimated that about 40% of the population might be affected by a supply-demand deficit by the 2020s rising to over 90% by the 2080s, although the uncertainty associated with these estimates is large. Plans are in place to close the deficit to 2035 but more action may be needed.

An indication of the likely future stress on water supplies is the number of river abstraction sites with sustainable abstraction. This is projected to change by between plus 10% (increase) and minus 65% (decrease) by the 2020s. By the 2080s a reduction of between 50% and 80% is projected compared with the 1961-90 baseline.

The overall impact on water supplies would be strongly affected by adaptation measures (for example, increased water storage) and changes in regulation and water use.

There is likely to be an increasing risk of drought in warmer drier summers. Whilst measures are likely to be taken in the future to adapt to changing water availability, drought is considered to be a major potential future risk. This is supported by aridity projections which indicate that the dry summer of 2003 could become a typical summer by the 2050s.

There is a particular concern regarding the impacts of climate change on private water supplies. These are often more vulnerable to change than public supplies because they are very dependent on rainfall in their local area and lack flexibility to obtain supplies from elsewhere.

Water supply infrastructure is likely to be increasingly vulnerable to flooding as flood risk increases. This in turn would affect water supplies and potentially lead to failures of supplies, as occurred in England during the July 2007 floods. This has not been quantified in the CCRA analysis owing to a lack of suitable data, but is an important potential impact of climate change. It is estimated that about two thirds of water pumping stations and treatment works are at significant likelihood of flooding in Wales, and this is likely to increase with climate change (Environment Agency, 2009).

4.5.6 Energy supply

Potential climate change impacts for the energy sector include disruption caused by increased flooding, changes in demand and effects of heat.

Power stations in Wales can generate about 9GW of energy, about 10% of the overall UK generation capacity. Most of the power stations are fossil fuel stations (coal or gas) on coastal or estuary sites. There is one nuclear station (Wylfa) and two large hydro pumped storage schemes (Dinorwig and Ffestiniog).



Figure 4.11 Renewable energy source: wind power

Some of the projections related to energy supply are highly uncertain because of the current transition to a low carbon economy, both in terms of generation and demand. Currently about 25% of electricity generating capacity is from hydropower including the pumped storage schemes referred to above. About 3% of generating capacity is currently from wind.

Flood risk

About 20% of power generation capacity is at significant likelihood of flooding. This could rise to about 30% by the 2020s and about 50% by the 2080s, assuming that the generation sites do not change. The actual flood risk to each station depends on the standard of protection provided by local flood defences, which may differ from the general standards of protection used in the CCRA analysis.

Power stations are connected to the National Grid, and therefore there is considerable flexibility in the system even if part of the generation capacity is disabled.

In practice the locations of future power stations may change. It is understood that one of the eight new nuclear power stations in Great Britain is likely to be located at Wylfa in Anglesey, a coastal site where most of the site has a low flood risk.

The electricity distribution and transmission system is vulnerable to flooding. An estimated 12 major sub-stations (400kV to 132kV transformation) are currently at significant likelihood of river and tidal flooding. This is projected to rise to about 14 by the 2080s.

The consequences of flooding of electricity infrastructure are difficult to assess because large events are rare and consequently there are not enough records to develop a statistically robust relationship. However the consequences can be severe. For example, the severe flooding that affected Carlisle in 2005 caused power outages for approximately 36 hours with about 63,000 customers affected.

Water availability

Changes in seasonal precipitation could affect water availability for hydro-electric power stations, although overall annual precipitation is not projected to change. Most of the hydro-electric power is generated by two pumped storage schemes (Dinorwig and Ffestiniog), which have a combined capacity of over 2GW. There are a number of smaller hydro-electric power stations, with a combined capacity of about 120MW.

The overall availability of water for hydropower generation may not change significantly, but there is projected to be more water in winter, the time of greatest demand for electricity, and less in summer. This may therefore provide a benefit for hydro-power production.

Water is required for cooling of power stations. As temperatures rise, the amount of water required for power station cooling may increase as more water would be needed to achieve the same amount of cooling. If water quantities are not increased, there would be a reduction in generation capacity. As power stations in Wales are generally on the coast, there is theoretically no limit to the amount of water available. However there may be a need to increase the capacity of cooling systems.

Energy demand

Heating energy demand per property in the winter is projected to reduce. The reduction in energy demand for heating is projected to be of the order of 15% by the 2020s, rising to about 25% by the 2050s for the p50 Medium emissions scenario. However, projected increases in population mean that the overall heating demand may show little change.

Projections indicate that cooling demand could change from a current level of about 25TWh per year (25,000GWh) to between 20 and 60 TWh per year by the 2020s and between 15 and 150TWh per year by the 2050s for the UK as a whole. Heating demand is however likely to continue to exceed cooling demand by the 2050s.

Impacts of increasing temperatures

Increasing temperatures could potentially cause heat damage to energy infrastructure resulting in disruption to supplies. However this is not expected to be a major climate change risk.

Distribution and transmission equipment could however suffer a capacity de-rating because of higher temperatures. It is projected that the capacity of the distribution and transmission system could reduce by between about 1.7% and 10% by the 2050s relative to the 1961-90 baseline.

Increasing temperatures could affect the efficiency of turbines, as the amount of air that can be drawn into turbines and the amount of fuel that can be burned would reduce. This could lead to a reduction in turbine-based power generation.

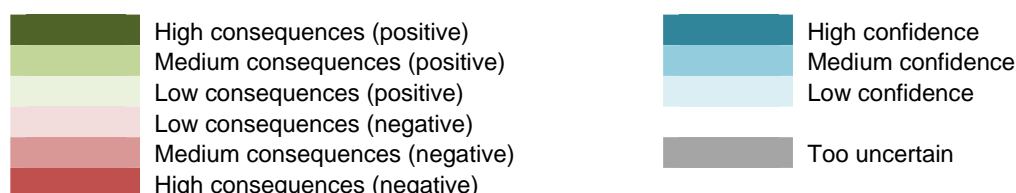
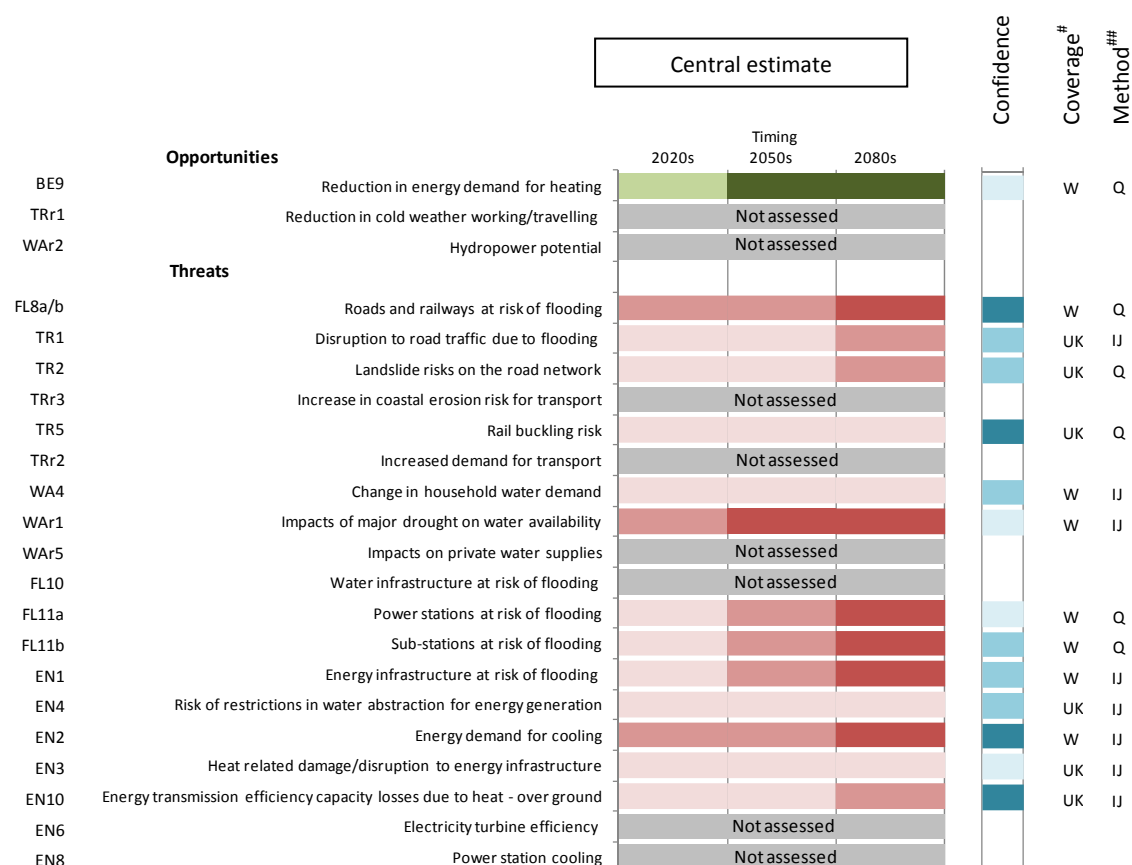
As discussed above, the amount of cooling water for power stations may increase, leading to an increase in the potentially adverse environmental impacts of temperature rise in the receiving waters. In practice, temperature increases may be limited for environmental reasons, particularly during heat wave and drought periods, leading to a reduction in power generation.

4.5.7 Infrastructure: summary

Summary of results

The results of the analysis are shown in Table 4.8. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA, 2012a) but have been adjusted for Wales where appropriate. In particular, the scores for energy infrastructure are based on Welsh data.

Table 4.8 Climate change impacts on Infrastructure



# Coverage of analysis		## Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on infrastructure

Reduction in water availability is a major potential impact of climate change. If adaptation measures are not taken this could have severe consequences for homes, businesses and other water users. This would be exacerbated if there is an increase in the magnitude and severity of future droughts.

Another major impact of climate change is a projected increase in flooding of critical infrastructure, resulting in a potential increase in failures of electricity, water and other essential services. Flooding of roads and railways is also projected to increase, resulting in delay, disruption and additional repair costs.

It is likely that there would be an additional requirement for energy in the summer for cooling, although this is likely to still be less than the capacity needed for winter heating demand by the 2050s.

4.6 Health and Wellbeing

Wales has a population of about 3 million people. This is projected to rise to about 3.7 million by the 2080s (range 2.6 to 5.0 million). The impacts of climate change on health and well-being are likely to include:

- Higher temperatures, causing both benefits (milder temperatures in winter) and adverse impacts (higher extreme temperatures in summer).
- Increase in flooding from sea level rise, higher winter precipitation and more intense rainfall.
- Changes in both air and water pollution.

Health effects of climate change are likely to have the greatest impact on vulnerable people, particularly those in poor socio-economic conditions. The health effects of climate change on vulnerable people are likely to be disproportionately severe because of their limited ability to cope.

Increased temperatures

Higher summer temperatures are likely to cause an increase in the number of heat related deaths. It is projected that the annual number of premature deaths from extreme heat in summer could rise from a present day figure of about 40 to between 60 and 350 by the 2050s and between 70 and 1,000 by the 2080s.

The number of patient days per year caused by heat related illnesses (i.e. cardiovascular and respiratory diseases) is also projected to increase. Tentative estimates in the CCRA indicate that the number could be between 6,000 and 30,000 patient days per year by the 2050s and be of the order of 10,000 to 100,000 by the 2080s. The current baseline is about 4,000 patient days per year.

Changes in sunlight / UV exposure as a result of climate change could lead to additional melanoma and non melanoma skin cancer cases. However, the many factors that affect the development of skin cancer mean that it is not currently possible to provide reliable projections of future numbers of cases or resultant deaths. These factors include changes in social behaviour and improved treatments.

A potential benefit of climate change is the number of premature deaths avoided annually because of milder winters. It is estimated that between 300 and 2,000 premature deaths could be avoided per year by the 2050s. These estimates are a substantial proportion of the present day figure of between 1,800 and 3,500 premature deaths per year as a result of cold weather.

Similarly to additional hospital admissions due to heat, the number of additional hospital days per year avoided as a result of milder winters could be about 100 times greater than the number of premature deaths avoided due to cold, although estimates have not been quantified in the CCRA.

The increases in summer deaths (heat) and decrease in winter deaths (cold) are shown on Figure 4.12. These figures take account of potential socio-economic change.

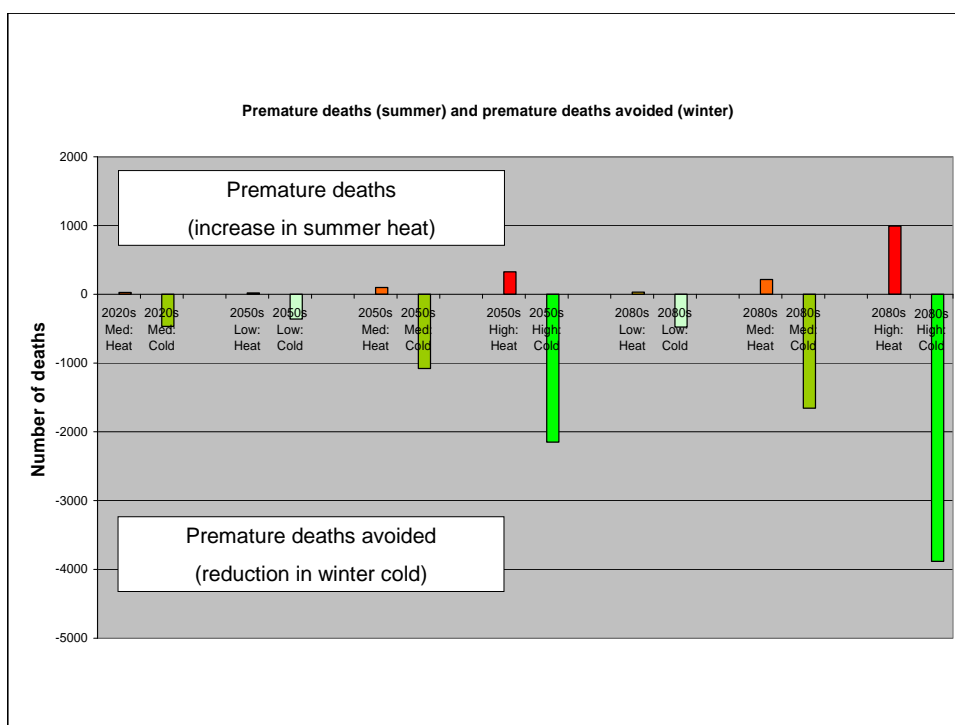


Figure 4.12 Temperature change impacts on mortality

Increasing temperatures are likely to lead to changes in lifestyles, with more activities being undertaken outdoors including leisure, sport and tourism. The overall impact on health is likely to be positive although there would be adverse impacts, for example increased sunlight / UV exposure referred to above.

Floods

Wales is at risk from tidal, fluvial (i.e. rivers and other watercourses) and surface water flooding. Deaths and injuries from floods and storms (including wave action on the coast) are projected to increase although the overall numbers are modest. It is estimated that about 20 people a year die from floods in the UK, and this could rise by between 20 and 40 by the 2050s. The number of injuries due to floods could be about 20 times these figures.

The overall number of people in homes exposed to flooding is likely to increase. The number of people at significant likelihood of tidal and river flooding is projected to increase from about 100,000 (1961-90 baseline) to between 120,000 and 200,000 by the 2020s rising to between 150,000 and 350,000 in the 2080s. Overall it is estimated that there are about 600,000 people (20% of the population) at risk of some form of flooding, although the annual probability of flooding in many cases is very low.

Vulnerable people are particularly affected by flooding. An assessment has been made based on the number of residential properties in the highest 20% of deprived areas¹³. Based on this analysis, it is estimated that there are of the order of 6,000 properties in deprived areas at significant likelihood of tidal and river flooding. It is projected that this could rise to between 8,000 and 16,000 by the 2020s and to between 8,000 and over 25,000 by the 2080s.

It is estimated that the number of people suffering from mental health problems as a result of flooding in the UK could increase from the present day estimate of 3,000 per year by an additional 4,000 to 7,000 by the 2050s.

¹³ Based on the Index of Multiple Deprivation (IMD), where Output Areas of the 2001 Census have been classified into ten divisions (or deciles) according to the degree of social deprivation.

Many health facilities are at risk of flooding including hospitals, health centres and GPs practices. Disruption to services could therefore occur during extreme conditions. It is estimated that about 10% of hospitals are currently at significant likelihood of flooding. This is projected to rise to between 12% and 18% by the 2050s.

Health facilities would also be disrupted if vital infrastructure and services fail. Flooding of transport links and failures of ICT services would contribute to service disruption during extreme weather events.

Flash flooding from watercourses and overland flow is a particular concern in Wales because of the steep topography. Flash flooding is caused by local heavy rainfall over steep catchments and can occur with little or no warning, leaving little time to prepare and remove assets (e.g. vehicles) from flood risk areas (Figure 4.13). Pollution caused by flooding of contaminated sites is also a concern. Both of these impacts are likely to increase as a result of wetter winters and more intense storms.



Figure 4.13 Flash flooding at Cilgerran

(Source: Welsh Government)

Air quality

Climate change is projected to contribute to a worsening of air quality in the summer but a possible improvement in the winter. A particular concern in summer is a potential increase in ground-level ozone in conditions of warmer temperatures and increased sunlight.

It is projected that the number of premature deaths per year caused by ground-level ozone could increase by between 40 and 300 by the 2080s compared with a current baseline of about 600 per year. The number of respiratory hospital admissions per

year could increase by between 100 and 1,000. The current baseline is about 1,900 per year.

There are currently high levels of respiratory problems in Wales during the winter. Winter air pollution episodes are likely to decline in frequency and intensity partly as a result of warmer temperatures. Apart from climatic effects, winter air pollution episodes are also likely to further decline due to projected reductions in atmospheric emissions caused by future tightening of both fuel and vehicle emission legislation.

Water quality and quantity

The availability of water is projected to reduce in summer. It is provisionally estimated that about 40% of the population might be affected by a shortage of water by the 2020s rising to over 90% by the 2080s, if adaptation measures are not implemented. This could potentially affect well-being and hygiene standards.

There could be a significant increase in the number, seasonality and severity of marine-acquired infections as sea surface temperatures rise and water quality is affected by changes in summer and winter discharges into the sea.

Freshwater quality (including rivers and lakes) may be adversely affected by an increase in the number and magnitude of floods and a reduction in flows in the summer. This could potentially lead to an increase in water borne diseases, for example cryptosporidium, which affects both animals and people. Another concern that has been identified but not analysed in the CCRA is a potential increase in chlorine depletion.

Cryptosporidium

Cryptosporidium is a single celled parasite which, if ingested, can cause an illness called cryptosporidiosis. It is the leading cause of gastrointestinal infection in the UK. Most healthy people would recover from the infection without treatment, but for those that are immune-deficient, the very old or very young, cryptosporidiosis can be severe and life-threatening.

The hardy stage of the parasites life cycle, the oocysts, is released in faecal matter and is spread when the recipient comes into contact with this matter, either through poor hygiene, infected water supplies, or recreational activities in contaminated water. Cryptosporidium is highly resistant to conventional water treatment methods (Public Health Wales, 2010).

Climate change has the potential to increase the spread of the disease, particularly in periods of heavy rainfall, which increases the chances of the oocysts getting into drinking water supplies. However, Wales' commitment to high standards of water-treatment technologies should be able to keep the outbreak risk to a minimum.

However, outbreaks do occur. In 2005, in Gwynedd and Anglesey, 231 people contracted the infection; 70,000 homes had to boil their water before drinking it or using it to prepare food for 6 weeks (Trewyn, 2008). Distributing warnings and advice in areas such as this is particularly difficult, with large numbers of transient occupants (holiday-makers).

Climate change impacts on emergency response and recovery

The need for emergency response to extreme weather events is likely to increase if projected increases in the magnitude and frequency of extreme weather events occur. Extreme weather events of greatest concern include floods, fires, heat waves and drought. It is provisionally estimated that the response and recovery requirement for

floods might increase by 2 to 3 times by the 2080s, and the frequency of heat waves might increase by a factor of 10 in the same period. The increase in emergency response requirement for heat waves will depend on the degree to which adaptation measures have been implemented.

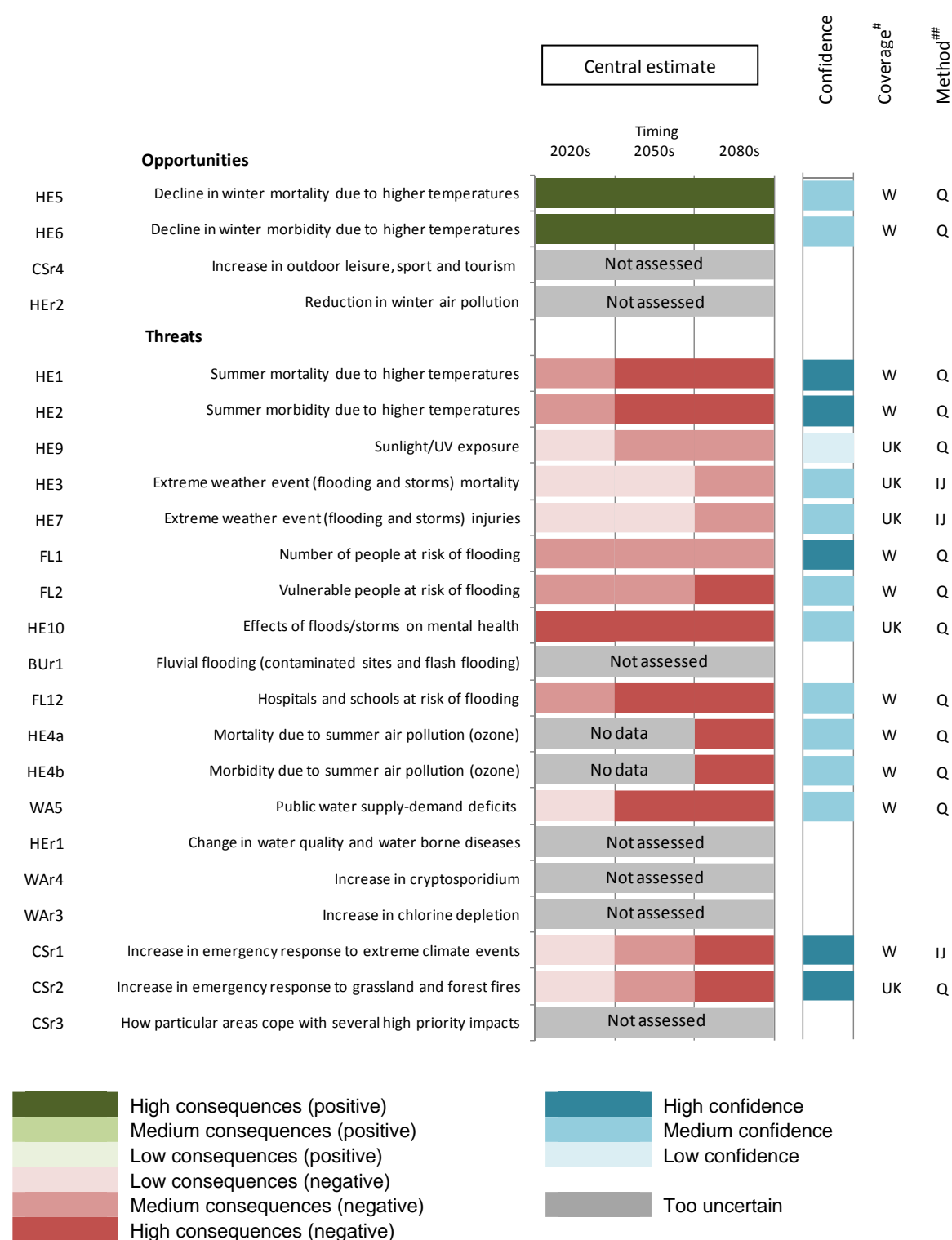
The requirement for emergency response to grassland and heathland fires is projected to increase by between 100% and 180% by the 2080s compared with present day (based on the projected number of fires per year for the UK as a whole).

Emergency response includes preparing for emergencies, responding in an emergency, and recovery after the event. Those involved in emergency response extends beyond the emergency services (police, fire & rescue, health) to Local Authorities and the voluntary sector.

Summary of results

The results of the analysis are shown in Table 4.9. The consequence and confidence scores are based on those used in the CCRA Evidence Report (CCRA, 2012a) but have been adjusted for Wales where appropriate.

Table 4.9 Climate change impacts on Health and Wellbeing



#Coverage of analysis		##Method of analysis	
W	Analysis undertaken for Scotland only	IJ	Informed judgement
UK	Analysis undertake for the UK	Q	Quantitative

Summary of the main impacts of climate change on health and well-being

The most important climate change impacts on health include:

- The effects of increasing temperatures (including heat waves).
- Flooding, particularly because of the large numbers of people affected and the potentially serious impacts that this can have on individuals.

Reduced water availability could also lead to adverse health impacts although it is likely that these will be managed by adaptation actions. The vulnerable in society will be most affected by these impacts.

Potential improvements in health include reduced cold weather mortality and morbidity, and possibly less air pollution in the winter.

The need for emergency responses to floods, heat waves and fires could potentially increase, affecting the emergency services, local authorities and other organisations.

5 Summary of consequences

5.1 Introduction

The potential consequences of climate change are assessed by theme in [Section 4](#). This section considers the consequences for different types of location as identified by stakeholders. Their concerns for each type of location are summarised in [Section 1.5](#).

Some impacts are not directly related to a single type of location. For example, climate change impacts on the financial sector would have consequences on investment and business in all parts of Wales.

5.2 Consequences for different types of location

5.2.1 Major towns and cities

Most of the major towns and cities in Wales are on the coast or in river valleys with many major industrial installations in the floodplain. In addition, many of the main transport links are on the coast.

The largest urban areas are in south Wales, including Cardiff, Swansea and Newport. This area also includes the largest concentrations of industry. The main transport links run along the coast or the river valleys, which contain a number of towns and villages.

Potential climate change impacts identified in the risk assessment include the following:

- An increase in flood risk from both tidal and fluvial (i.e. rivers and other watercourses) sources. Estimates have been made for the whole country of increases in the consequence of river and tidal flooding including property numbers, property damage (both residential and non-residential), and roads and railways affected.
- Surface water flooding is also a major source of flood risk. Estimates of the number of properties currently at risk are available, but projections of how the risk may change in the future have not been made because of a lack of suitable data.
- Increased occurrences of combination flooding may occur (particularly tidal/fluvial and tidal/surface water) although the magnitude has not been assessed.
- Increased disruption to communities, the economy and employment caused by flooding. Estimates have been made for the whole country of the number of people affected by river and tidal flooding, and damage to both residential and non-residential properties. Impacts on the economy and employment have not however been assessed in detail.
- Disruption to services caused by flooding, including water supply, wastewater disposal, energy supply and health services. Flood risk to assets has been assessed, although the wider effects on people caused by the loss of services have not been covered in detail. An assessment has

been made of the potential impact of increased flooding on property insurance.

- An increase in property and other damage caused by landslips as many properties are located on valley sides. However estimates of numbers of properties affected have not been made.
- A reduction in water availability in the summer which would affect all water users including homes, industry and business. Estimates have been made of future water availability, future demand and the population affected by shortages based on the three river basin regions in Wales.
- The effects of climate change are likely to be more severe for vulnerable groups. An estimate has been made for the whole of the country of the number of vulnerable people at risk of river and tidal flooding based on the number of properties in the most deprived areas.

IMPACTS OF EXTREMES ON THE URBAN ENVIRONMENT: CARDIFF

Heavy rain-related events:

During the winter of 2006/07, heavy rainfall caused local sports pitches to become waterlogged. This led to a 16% decrease in income for Parks Services. More intense rainfall may be the biggest climate change issue for Cardiff.



Flooding in Cardiff

(Source: www.geograph.org.uk)

Heat-related events:

In July 2006, when temperatures reached over 30°C, the Council received a 3-fold increase in complaints about noisy-neighbours. Air quality is a particular concern for the health of inner-city occupants during longer heat waves.

Cold weather-related events:

The heavy snow experienced in Cardiff in February 2007 is estimated to have cost city businesses £5.5 million.

Wind-related events:

In January 2007, a local school experienced £139,000 worth of roof damage due to strong winds.

Other important impacts identified by Cardiff City Council include a decline in work efficiency, school closures, changes in pest populations, increased littering, damage to sports pitches and urban green spaces, disruption to transport services, health and safety issues for the public and city council staff and increased morbidity.

Climate change may increase the number and severity of extreme weather events such as floods, heat waves and droughts. The frequency and magnitude of the consequences of these events would also increase, together with the cost to the community and the Council.

5.2.2 Rural areas

Much of Wales consists of uplands where the main land use is agriculture. Most of this land is Grade 4 and Grade 5 (primarily grass land) and is used for livestock. Western areas including Anglesey, the Llŷn Peninsular and south west Wales are lower lying and have a higher proportion of Grade 3 land, including arable farming. It is estimated that about 10% of all agricultural land is used for arable farming. There are also extensive forests which occupy about 14% of the total land area.

The population in rural areas is relatively sparse and there are many small communities and farms. Potential climate change impacts identified in the risk assessment include the following:

- A potential increase in crop yields as temperatures increase, based on an analysis of arable crops. Increases in yield are also projected for grass, although the constraints to growth (particularly moisture and nutrient requirements) have not been assessed.
- A potential increase in occurrences of pests and diseases in plants, trees and livestock, based on the assessment of sample pests and diseases. However the results are uncertain. Livestock disease is a particular concern.
- A reduction in water availability during the summer (although there is projected to be little overall change in annual rainfall). Estimates of the potential reductions have been made by river basin region. The consequences of a potential increase in the frequency and magnitude of droughts are likely to be very serious.
- Drying out of land with consequences for the landscape and biodiversity. This has been assessed in terms of relative aridity for river basin regions and increase in fire risk for parts of Wales.
- Changes to the natural environment including impacts on habitats and species. These changes are likely to include changing locations of species, different migration patterns and disruption to the synchronisation of breeding cycles with food supplies.
- An increase in the impacts of extreme events on remote communities including the loss of service connections and flooding of roads. Estimates have been made for the whole country of the increase in river flood risk on properties, roads and critical infrastructure.
- There is a concern that the sustainability of agriculture and forestry could be affected by the combined effects of drier, hotter summers and wetter winters, leading to drying of land in the summer and increased erosion and flooding in winter. This in turn would affect rural economies and

communities. However, this combination of impacts has not been assessed.

- The effects of climate change would be more severe for vulnerable groups. Social vulnerability has been assessed at a national level in relation to flooding, but the impact on vulnerable groups in rural areas has not been investigated.

INLAND FLOODING



Abergwili, Carmarthenshire, November 2008

(Source: Welsh Government)

In addition to the major floods of Autumn 2000 and July 2007, serious flooding has occurred in each of the last four years (2008 to 2011). In September 2008, high levels of rainfall caused damage and disruption across Wales (BBC, 2008a). More than 100mm of rain fell in two days in many areas of mid-Wales. The South Wales Fire and Rescue Service had to deal with over 500 calls to flood incidents on the first day. Landslips occurred in several areas, affecting seven Rhymney and Gwent valley villages.

Rail services were disrupted between Cardiff and Swansea, Ebbw Vale and Caerphilly, Cardiff and Treherbert (where a landslide blocked the line) and Aberdare and Bridgend. People were advised not to travel.

Road links were also badly affected. The A470 was closed for hours southbound between the Abercynon roundabout and Pontypridd junctions; other more minor roads and the A40 and A465 were also affected. Ferries from Holyhead had to be cancelled, as did a number of community events including Cardiff Pride 2008 and Jazz in the Park.

At least 100 homes had to be evacuated from various towns and villages because of flooding from the River Taff. Several houses in Ynysboeth were flooded with 1.2m of

water after a culvert and a manhole burst due to the pressure of the water. People had to be rescued or evacuated from their homes, vehicles and places of work, including 155 children from Cradoc junior school in Brecon.

Climate change is projected to cause more winter rain and more intense rainfall events, leading to more frequent and severe emergencies of this type in the future.

5.2.3 Mountainous areas

There are a number of distinct mountainous areas that provide important biodiversity, landscape, public amenity and tourist areas. These include Snowdonia in the north and the Black Mountains and Brecon Beacons in the south. Potential climate change impacts identified in the risk assessment include the following:

- Drying out of bogs and other habitats in the summer, leading to a loss of biodiversity and carbon storage. This would also affect the mountain landscape. An assessment has been carried out on blanket bog, indicating that this important habitat and carbon store is likely to become more vulnerable.
- Migration of species to higher altitudes. This would affect both biodiversity, including the potential loss of species, and landscape. Whilst this was not assessed in detail in the CCRA analysis, there is already evidence that some species are moving to higher ground.
- An increase in soil erosion (or damage, then subsequent erosion) in drier summers, potentially exacerbated by an increase in tourism. Consequences include damage to habitats and footpaths, and sedimentation in watercourses.

BLANKET BOG



Ditch blocking using peat from on site

(Source: Countryside Council for Wales)

BLANKET BOG (Continued)

For the past five years major land owners in north Wales have been reversing the widespread practice of draining blanket bog. This historic drainage, believed to make the soil more favourable for farming and forestry, had resulted in peat shrinkage and erosion. This can cause biodiversity loss, flooding downstream and deterioration of water quality when rainwater flushes rapidly through the system.

As the climate changes over the coming decades, Wales can expect to see wetter winters and drier summers; storing water in peaty soil can help to attenuate flows and reduce the likelihood of flooding. Farmers have now been persuaded that they will still be able to graze sheep safely and over 500 hectares of blanket bog have been restored by using heather bales to block drains or by constructing peat dams. Healthy water-logged peat bogs also store more carbon.

5.2.4 The coast

Wales has about 1,500km of coastline, about 40% of which is designated as Heritage Coast. There are also extensive coastal and offshore sites that have international and national environmental designations. The coast thus provides an internationally important resource for people and wildlife. Potential climate change impacts identified in the risk assessment include the following:

- Loss of designated habitats and protected species as a result of coastal squeeze (caused by sea level rise) and erosion. The amount of loss has not been assessed in detail, although new information should make this possible in the near future. Species migration patterns are also likely to be affected.
- Erosion and damage to coastal areas including communities and transport links, due to coastal erosion and sea level rise. Estimates of erosion rates have been made together with an assessment of the potential loss of agricultural land.
- Damage to fisheries including shellfish caused by sea level rise, erosion and changes in water quality. Sea level rise and erosion are likely to reduce the area of shellfish beds.
- The uncertain impacts associated with a rise in sea temperature, which may include loss of local species and an increase in non-native invasive species. A qualitative assessment of this impact has been carried out.

THE DYFI ESTUARY

Located on the west coast, the area around the Dyfi river and estuary has been designated a UNESCO Biosphere Reserve - the only one in Wales. The designation means that the area must provide three functions: nature conservation at all scales, sustainable economic and human development and logistical functions (to support research, monitoring, education and information exchange in conservation and development).

The estuarine complex includes sandbanks, mud-flats, saltmarsh, peat bogs, river channels, creeks and an extensive sand dune complex. Within the valley and estuary area, there are a number of other designations including a Special Protection Area (SPA) comprising the estuary and adjoining saltmarsh and grassland (JNCC, 2001). The estuary also includes SSSI, SAC and RAMSAR designations.

THE DYFI ESTUARY (Continued)

The site is a traditional wintering area for Greenland White-fronted Goose *Anser albifrons flavirostris* – the most southerly regularly used area for this population in the UK. Large numbers of waders and wildfowl use the estuary to overwinter including wigeon, lapwing and golden plover. Other birds that breed in the dune and pebble beach areas include skylark, linnet, stonechat and shelduck.



Golden Plover

This area is already experiencing changes, both negative and positive; the most westerly area of bog has been eroded away by rising sea levels.

Evidence of this can be seen at low tide: the stumps of dead trees are still visible on the new beach near Borth. In the estuary, large areas of tidal sand and mud has given way to saltmarsh.



Shelduck



The sand dunes at Ynyslas are also very diverse and important to the conservation function of the biosphere reserve. The dune slacks contain rich orchid populations, including marsh orchids and marsh helleborine. They also contain important mosses and liverworts such as the rare petalwort. The dunes also support a rich variety of fungi, insects and spiders, some of which are very rare and only known at this site including one nocturnal hunting spider *Agroeca dentigera*, unknown elsewhere in Britain.

The Dyfi is a sensitive area where climate change (particularly sea level rise) could have significant impacts on the delicate balance between biodiversity and human activity.

Marsh orchid

Wales has a large number of coastal tourist resorts. The north coast has a series of large resorts including Llandudno, Colwyn Bay and Rhyl. These towns include urban areas along the coast, connected by a railway and trunk roads that run along the coast at some locations.

Potential climate change impacts identified in the risk assessment that affect coastal tourist resorts include the following:

- A longer tourist season with more visitors and increased tourism revenues. This provides an important opportunity arising from climate change.
- Increased pressure on limited natural assets and infrastructure if tourism increases.
- Loss of natural assets (particularly beaches) to sea level rise and erosion. An assessment has been made of the approximate loss of beach area caused by sea level rise alone.
- Increased flooding from tidal, fluvial (i.e. rivers and other watercourses) and surface water sources. There is a particular concern that combinations of fluvial and tidal flooding could become more frequent. The CCRA has included an assessment of the national increase in flood risk to property, people and infrastructure, although the potential increase in combined flooding has not been assessed.
- Adverse impacts on the marine environment including reduced marine water quality and an increase in non-native invasive species. These arise from an increase in seawater temperature and (in the case of water quality) more pollution caused by an increase in sewer overflows. These have been assessed qualitatively in the CCRA.

COASTAL TOURISM

Tourism contributes around £3.5 billion a year to the Welsh economy and employs up to 100,000 people in peak season. Wales attracts 10 million UK visitor trips a year. Coastal tourism is particularly important and contributes the largest proportion to the visitor economy.

Climate change, largely through erosion and flooding, could potentially have significant adverse impacts upon coastal towns. Beaches and estuaries are likely to suffer from a loss of beach area due to sea level rise and erosion. Coastal assets including sea-front properties and infrastructure would also be affected.

However, rising temperatures and reduced summer rainfall may provide opportunities for increased coastal tourism, particularly over the spring and summer months. Analysis of recent years shows more coastal visitor trips and tourism revenue in hotter, drier years, compared to cooler, wetter years (ADAS UK 2010a). Climate change may, therefore, mean a larger tourism service economy and more seasonal employment.

However, any increase in tourism would require careful management and planning. Increased tourist numbers would place additional pressures on transport, water supplies, wastewater facilities and health services.

In addition to a potential loss of beach area, changes in rainfall and higher temperatures may affect bathing water quality, partly as a result of more discharges from Combined Sewer Overflows (CSOs). Beaches and estuaries may also be affected by algal blooms as sea temperatures rise, reducing their appeal to bathers.

The potential impacts of climate change on coastal tourism in the short to medium term (2020s) may include:

- An increase in the number of optimum tourism activity days (>26°C and dry).
- An increase in extreme weather events.
- An increase in the appeal of Wales to the domestic holiday market in the summer months. Projected changes in average temperatures and precipitation suggest that major adverse climate effects on tourism activities are unlikely by the 2020s.

In the longer term (2050s):

- Warmer and drier summers mean that there are likely to be more days that are favourable for outdoor tourist activities.
- Some summer days could be too hot for outdoor activities such as walking or visiting outdoor attractions, particularly in urban areas. Coastal locations may therefore become more attractive for tourists than cities and the countryside.
- The Welsh market may gain additional domestic and international tourism in the summer from those who have previously holidayed in Southern Europe, and find that the climate there has become too uncomfortable.

6 Gaps in evidence

6.1 Summary

Gaps in evidence come in a number of forms, including:

- UK-wide gaps identified as part of the CCRA analysis for the UK;
- Specific gaps for Wales identified as part of the CCRA analysis for the UK; and
- Specific gaps for Wales identified as part of this assessment including the Tier 2 list of impacts for Wales.

This section summarises some of the main gaps in evidence that have been identified for Wales.

Some of the UK-wide gaps that are relevant to the assessment for Wales include the following:

- Consideration of climate extremes and associated uncertainty. This particularly applies to the effects of droughts on water availability and biodiversity.
- Changes in storminess and wind speed. Current guidance from the Met Office indicates that changes are projected to be small, but further research is in progress.
- Consequences of surface water and groundwater flooding.
- Overall impacts of climate change on vulnerable people and communities. Vulnerable locations include flood risk areas, remote locations and coastal locations which are threatened by erosion.
- Understanding the effects of climate change on biodiversity and ecosystems. This reflects the complexity of natural systems and limitations in current knowledge.
- Knowledge of potential changes in pests and diseases and consequences for livestock, crops, forests and ecosystems.
- Overall impacts of climate change on land use and spatial planning.

Some of the main gaps in evidence relating to each of the five themes are discussed below.

6.2 The Natural Environment

Much of the climate change research conducted to date has, of necessity, been focused either upon individual species or on specific locations or habitat types. Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment, remain in the early stages.

The basic knowledge gap is the understanding of ecosystems including the interaction with people. This is mainly due to the complexity of dependencies within ecosystems and the way in which they are affected by external factors. A coherent baseline is required on the current state of ecosystems in Wales and how they relate to the rest of the UK.

Some of the main gaps that have been identified in the CCRA analysis for Wales are listed below.

Terrestrial (including freshwater)

- Knowledge of potential changes in the organic content of soils including the storage of organic matter and carbon.
- Knowledge of the consequences of climate change for ecosystems and the landscape including:
 - Changes in the water environment including a potential reduction in water availability, increases in water temperatures and increases in pollution and eutrophication;
 - Increases in temperature and aridity during the summer; and
 - The consequences of extreme conditions, particularly individual droughts and successive years of drought.
- Knowledge of the consequences for ecosystems of an increase in fire risk.
- Detailed epidemiological knowledge of different pests and diseases (and their vectors) and their relationship with climate and climate change.
- Knowledge of the potential impacts of climate change on species migration patterns. This is a complex issue as migration patterns are world-wide.
- Understanding of the implications of asynchrony in the timing of species life-cycle events.
- Projections of future changes in agriculture and implications for ecosystems.

Coastal and marine

- Assessment of the effects of climate change on protected habitats and species.
- Analysis of the potential impacts of coastal erosion based on the National Coastal Erosion Risk Map (NCERM).
- Knowledge of the potential impacts of climate change on species migration patterns. As stated above, this is a complex issue as migration patterns are world-wide.
- Knowledge of the potential for Harmful Algal Blooms. Consideration of stratification as well as average temperature increases is important.
- Understanding of the effects of ocean acidification on species and ecosystems.

- Knowledge of the potential impacts of non-native invasive species on ecosystems and ecosystem services (including fisheries).
- Potential impacts of increased tourism. This could be addressed by case studies for selected areas.

6.3 Agriculture and Forestry

Major changes have taken place in agriculture and forestry over the past 100 years and changes continue to take place. These include the improvement of grasslands and an increase in forest area (NEA, 2011). Climate change must therefore be considered against a background of change in the requirements for agriculture and forestry.

Some of the main gaps in evidence that have been identified in the CCRA analysis for Wales are listed below.

Agriculture

- Understanding of the combined effects on crop yield of temperature increases, changes in precipitation and changes in soils. Grassland yield is of particular importance in Wales.
- Assessment of the consequences of droughts for agriculture.
- Potential future allocation of water for agriculture.
- Current and future extent of surface water flooding and waterlogging of agricultural land, and associated impacts on land use and crops.
- Knowledge of the impacts of climate change on pollination.
- Knowledge of the effects of climate change on the occurrence of cryptosporidium.
- The estimate of coastal erosion of agricultural land should be updated using the NCERM.
- Knowledge of the potential climate change effects of pests and diseases on livestock.
- Assessment of the potential effects of climate change on meat production including livestock stress factors, yield and product quality.

Forestry

- Assessment of the impact of fire risk on forest production.
- Understanding of the implications of phenological changes on tree growth and forest management.
- Current and future extent of waterlogging and landslips in forests and associated impacts on forest yield.

6.4 Business

Businesses and services are complex systems which require a wide range of supporting infrastructure. In addition to basic services including power, water, etc, businesses generally have a high level of dependence on Information and Communications Technologies (ICT), national and international supply chains and financial services.

One of the main gaps in evidence is a general lack of information that can be used to assess climate change impacts for Business.

Specific gaps related to the metrics identified on the Tier 2 list of impacts for Wales are listed below.

- Impacts of surface water flooding on business premises.
- Information on the effects of supply chain disruption on business caused by extreme weather events. This is a complex issue as many supply chains are international and are affected by disruption in other countries.
- The assessment of flood and coastal erosion impacts on mortgages and insurance is very high level and requires refinement.
- Potential future allocation of water for business.
- Understanding of the potential impacts of climate change on the disposal of solid and liquid wastes.
- Detailed knowledge of the impacts of climate change on ICT systems and quantification of the consequences. Whilst the probability of failure is considered to be low, the consequences could be very serious.
- Knowledge of coastal tourist assets potentially at risk from flooding and coastal erosion.
- Understanding of the potential impacts of climate change on the financial sector.

6.5 Buildings and Infrastructure

Much of the analysis has been concerned with specific impacts of climate change on either buildings or types of infrastructure. However one of the main gaps related to buildings and infrastructure is assessing the magnitude of the consequences of disruption to infrastructure caused by extreme weather events.

Specific gaps in evidence related to the Tier 2 list of impacts for Wales are listed below.

Buildings and the urban environment

- Impacts of surface water and groundwater flooding on buildings. The potential for flash floods is also a concern: this can occur from rivers or surface water flooding.
- Location of all relevant heritage sites by category (SAMs, listed buildings, etc) and analysis of the flood and erosion risk.

- Consideration of the potential magnitude of combination flooding (including tide-locking of drainage outfalls) in addition to the flood risk already covered in the CCRA analysis.
- Evidence on damage to buildings from heat/drying.
- Knowledge of the potential for soil erosion and landslips that could affect buildings.
- Potential erosion of land in coastal communities.

Infrastructure

- Impacts of surface water and groundwater flooding on infrastructure.
- Knowledge of the potential for soil erosion and landslips that could affect transport links.
- Potential for coastal erosion on transport links including roads and railways. This could be assessed using the NCERM data.
- Assessment of the impacts of climate change on cold weather working and travelling. Whilst there will be benefits, there could also be adverse effects including, for example, a possible increase in damage caused by the freeze/thaw cycle.
- Potential future allocation of water between different uses including domestic, business, agriculture and the environment.
- Assessment of the impacts of droughts on water supply and the potential consequences for people and businesses.
- Assessment of the consequences of climate change on private water supplies.
- Knowledge of the location of water supply infrastructure in order to assess the consequences of an increase in flood risk.
- Assessment of the number of people who could be affected by failure of water supply and sewerage infrastructure as a result of extreme weather events.
- Assessment of the number of people who could be affected by failure of energy supply infrastructure as a result of extreme weather events.
- Assessment of the impacts of climate change on water supply for energy generation. This may require site specific assessments as local circumstances are very variable.
- Combined assessment of heating and cooling requirements to provide an overall view of changes in energy requirements.
- Assessment of the impacts of climate change on power station turbine efficiency and cooling processes. This may affect the generation capacity and identify the need for power station modifications.

6.6 Health and Wellbeing

Some of the main gaps related to health and well-being are the effects of climate change on particular groups (for example, vulnerable people) and communities (for example, isolated communities). Specific gaps in evidence related to the Tier 2 list of impacts for Wales are listed below.

- Impacts of climate change on social inequalities, particularly vulnerable people in flood risk areas and isolated rural areas.
- Knowledge of the potential effects of increased sunlight and UV exposure.
- Assessment of potential changes in outdoor leisure, sport and tourism. This could be based on equivalent metric to the 'Tourist Comfort Index' used to assess changes in tourism.
- Projections of the number of people at risk from surface and groundwater flooding.
- Improved knowledge of the number of vulnerable people, taking account of deprivation and social vulnerability indices.
- Improved projections of the number of vulnerable people at risk from flooding.
- Knowledge of the long-term effects of extreme weather events on mental health.
- Flood risk to health centres.
- Potential impacts of future droughts on water supply and public health.
- Review of potential changes in water quality and water-borne diseases. It is assumed in the CCRA that adaptation will take place to ensure safe water supplies, but the potential risks in this assumption should be considered.
- Assessment of potential resources needed for emergency response to more frequent and more severe extreme weather events (including flood, heat wave and fire).

6.7 Cross-theme impacts

There are gaps in knowledge related to wider impacts that cut across the five themes covered above, for example the combined consequences of climate change on different parts of Wales. Areas of particular concern include isolated rural communities, small coastal communities, upland farming, and environmentally sensitive locations (for example, the estuaries of west Wales).

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Appendices

Appendix A Wales Tier 2 list of climate change impacts

A.1 Tier 2 list by Sector

This version of the Wales Tier 2 list shows the impacts by sector. The order of the impacts is based on the Wales Tier 2 list.

The metric numbers are also listed. Where metrics have not been identified, impacts have been given a number for reference purposes (e.g. BDr1, etc). Some metrics (e.g. BD6) are “missing”, because they are included in the UK Tier 2 list but not the Wales Tier 2 list.

The sectors are as follows:

- Marine and Fisheries
- Biodiversity and Ecosystem services
- Water
- Floods and Coastal Erosion
- Agriculture
- Forestry
- Health
- Built Environment
- Transport
- Energy
- Business, Industry and Services.

The analysis that has been carried out is as follows:

- a. Impacts that have been analysed for Wales (in green)
- b. Impacts that have been analysed for the UK but not specifically Wales (in light green)
- c. Impacts that have not been analysed (in red)

Marine and Fisheries	
Impact	Metric or ref. no.
Risk of harmful algal blooms	MA1
Decline in marine water quality due to sewer overflows and pathogens	MA2a, MA2b
Increased ocean acidification	MA3
Changes in fish catch latitude/centre of gravity	MA4
Northward spread of invasive non-native species	MA6
Impacts on protected habitat and species	MAr1
Damage to cultured aquatic species	MAr2
Rise in sea levels effects on commercial shell-fisheries	MAr3
Expansion of new or existing tourist destinations	BU8

Biodiversity and Ecosystem services	
Impact	Metric or ref. no.
Risks to species and habitats due to drier soils	BD1
Risks to species and habitats due to coastal evolution and flooding	BD2/7
Risk of pests to biodiversity	BD3
Risk of diseases to biodiversity	BD4
Species unable to track changing climate space	BD5
Changes in soil organic carbon (also a concern for forestry and agriculture)	BD8
Changes in species migration patterns	BD9
Biodiversity risks due to warmer rivers and lakes	BD10
Increased risk of wildfires due to warmer and drier conditions	BD12
Water quality and pollution risks	BD13
Ecosystem risks due to low flows and increased water demand	BD14
Agricultural intensification	BDr1
Increase in major drought events	BDr2
Increase in flood defence structures	BDr3
Asynchrony leading to ecological disruption	BDr4
Changing competition and colonisation with altitude	BDr5

Water	
Impact	Metric or ref. no.
Low summer river flows	WA2
Change in household water demand	WA4
Public water supply-demand deficits	WA5
Combined Sewer Overflow spill frequency	WA10
Impacts of major drought on water availability	WAr1
Hydropower potential	WAr2
Increase in chlorine depletion	WAr3
Increase in Cryptosporidium	WAr4
Impacts on private water supplies	WAr5

Floods and coastal erosion	
Impact	Metric or ref. no.
Tidal flooding	FL1, FL2, FL4, FL6, FL7, FL8
River flooding	FL1, FL2, FL4, FL6, FL7, FL8
Surface water ('pluvial') flooding	FLr1
Damage to critical infrastructure (water)	FL10
Damage to critical infrastructure (energy, hospitals, schools)	FL11, FL12
Ability to obtain flood insurance for residential properties	FL13
Agricultural land lost to coastal erosion	FL14a
BAP habitats lost to coastal erosion	FL14b
Flood risk for Scheduled Ancient Monument sites	FL15
Fluvial flooding (contaminated sites and flash flooding)	FLr2
Increase in combination flooding	FLr3
Increase in tide-locking of drainage outfalls	FLr4

Agriculture	
Impact	Metric or ref. no.
Change in crop yield	AG1
Flood risk to agricultural land	AG2, FL4
Risk of crop pests and diseases	AG3
Drier soils due to warmer and drier summer conditions	AG4
Increase in water demand for irrigation of crops	AG5
Increase in water demand for livestock	AG6
Reduction in milk production and dairy herd fertility due to heat stress	AG7
Heat stress effects on dairy cows including livestock deaths	AG8
Opportunities to grow new crops	AG9
Changes in grassland productivity	AG10
Change in crop stress factors	AGr1
Change in livestock pests and diseases	AGr2
Impacts on pollination (crop yield)	AGr3
Increased countryside recreation (impacts on land use and agricultural production)	AGr4

Forestry	
Impact	Metric or ref. no.
Forest extent affected by pests and diseases	FO1
Loss of forest productivity due to drought	FO2
Change in potential yield	FO4
Increase in erosion and landslips	FOR1
Impacts associated with phenology	FOR2
Increase in waterlogging	FOR3
Changes in soil organic carbon	See Biodiversity Sector (BD8)
Increased risk of wildfires	See Biodiversity Sector (BD12)

Health	
Impact	Metric or ref. no.
Summer mortality due to higher temperatures	HE1
Summer morbidity due to higher temperatures	HE2
Extreme weather event (flooding and storms) mortality	HE3
Mortality and morbidity due to summer air pollution (ozone)	HE4
Decline in winter mortality due to higher temperatures - opportunity	HE5
Decline in winter morbidity due to higher temperatures - opportunity	HE6
Extreme weather event (flooding and storms) injuries	HE7
Sunlight / UV exposure	HE9
Effects of floods/storms on mental health	HE10
Change in water quality and water-borne diseases	HEr1
Reduction in winter air pollution - opportunity	HEr2
Inequalities: socio-economic conditions and socio-economic position of individuals influence health impacts	HEr3

Built Environment	
Impact	Metric or ref. no.
Increased subsidence risk due to rainfall changes	BE2
Overheating of buildings	BE3
Effectiveness of green space for cooling	BE5
Reduction in energy demand for heating - opportunity	BE9
Damage from heat/drying	BEr1
Increase in soil erosion and landslips	BEr2
Change in household water demand	See Water Sector (WA4)
Increase in properties at risk of flooding	See Floods Sector (FL6/7)
Flood risk for Scheduled Ancient Monument sites	See Floods Sector (FL15)

Transport	
Impact	Metric or ref. no.
Disruption to road traffic due to flooding	TR1
Landslide risks on the road network	TR2
Energy demands. (This was not regarded as an important national issue and was removed from the CCRA)	TR3
Rail buckling risk	TR5
Reduction in cold weather working/travelling - opportunity	TRr1
Increased demand for transport	TRr2
Increase in coastal erosion risk for transport	TRr3

Energy	
Impact	Metric or ref. no.
Energy infrastructure at risk of flooding	EN1
Energy demand for cooling	EN2
Heat-related damage/disruption to energy infrastructure	EN3
Risk of restrictions in water abstraction for energy generation	EN4
Electricity turbine efficiency	EN6
Power station cooling	EN8
Energy transmission capacity losses due to heat - overground	EN10
Increase in power generation capacity and electricity sub-stations at risk of flooding	See Floods Sector (FL11)

Business, Industry and Services	
Impact	Metric or ref. no.
Climate risks to investment funds	BU1
Monetary losses due to tourist assets at risk from flooding	BU2
Risk of restrictions in water abstraction for industry	BU3
Risk of business disruption due to flooding	BU4
Loss of productivity due to ICT disruption	BU5
Mortgage provision threatened due to increased flood risk	BU6
Insurance industry exposure to flood risks	BU7
Expansion of new or existing tourist destinations – opportunity	BU8
Decrease in output for businesses due to supply chain disruption	BU9
Increase in energy use for machine cooling systems	BUr1
Difficulties in disposal of solid/liquid wastes due to low flows	BUr2
Increase in infrastructure disruptions (including gas/electricity)	BUr3

Impacts not covered by the sectors	
Impact	Metric or ref. no.
Increase in emergency response to climate events (including flood)	CSr1
Increase in emergency response to increase in grassland and forest fires	CSr2
How particular areas cope with several high priority impacts	CSr3
Increase in outdoor leisure, sport and tourism: opportunities and risks	CSr4

A.2 Tier 2 list by Theme

This version of the Tier 2 list shows the impacts by theme. The themes are as follows:

- The Natural Environment
- Agriculture and Forestry
- Business
- Infrastructure and Buildings
- Health and Well-being

The sector impacts have all been allocated to one or more themes. For example, there is no specific theme for 'water', but elements of the water sector appear in all of the themes. The order of the impacts is generally the order that has been used in the main text.

The left hand column shows the analysis that has been carried out, as follows:

- a. Impacts that have been analysed for Wales (in green)
- b. Impacts that have been analysed for the UK but not specifically Wales (in light green)
- c. Impacts that have not been analysed (in red)

The Natural Environment – terrestrial

Impact	Metric	Ref. no.
Changes in soil organic carbon	BD8	
Ecosystem risks due to low flows and increased water demand	BD14	
Water quality and pollution risks	BD13	
Biodiversity risks due to warmer rivers and lakes	BD10	
Increase in major drought events		BDr2
Risks to species and habitats due to drier soils	BD1	
Increased risk of wildfires due to warmer and drier conditions	BD12	
Risk of pests to biodiversity	BD3	
Risk of diseases to biodiversity	BD4	
Species unable to track changing climate space	BD5	
Changing competition and colonisation with altitude		BDr5
Changes in species migration patterns	BD9	
Asynchrony leading to ecological disruption		BDr4
Agricultural intensification		BDr1
Increase in flood defence structures		BDr3
Impacts on inland designated sites (This is not on the original Tier 2 list but was added following consultation)		BDr6

The Natural Environment - coastal

Impact	Metric	Ref. no.
Impacts on protected habitat and species		MAr1
Risks to species and habitats due to coastal evolution and flooding	BD2/7 FL14	
Changes in species migration patterns	BD9	
Expansion of new or existing tourist destinations	BU8	

The Natural Environment – marine

Impact	Metric	Ref. no.
Changes in fish catch latitude/centre of gravity – opportunity and threat	MA4	
Decline in marine water quality due to sewer overflows and pathogens	MA2	
Risk of harmful algal blooms	MA1	
Rise in sea levels effects on commercial shell-fisheries		MAr3
Increased ocean acidification	MA3	
Damage to cultured aquatic species		MAr2
Northward spread of invasive non-native species	MA6	
Expansion of new or existing tourist destinations	BU8	

Agriculture

Impact	Metric	Ref. no.
Change in crop yield - opportunity	AG1	
Opportunities to grow new crops - opportunity	AG9	
Changes in grassland productivity - opportunity	AG10	
Change in crop stress factors		AGr1
Impacts on pollination (crop yield)		AGr3
Increased countryside recreation		AGr4
Increase in water demand for irrigation of crops	AG5	
Increase in water demand for livestock	AG6	
Drier soils due to warmer and drier summer conditions	AG4	
Increase in Cryptosporidium		WAr4
Flood risk to agricultural land	AG2/ FL4	
Agricultural land lost to coastal erosion	FL14a	
Risk of crop pests and diseases	AG3	
Change in livestock pests and diseases		AGr2
Reduction in milk production and dairy herd fertility due to heat stress	AG7	
Heat stress effects on dairy cows including livestock deaths	AG8	

Forestry

Impact	Metric	Ref. no.
Change in potential yield – opportunity and threat	FO4	
Forest extent affected by pests and diseases	FO1	
Loss of forest productivity due to drought	FO2	
Increased risk of wildfires due to warmer and drier conditions	BD12	
Increase in waterlogging		FOr3
Increase in erosion and landslips		FOr1
Impacts associated with phenology		FOr2

Business

Impact	Metric	Ref. no.
Expansion of new or existing tourist destinations - opportunity	BU8	
Increase in non-residential properties at risk of flooding	FL7	
Risk of business disruption due to flooding	BU4	
Decrease in output for businesses due to supply chain disruption	BU9	
Mortgage provision threatened due to increased flood risk	BU6	
Insurance industry exposure to flood risks	BU7	
Risk of restrictions in water abstraction for industry	BU3	
Increase in energy use for machinery cooling systems		BUR1
Difficulties in disposal of solid/liquid wastes		BUR2
Increase in infrastructure disruptions (including gas/electricity)		BUR3
Loss of productivity due to ICT disruption	BU5	
Monetary losses due to tourist assets at risk from flooding	BU2	
Climate risks to investment funds	BU1	

Buildings

Impact	Metric	Ref. no.
Increase in properties at risk of flooding	FL6 / 7	
Ability to obtain flood insurance for residential properties	FL13	
Flood risk for Scheduled Ancient Monument sites	FL15	
Increase in combination flooding		FLr3
Increase in tide-locking of drainage outfalls		FLr4
Combined Sewer Overflow spill frequency	WA10	
Overheating of buildings	BE3	
Damage from heat/drying		BEr1
Increased subsidence risk due to rainfall changes	BE2	
Increase in soil erosion and landslips		BEr2
Effectiveness of green space for cooling	BE5	

Infrastructure

Impact	Metric	Ref. no.
Reduction in energy demand for heating - opportunity	BE9	
Reduction in cold weather working/travelling - opportunity		TRr1
Hydropower potential - opportunity		WAr2
Increase in flooding of road and rail	FL8	
Disruption to road traffic due to flooding	TR1	
Landslide risks on the road network	TR2	
Increase in coastal erosion risk for transport		TRr3
Rail buckling risk	TR5	
Increased demand for transport		TRr2
Change in household water demand	WA4	
Impacts of major drought on water availability		WAr1
Impacts on private water supplies		WAr5
Water infrastructure at risk of flooding	FL10	
Increase in power generation capacity and electricity sub-stations at risk of flooding	FL11	
Energy infrastructure at risk of flooding	EN1	
Risk of restrictions in water abstraction for energy generation	EN4	
Energy demand for cooling	EN2	
Heat-related damage/disruption to energy infrastructure	EN3	
Energy transmission capacity losses due to heat - overground	EN10	
Electricity turbine efficiency	EN6	
Power station cooling	EN8	

Health and Well-being

Impact	Metric	Ref. no.
Decline in winter mortality due to higher temperatures - opportunity	HE5	
Decline in winter morbidity due to higher temperatures - opportunity	HE6	
Winter air pollution - opportunity		HEr2
Increase in outdoor leisure, sport and tourism: opportunities and risks - opportunity		CSr4
Inequalities: socio-economic		HEr3
Summer mortality due to higher temperatures	HE1	
Summer morbidity due to higher temperatures	HE2	
Sunlight / UV exposure	HE9	
Extreme weather event (flooding and storms) mortality	HE3	
Extreme weather event (flooding and storms) injuries	HE7	
Number of people at risk of flooding	FL1	
Vulnerable people at risk of flooding	FL2	
Effects of floods/storms on mental health	HE10	
Fluvial flooding (contaminated sites and flash flooding)		FLr2
Hospitals and schools at risk of flooding	FL12	
Mortality and morbidity due to summer air pollution (ozone)	HE4	
Public water supply-demand deficits	WA5	
Water quality and water-borne diseases		HEr1
Increase in Cryptosporidium		WAr4
Increase in chlorine depletion		WAr3
Increase in emergency response to climate events		CSr1
Increase in emergency response to grassland and forest fires		CSr2
How particular areas cope with several high priority impacts		CSr3

Appendix B Assessment of the Wales Tier 2 impacts

Introduction

This assessment has been carried by sector, as follows:

B.1	Marine and Fisheries
B.2	Biodiversity and Ecosystem services
B.3	Water
B.4	Floods and Coastal Erosion
B.5	Agriculture
B.6	Forestry
B.7	Health
B.8	Built Environment
B.9	Transport
B.10	Energy
B.11	Business, Industry and Services
B.12	Impacts not covered by other sectors

The Tier 2 impacts for each sector have been assessed using the results of the CCRA analysis in the following sections (B.1 to B.12). A summary is provided for each sector at the end of each section.

The information in this appendix is based on the more detailed information contained in the eleven sector reports. References for these reports are given in the reference list.

B.1 Marine and Fisheries

Risk of harmful algal blooms

Risk metric MA1 in the CCRA analysis (UK analysis)

Harmful Algal Blooms (HABs) via their toxins can cause the deaths of fish, sea birds, marine mammals and humans. They are an issue economically as they can render shellfish unfit for human consumption and they are also important in relation to bathing water quality and therefore tourism.

HAB species respond to climate variables in a variety of different ways, and the prognosis for the future seems unclear. Blooms of warm water species such as *Prorocentrum micans* may increase their prevalence generally, whereas other species such as *Karenia mikimotoi* may shift their distribution and become less prevalent in southern parts of the UK, but more prevalent in the north.

Decline in marine water quality due to sewer overflows and water borne pathogens

Risk metrics MA2a (sewer overflows) and MA2b (pathogens) in the CCRA analysis (UK analysis)

Projected future changes in rainfall and increasing temperatures pose significant problems regarding the occurrence of microbial pathogens (e.g. viruses, bacteria, protozoans) in the marine environment, with a direct result on human health. This is a primary concern for local communities that depend on water-based recreation and tourism, for example bathing, diving and sailing and the shellfish industry.

The CCRA analysis used a case study to estimate the consequences on the River Dart in South West England. This has a long tidal estuary which is an important shell fishery and tourist area.

The analysis includes some key simplifications and could be improved through a broader assessment involving many more UK catchments, but generally it suggests that permissible limits on pathogen contaminants will be exceeded more often in the future as a consequence of climate change.

The potential impact of climate change on human health has been considered in relation to the major pathogenic marine *Vibrio* spp (*Vibrio parahaemolyticus* and *Vibrio vulnificus*).

Whilst it was not possible to produce reliable projections regarding future change in *Vibrio* infections because of gaps in data, assessment based upon global sites suggests that changing climatic conditions could result in increased rates of infection and illness in humans via bathing and eating shellfish.

It is therefore expected that there would be a significant increase in the number, seasonality and severity of marine-acquired *Vibrio* infections as sea surface temperatures rise.

Increased ocean acidification

Risk metric MA3 in the CCRA analysis (UK analysis)

The world's oceans play an important role in reducing the contribution of CO₂ to global warming by absorbing CO₂ released by human activities. A consequence of this uptake is increased acidification of the seas and oceans (causing a reduction in pH). The CCRA analysis anticipates a pH change of 0.2 to 0.5 pH units compared to pre-industrial values in the North Sea by 2100.

The impacts of acidification on marine species and ecosystems are not fully understood. However a wide variety of ecosystem processes and species are thought to be vulnerable to changing pH, for example the growth rate of corals and other reef organisms. Changes in pH could also have dramatic consequences for organisms that lay down hard calcareous shells, including commercial shellfish species. It is estimated that the economic losses in the UK to the shellfish, mollusc and aquaculture fisheries could be of the order of £15 million to £120 million per year by the 2080s.

Changes in fish catch latitude/centre of gravity

Risk metric MA4 in the CCRA analysis (UK analysis)

Temperature is one of the primary factors (together with food availability, depth, salinity, shelter and suitable spawning grounds) that determine the large-scale distribution patterns of fish. Theoretically for fish in the northern hemisphere, warming of the sea results in a distributional shift northward, and cooling draws species southwards.

Projections of the distribution shift of sole, plaice, cod and haddock have been made in the CCRA analysis, which indicate that these commonly fished species would move north (by about 20 to 150km by the 2080s relative to the 1961-1990 baseline). This would affect the fishing industry, although there are also likely to be new opportunities as other species move into UK waters. A northward shift in the distribution of plankton would have impacts through the food chain, affecting seabirds and other species.

Northward spread of invasive non-native species

Risk metric MA6 in the CCRA analysis (UK analysis)

Marine biological invasions are increasingly recognised as a threat to biodiversity and industry, particularly with regard to commercial fisheries and aquaculture. These include species that have been introduced via human activities (for example, shipping and mariculture) and species that spread naturally to become established in UK waters.

Nine key non-native marine species that are already present in the UK and are considered to pose a significant risk were identified in the CCRA analysis. The analysis has shown that under a Medium Emissions scenario the projected rise in temperatures for seas around the UK are such that all assessed invasive species could have expanded their potential range by the 2080s to encompass the entire UK.

Whilst the potential impacts of the invasive species have not been assessed, there is considerable potential for them to have significant economic and environmental implications, particularly where they occupy the same niche as native or commercial species.

Impacts on protected habitat and species

Reference number MAr1 (UK analysis)

About 30% of Wales has environmental designations, including inland, coastal and marine sites. International protected areas include Special Protection Areas (SPAs) for birds, Special Areas of Conservation (SACs) for selected habitats and species and Ramsar Sites for wetlands.

Coastal sites are threatened by sea level rise, coastal squeeze and coastal erosion. Marine sites are threatened by changes in water temperature and potential reductions in water quality.

The CCRA analysis has considered the following impacts of climate change on protected habitats and species in the coastal and marine environment:

- Coastal evolution and flooding, covered under the Biodiversity Sector ([Appendix B.2](#));
- Species migration patterns, covered under the Biodiversity Sector ([Appendix B.2](#)); and
- Potential loss of Biodiversity Action Plan (BAP) habitats due to erosion, covered under the Flooding and Coastal Erosion Sector ([Appendix B.4](#)).

The UK CCRA analysis also considered the impacts of climate change on ecosystem function (metric MA10) and the breeding distribution of seabirds and inter-tidal invertebrates (metric MA8). Discussion is included here on these impacts as they are considered to be important but were added to the CCRA Tier 2 list for the UK after the Tier 2 list for Wales was compiled.

Climate change could have serious consequences for ecosystem function and may increase the risk of eutrophication given the same anthropogenic nutrient inputs. It is suggested that climate warming will increase rates of carbon cycling in the pelagic (water column) system, making less carbon available to the benthic (sea-bed) system, resulting in reduced biomass of benthic organisms and possible consequences for marine food webs and fisheries.

Warming temperatures are likely to result in increased stratification of surface waters. This is likely to have a considerable impact on ocean productivity by reducing the upwelling of nutrients, with knock on effects for species at multiple levels of the food chain.

Changes in marine temperatures and seawater chemistry, and changes in ocean currents are likely to affect individual species associated with specific habitat types. In some instances the effects of such changes can be sufficient to significantly alter the community composition and structure of habitats. In the sub-tidal region, eelgrass beds, which are a UKBAP high priority habitat, may be affected by increased temperature and any potential increase in storminess and erosion.

In addition, rocky shores are likely to experience a northward movement of benthic marine organisms, particularly if an increase in coastal defence structures facilitates greater connectivity between habitats.

There is clear evidence that climate-driven changes in the food chain have had acute negative impacts on seabirds. For example, changes in the North Sea plankton community in the late 1980s, caused by rising sea temperatures, has led to large reductions in abundance of the zooplankton, on which larval fish feed, and poor sandeel productivity is associated with warmer sea-surface temperatures.

Studies of bird breeding sites and the occurrence of inter-tidal marine invertebrates anticipate significant shifts in the distribution of species (usually northwards), with some species being excluded from the UK altogether in the future and others arriving and becoming established for the first time. Some key seabird species are projected to vacate sites in Wales over the next 100 years including black headed gulls and razorbills. Seabird associated ecotourism activities in Wales are anticipated to suffer as a result of these changes.

Damage to cultured aquatic species

Reference number MAr2 (Wales analysis)

Aquaculture refers to the production or culturing of aquatic organisms (fish, molluscs, crustaceans, plants). There are opportunities and threats to the cultured aquatic species industry including marine shellfish, marine finfish, marine invertebrates and freshwater species.

The aquaculture industry could be affected by a number of climate change factors including sea level rise, increase in water temperature and decrease in water quality. Given the current projections, climate change is unlikely to have a significant effect on UK mariculture (cultivation of marine organisms in the open ocean) over the next decade.

Further into the future however, the projected changes are likely to result in noticeable effects. Rises in annual and seasonal mean water temperature could result in faster growth rates for some species which are more tolerant of higher temperatures (e.g. Atlantic salmon, mussels and oysters). However prolonged periods of warmer summer temperatures may adversely affect some cold water species (e.g. cod and Atlantic halibut) and intertidal shellfish (oysters). Such changes could make sheltered, warmer sites unsuitable for those species during the summer months.

The culture of species which are currently of marginal (but growing) value to UK market but which thrive in warmer conditions such as sea bass, sea bream and hake could be a positive new opportunity caused by climate change.

Disease of mariculture species through bacterial, viral, parasitic and fungal infection will be affected by a changing thermal regime, but in a largely unpredictable manner. A projected increase in the frequency of harmful algal and jellyfish blooms (associated with an increase in warmer waters with calmer, drier summer months) could potentially cause more fish kills and closures of shellfish harvesting areas.

Rise in sea levels effects on commercial shell-fisheries

Reference number MAr3 (not analysed)

There are important intertidal shell-fisheries in Wales and the shell-fish industry is worth over £10m/year. Sea level rise would affect intertidal zones and therefore the ability of these fisheries to operate. It is possible for example that some 'beds' may be lost, leading to increased pressure on the remaining beds.

Expansion of new or existing tourist destinations

Risk metric BU8 (UK analysis)

Coastal tourism may increase as temperatures rise and the tourist season becomes longer. This would lead to additional demands on existing physical infrastructure (including water supply), communities and the environment.

This impact has been assessed in the Business, Industry and Services Sector (metric BU8, [Appendix B.11](#)). The climate for tourism activity is projected not to change significantly in the winter but the summer and both 'shoulder seasons' are likely to experience an increase in activity. This in turn could mean more visitors, not only throughout the season but also at peak times.

However, the incidence of severe weather events (e.g. flooding, heat waves and drought) is projected to increase. These events have the potential to directly and indirectly affect tourism.

Impacts on the marine environment include increased pressure on coasts, beaches and wildlife conservation areas. This could in turn lead to significant adverse impacts on marine ecology as a result of erosion, disturbance and pollution.

Marine Sector: Summary

Climate change is likely to cause changes in the marine environment. This in turn would have impacts on tourism, shell fisheries and the natural environment. It was not possible to quantify in any detail the magnitude of these changes in the CCRA analysis because the processes are not sufficiently well understood. However, it is concluded from the CCRA analysis that:

- There is likely to be an increase in harmful algal blooms which would affect people and wildlife (MA1).
- Coastal water quality could decline as a result of increases in sewer overflows and disease pathogens (MA2).
- Coastal shell-fisheries could be adversely affected by sea level rise, a decline in water quality and acidification of the sea (MA3, MAr4).
- Species shifting is projected to continue and is regarded as both a threat and an opportunity (MA4).
- Non-native invasive species could potentially affect the whole coastline as sea temperatures increase, with potentially significant economic and environmental implications (MA6).
- Coastal habitats would be affected by sea level rise and consequent coastal squeeze, resulting in a loss of habitat area and quality (MAr1).
- Climate change could affect the distribution of protected species including sea birds as a result in changes in the availability of food. Some species may vacate sites in Wales altogether (MAr1).
- There are both opportunities and threats for cultured aquatic species as increases in sea temperature would have beneficial effects on some species but adverse effects on others (MAr2).
- There could be increased pressure on coasts, beaches and ecosystems if tourism increases as a result of warmer and drier summers (BU8).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.2 Biodiversity and ecosystem services

Risks to species and habitats due to drier soils

Risk metric BD1 in the CCRA analysis (Wales analysis)

Most Welsh habitats and species are adapted to a temperate wet climate with water availability only a problem in extreme dry years. They are therefore sensitive to a change in climate towards a state where present-day 'extreme' dry conditions become the norm. This can lead to loss of ecosystem function and key services provided by wetlands and other habitats.

Whilst increased soil moisture deficits and drying is possibly less of a risk in Wales than England, it is likely to be risk in south east Wales in hydrologically sensitive habitats.

The CCRA analysis provides projections for relative aridity. For the p50 Medium Emissions scenario the relative aridity for UKCP09 river basin regions in Wales is projected to rise to about 1.00 in the 2020s, 1.80 in the 2050s and 2.55 in the 2080s. These may be compared with observed values for dry summers of 1.77 in 2003 and 2.59 in 1921, the most severe drought in the twentieth century.

In the CCRA analysis, this risk was investigated for two priority habitats (beech woodland and blanket bog) and upland birds. It was concluded that the priority habitat *lowland beech and yew woodland* is at risk of a considerable contraction in area due to the effect of increasing soil moisture deficit and drying. Whilst Wales has a relatively low number of beech trees, these findings suggest that other priority habitats would be affected by more arid soils.

The CCRA analysis also indicates that there is likely to be a significant drying of soils at a regional scale and stress to blanket bog would increase. Land-use practices, particularly changes to drainage and fire regimes, would also have a significant effect on blanket bog.

A continued increase in summer temperatures implies a considerable risk of extinction for the golden plover within the next 100 years. Other bird species are also considered to be at risk due to the decline in invertebrates that prefer cool, damp conditions. The less sensitive species tend to have a wider variety of diet including prey species that are less sensitive to drier conditions.

Risks to species and habitats due to coastal evolution and flooding

Risk metrics BD2 and BD7 in the CCRA analysis (UK analysis)

Climate change could lead to an increase in tidal flooding and coastal erosion as the sea level rises. Reconfiguration of the coast might also occur during a major storm event.

The Welsh coastline comprises areas that are predominantly stable (e.g. those comprising hard rock formations) and those that are either eroding or accreting (e.g. soft rock coast, shingle, beaches etc.) under current climate conditions. It is estimated that about 23% (346km) of the Welsh coastline is currently eroding.

Coastal squeeze is a particular problem for the following reasons:

- There is a large number of designated sites and other locations of environmental interest. These cover a wide range of habitats including intertidal areas, sand dunes and grazing marshes.

- A large proportion of the coast has infrastructure constraints, for example railways and roads. This provides a fixed barrier to inland migration of intertidal areas and the risk of loss of some of these areas is high.

Projected losses for Coastal Floodplain and Grazing Marsh, Deciduous Woodland, Fen, Purple Moor Grass and Rush Pasture, Reedbed and Saline Lagoon have been made for England although the equivalent data are not available for Wales.

Defra project CR0422 suggests that in England an average of around 4-6% of total terrestrial and freshwater habitats in the coastal floodplain could be lost under the worst case flood inundation scenarios, although a significant portion of this represents habitat that is already at risk under current climate conditions (Defra, 2011).

Quantification of habitat losses for Wales is not available at present. However, in Wales a previous assessment by Pye & Saye (2005) suggested that several important sites could experience net loss of dune habitat, notably Morfa Dyffryn, Newborough Warren, Whiteford Burrows and Kenfig. Perhaps equally importantly, the same study highlighted that if sediment supply rates are maintained at current high rates then a net gain may be experienced at some sites, including Laugharne-Pendine, Morfa Harlech and Ynyslas.

The case studies on coastal biodiversity ([Section 4.2.2](#)) and the Dyfi Estuary ([Section 5.2.4](#)) provide further information on specific impacts for Wales.

Risks of pests and diseases to biodiversity

Risk metrics BD3 and BD4 in the CCRA analysis (UK analysis)

Pests already present a severe risk to some habitats and species but their prevalence is limited by the climate, particularly minimum temperatures in winter. A rise in temperature is likely to lead to an increased survival rate for pest species and this may be accompanied by other factors that favour their spread, such as wetter winters for fungal pests.

There is also widespread concern that future conditions in the UK may be such that diseases prevalent in other countries become problematic locally. The potential consequences to biodiversity are demonstrated by examples of the spread of diseases such as Dutch Elm Disease in trees and seal distemper virus in mammals.

However, each pest and disease has its own characteristics and there is rarely a single variable that would cause a pest or disease to increase in destructive ability. It is therefore very difficult to make generalisations about the implications for biodiversity.

In the CCRA analysis, this risk was investigated for the following:

- *P. ramorum*, a fungus-like species that causes damage to trees including larch and spruce.
- Parrot's feather, an invasive aquatic plant that can develop dense infestations in natural ponds and slow-flowing canals or rivers.
- *Chytridiomycosis*, a potentially fatal frog disease now found in the UK.

Studies into the sensitivity of *P. ramorum* to temperature, humidity and water potential have identified optimal levels for growth at different stages of the organism's life cycle.

The findings suggest that the UK has a very suitable climate for *P. ramorum* survival. The areas at highest risk are in the moister west of the UK, especially in Wales and south west England. However, compounding factors as mentioned previously mean that even experts in the field are not certain about the future of the pest in relation to climate change.

No future projections are currently available for the potential distribution of Parrot's feather. However, one of the indirect effects of increased water temperatures is likely to be the increased potential for overwinter survival of this invasive species. As low temperatures seem to be a key control it is reasonable to infer that there is a significant risk of the species spreading north and invading more aquatic habitats. Changes in water flow regimes will also be a key influence, as the plant is at its most aggressive in still water. By covering large areas of aquatic habitat, Parrot's feather can effectively smother a water body and by reducing light, oxygen and nutrients available to other species then its likely spread has important implications for priority species and habitats.

Chytridiomycosis has been identified as a major cause of amphibian extinctions and catastrophic population declines in many species across North, Central and South America. It seems to be temperature limited and climate change has been recognised as a causal factor enhancing the ability of the fungus to spread and/or induce disease.

Shorter milder winters producing elevated temperatures and humidity values are believed to favour the fungus. The climate 'envelope' for this disease is inferred to be expanding across Europe to include much of the UK and an increased frequency of milder wetter winters is therefore associated with an increased risk.

All pest species and diseases need to be fully understood on an individual level before an accurate projection of change can be made. This is considered to be an important impact partly because of uncertainty in this area, and also because of the potentially dramatic consequences for wild species should populations become affected by a pest or disease new to the UK.

Species unable to track changing climate space

Risk metric BD5 in the CCRA analysis (UK analysis)

Species may not be able to track changing climate space for a number of reasons including ability to disperse, lack of suitable habitats and fragmentation of habitats. In addition, some species may be unable to find a suitable microclimate, for example those with habitats at high altitude.

The CCRA analysis has shown that (a) many species are at risk of being unable to adapt to their changing climate space and (b) many other species would gain additional suitable climate space. The analysis includes examples of species in both categories, although other factors would have a major impact on survival in the future, such as habitat loss and fragmentation.

In addition, new species may be able to survive in the UK in the future. Some new species may be of benefit and have little impact on existing ecosystems. However it is also possible that invasive species could be very detrimental to current native species and habitats.

There is a concern that if the risk to some species is increased (e.g. beech woodland) there could be consequences for the integrity of whole ecosystems.

A major barrier to the tracking of climate space is the current fragmentation of habitats. This could affect the long-term sustainability of current biodiversity in the UK in the face of climate change.

Whilst this is an important impact for Wales, there is potentially more natural adaptive capacity than other parts of the UK because of topographical variation and the largely rural nature of much of the country.

Changes in soil organic carbon (also a concern for forestry and agriculture)

Risk metric BD8 in the CCRA analysis (UK analysis)

The organic content of soils is a key regulator of plant nutrient cycling and water availability, and the release of the greenhouse gas CO₂. Soil contains more than 90% of species biodiversity and forms the basis for both effective ecosystem functioning and associated services (e.g. crop production, water regulation and purification, etc.). Of particular importance is the storage of organic matter and carbon in soils, particularly highly organic soils such as peat (defined as organic soil > 0.5m depth).

Peat lands (i.e. blanket bog, lowland raised bogs and fen) are particularly important for the storage of carbon. The ability of peat lands to store new reserves of carbon has been significantly reduced due to damage from a number of sources, predominantly land management. Climate change could cause additional stresses which might affect this habitat.

The CCRA analysis has considered the impact of increased soil moisture deficits and drying on blanket bog. There are about 70,000ha of blanket bog in Wales and 1.5 million ha in the UK as a whole, containing an estimated 5.1 billion tonnes of carbon. The analysis shows that blanket bog across the UK may become more vulnerable. Areas that are currently vulnerable may become inactive (no longer peat-forming) or disappear altogether. This would have implications for carbon sequestration and emissions, although land management practices have greater influence on the status of this habitat than climate change in the short term.

In general, there is considerable uncertainty surrounding the potential impact of climate change on soil organic carbon because of the complexity of interactions involved. Whilst these interactions could be modified by climate change, it is not currently possible to state with certainty what the effect on soil organic carbon will be.

The impact of climate change on soil organic carbon is therefore a major uncertainty in the CCRA analysis, and an area where further research is needed. This risk is considered to be particularly important given the high proportion of organic and peat soils, particularly in mid and north west Wales.

Changes in species migration patterns

Risk metric BD9 in the CCRA analysis (UK analysis)

A wealth of observational evidence clearly indicates that migration patterns in birds are changing. Migration patterns are likely to continue to change increasingly in the future, particularly due to changes in seasonal temperatures both in the UK and other locations on migration paths. This presents both threats and opportunities, with some species using new sites or new species arriving in the UK, taking advantage of milder winters.

These changes will occur in combination with other factors, such as habitat change, changing species interactions, and possibly behavioural change. Given the complex relationships that exist between species behaviour, climate variables and other factors, the overall outcome of this risk for biodiversity cannot be predicted at this stage.

For example, where migratory species arrive earlier in the year, the receiving habitat may become less able to support the population. This could occur, for example, if plants and invertebrates are not at the right point in their own life cycle to provide food to the arriving migrants.

The CCRA analysis has identified changes in the migration patterns for specific species using recent data, both in terms of timing (where migratory species arrive

earlier in the UK in warmer years) and location (where overwintering migratory species go to different locations in the UK during warmer years).

Changes in migration patterns would have important implications for biodiversity, particularly the designated site network, which might not cover the new migration sites. It also has implications for the cultural benefits that society gains from migratory species as they often have important associations with the annual cycle of seasons, local landscape identity and sense of place.

Changes in species migration patterns are a risk for some species groups. For example, large reductions in overwintering wildfowl on coastal estuaries have already been linked to climatic change.

Biodiversity risks due to warmer rivers and lakes

Risk metric BD10 in the CCRA analysis (UK analysis)

Warmer air temperatures would result in greater evaporation, which combined with change in rainfall patterns and distribution may reduce water levels in water bodies and decrease groundwater recharge. Increased stratification can result in changes to the distribution of dissolved oxygen and nutrients within the water column which could then have an impact on water quality and the ecological status of the water body.

This risk has been assessed in the CCRA but the ecological implications remain uncertain because of the complexity of aquatic ecosystems and the effects of other factors such as water quality. Some fish and other species may be affected due to changes in the availability of food and their ability to survive at higher temperatures. For example, there is a risk to salmon growth from increased water temperatures.

The analysis also suggests that stratification of water bodies in the UK could occur more frequently as a direct response to increasing air temperatures. Whilst this outcome remains uncertain, the risk to aquatic habitats from projected increases in temperature could be significant.

This impact is particularly important for Wales because of the predominance of surface water flows and reservoirs for water storage.

Increased risk of wildfires due to warmer and drier conditions

Risk metric BD12 in the CCRA analysis (Wales analysis)

The risk of fire is projected to increase if there is an increased prevalence of hotter, drier conditions. Some ecosystems such as woodlands, semi-natural grasslands, and those on peat soils (e.g. bogs) are particularly sensitive to fire. Therefore an increased prevalence of large wildfires could lead to significant loss of biodiversity.

This could potentially result in the local extinction of species at the expense of those that are more fire-tolerant. Wildfires can also increase rates of erosion and have a detrimental effect on water quality. Of particular significance is the damage that fire can cause to areas of peat, which are a significant carbon sink. Once ignited, peat habitats can 'smoulder' for an extended period and are difficult to extinguish.

Where there is damage as a result of fire, carbon stored within the peat can be released back to the atmosphere and the ability of the habitat to act as an effective carbon sink is severely constrained.

One example of a priority habitat that is threatened by fire is *Lowland Heathland*, which is of particular significance for British reptile species including rare lizards and snakes.

The CCRA analysis includes an assessment of the increase in wildfire risk from 1980 to the 2080s using a Fire Danger Index. The projected increases for National Parks are as follows:

Pembrokeshire Coast	30 – 40%
Brecon Beacons	30 – 40%
Snowdonia	40 – 50%

Water quality and pollution risks

Risk metric BD13 (Wales analysis). Risk metric WA7 (WFD flow indicators, Wales analysis) is also relevant

Pollution of water bodies occurs through runoff of fertiliser from agricultural land, influx of human wastes, and deposition from the atmosphere. The impact of these pollutants depends also on the temperature and quantity of water for dilution, but is already a major source of damage to aquatic habitats.

Impacts on water quality will occur as a result of the interaction of warmer temperatures and pollution, particularly from land use. These may be exacerbated by lower summer flows and runoff due to increased rainfall intensity. These changes could further modify species and community composition.

Poor water quality is detrimental to the effective functioning of aquatic ecosystems including supporting services such as nutrient cycling and oxygenation. A surplus of nutrients during eutrophication mean that surplus nutrients are not cycled through the system and the dynamic balance of the ecosystem is destabilised, particularly when harmful algal blooms occur.

This has implications for the purification and supply of clean water. Impacts are also apparent for fish stocks which provide an important economic, social and cultural service in key locations, and for other important species. Poor water quality can also cause issues with human recreational and amenity use of water bodies, including water sports and tourism, to the detriment of local communities.

Warmer, drier summers are likely to lead to lower flows in watercourses and reduced dilution of pollutants. The CCRA analysis indicates that the Q95 flows would reduce by up to 20% by the 2020s, 10 to 25% by the 2050s and 20 to 35% by the 2080s relative to the 1961-1990 baseline. These estimates are based on the Medium Emissions scenario and there is a wide range of uncertainty in these figures.

The CCRA analysis includes an assessment of the number of sites meeting Water Framework Directive Environmental Flow Indicators (metric WA7) and the percentage of rivers with a net decline in ecological status (metric WA9). These metrics are not on the Wales Tier 2 list.

The Environmental Flow Indicators (EFIs) provide a good estimate of the physical habitat required to meet Good Ecological Status. There are currently about 1200 sites meeting EFIs in the three UKCP09 river basin regions in Wales (Dee, Severn and West Wales). It is estimated that this number would reduce to about 730 in the 2020s, about 150 in the 2050s and about 130 in the 2080s (corresponding to reductions of about 40%, 85% and 90% respectively compared with present day conditions).

The decline in ecological status was also assessed qualitatively for the UK as a whole in terms of the percentage of rivers with a decline in status. The indicative projections for the UK are as follows:

- 2020s: About 50% of rivers would decline by 0 to 5%; about 40% of rivers would decline by 6 to 10%; about 10% of rivers would decline by 11 to 50%.
- 2050s and beyond: About 10% of rivers would decline by 0 to 5%; about 40% of rivers would decline by 6 to 10%; about 40% of rivers would decline by 11 to 50%; about 10% of rivers would decline by 51 to 90%.

It is clear that decline in water quality is likely to have significant impacts on Welsh rivers in warmer drier summers, with adverse implications for biodiversity and water supplies.

Ecosystem risks due to low flows and increased water demand

Risk metric BD14 (low flows, societal water demand and drought) (Wales analysis)

A change in water supply due to climate change is likely to be accompanied by increased demands for water from other sectors, particularly agriculture. This combined impact will act to modify flow and water levels, which will reduce the capacity of aquatic ecosystems to adapt to change, particularly when aggregated with changes in water quality and thermal profile.

The most pronounced risk occurs during extreme drought events when there could be major biodiversity loss and some ecosystems may experience irreversible change without a more precautionary approach to water usage.

The CCRA analysis includes the following risk metrics associated with societal water demand:

WA2 – Low flows: Change in Q95 flows (i.e. the flow that is exceeded for 95% of the time).

WA3 – Deployable Output (DO): The amount of water that can be provided by a water company taking account of licence, hydrology, hydro-geology and works capacity constraints. Whilst it is not a direct measure of water availability, it provides an indication of the availability of water to society.

WA4 – Household water demand.

WA5 – Water supply / demand deficit: This is the difference between demand and the available supply.

These metrics have been used for the analysis in the Biodiversity Sector. WA3 and WA5 are not included in the Wales Tier 2 list.

The CCRA analysis indicates that the Q95 flows are projected to reduce by up to 20% in the 2020s, 10 to 25% by the 2050s and 20 to 35% by the 2080s compared with the 1961-90 baseline. These estimates are based on the Medium Emissions scenario and there is a wide range of uncertainty. This provides an indication of the reduction in available water during low flow periods although it does not take account of water storage.

Deployable Outputs are estimated to reduce by about 5% by the 2020s, 10 to 20% by the 2050s and 20 to 30% by the 2080s. It is also estimated that household water demand may increase by 2% by the 2020s rising to 5% by the 2080s. This does not take account of population increase (estimated to be 9% by the 2020s, 17% by the 2050s and 24% by the 2080s).

Overall it is estimated that the supply demand balance in the three UKCP09 river basin regions in Wales (Dee, Severn and West Wales) would change from a surplus of about 160Ml/day at present to a surplus of about 20Ml/day in the 2020s, a deficit of about

350MI/day by the 2050s and a deficit of about 600MI/day by the 2080s if no adaptation is carried out.

These changes are likely to be mitigated to some extent, for example by the use of reservoirs to store winter rainfall for use in the summer. However they indicate the magnitude of changes that could occur.

Changes in flow regime would combine with temperature rise and changes in dissolved oxygen to have serious impacts on the life cycles and interactions of many aquatic organisms, including invertebrates, amphibians, fish and birds. Specific impacts depend upon the species under consideration. For example, research results suggest that salmon could be severely affected whereas the impact on brown trout may be small.

Agricultural intensification

Reference number BDr1 (not analysed)

Agricultural intensification may occur if agricultural imports become more expensive and there is a greater demand for agricultural products grown in the UK. Reasons that this might occur include the impacts of climate change in other countries. An ultimate consequence of agricultural intensification is that a higher proportion of biomass produced by net primary productivity is removed from the ecosystem and that nutrients become depleted unless replaced by artificial fertilisers.

This has negative implications for biodiversity which, together with the application of pesticides and herbicides, results in severe reductions in species abundance and diversity unless remedial measures are applied. An example of intensification is the shift from spring-sown to autumn-sown crops that has occurred in many arable areas of the UK because of the potential for greater yields: the shorter fallow period in the field means a reduced food supply for wild species.

A changing climate means that the bioclimate factors associated with different agricultural activities will also shift. For example, areas of prime agricultural land may expand and, in marginal areas, a greater proportion of land may be capable of agricultural 'improvement' where soils are suitable.

An increase in the area of land used for intensive agriculture could have further negative consequences for biodiversity, particularly in marginal areas that have high biodiversity value. The expansion of prime agricultural land may also be dependent on the additional availability of irrigation water, because it tends to occupy the drier areas that could experience exacerbated moisture deficits in the future.

Some marginal agricultural areas in some locations may also be at risk of land abandonment. This may result from high precipitation rates causing soils to remain wet or becoming wetter for key periods of the year in spring and autumn. When soils are at high water-holding levels ('field capacity') access to the land is very difficult and would be highly likely to cause damage to soil structure due to compaction. This can severely limit agricultural activities or make them highly dependent on favourable weather from year to year.

Land abandonment would have mixed results for biodiversity: some species would gain and some would lose, but there could be significant consequences for some important and rare UK species that are present only in a few locations.

Increase in major drought events

Reference number BDr2 (UK analysis)

Major drought events have not been specifically addressed in the CCRA analysis. However their impact on biodiversity is likely to be substantial, partly because of the predominance of surface water and the projected water resource shortfalls.

Risk metrics that contribute to an understanding of the impacts of major drought events include the following:

BD1	Increased soil moisture deficits and drying
WA1	Relative aridity
WA2	Change in Q95 flows
WA7	Number of sites meeting Water Framework Directive Environmental Flow Indicators
WA8	Number of sites with unsustainable abstraction

WA1, WA7 and WA8 are not included in the Wales Tier 2 list.

The relative aridity projections indicate that by the 2050s an average summer could be similar to the dry summer of 2003, and similar to the major drought year of 1921 by the 2080s. The projections for a p90 High emissions scenario in the 2080s give an average relative aridity of about 4.7, compared with a 1921 value of 2.59. This indicates that future major droughts could be very severe events, far more so than droughts experienced to date.

Increase in flood defence structures

Reference number BDr3 (not analysed)

For a river in its natural state during high flow conditions a critical level is reached when some water leaves the normal watercourse and spreads out over a larger area which represents its floodplain. The variety of sediment left during floods and the ephemeral state of the floodplain produce a diverse range of habitats that support many important species.

Man-made engineering structures are designed to protect people, properties, and land on the floodplain from the adverse effects of flood inundation by maintaining the river within a predictable course. However, these structures act to separate the river from its floodplain to the detriment of the associated riparian and wetland habitats. In tidal waters fish and other aquatic species would be unable to access floodplain and intertidal areas behind new flood defence structures.

One reason for building new flood defence structures would be to mitigate the increase in flood risk from climate change. Increase in flood defence structures is therefore, partially at least, an indirect climate change impact. It is regarded as a potentially serious problem for biodiversity, particularly on the coast.

Asynchrony leading to ecological disruption

Reference number BDr4 (not analysed)

The timing of seasonal events is changing (e.g. earlier flowering, leaf-growth, egg-laying, earlier arrival of migrants, etc). These adaptive responses may be leading to ecological disruption, for example when food supply and breeding cycles become asynchronous. They may also be leading to competitive advantages and changing niches for some species with implications not only for community ecology, but also for

humans (for example reports of tick bites have increased in recent years, linked with increased survival in warmer winters).

This is an important risk factor for some species although it has not been analysed in the CCRA.

Changing competition and colonisation with altitude

Reference number BDr5 (UK analysis in metric BD5)

As temperatures increase some species may migrate to higher altitudes to maintain suitable climate space. The CCRA analysis of upward migration of species has shown that some species may migrate but others may not. One example from the analysis is *Ulex gallii* (western gorse), where upward migration is projected. There is already some evidence that upward migration is occurring in certain species such as western gorse and bracken. This is a significant concern for much of upland Wales which could lead to significant changes in biodiversity and landscape.

Projections indicate that the climate space for many but not all species will move with altitude and their abundance would shift up-slope, especially under the High Emissions scenarios. However, climatic variables other than temperature may be more important for some species, for example water balance, aspect of slopes and wind effects.

In areas of high topographic diversity, where high mountains are dissected by deep valleys, a wide variation of microclimatic conditions exists (especially at locations that are also adjacent to the coast). This provides a wide variety of ecological niches and these areas will therefore continue to be areas of high biodiversity value. However, it is highly likely that some BAP species and habitats in upland areas will be highly vulnerable to change because they are unable to track their climate space uphill due to unsuitable soils or unfavourable exposure.

For montane species that currently inhabit the higher areas of the mountains and specialist environments such as snow-bed communities, they simply have 'nowhere to go'. In these cases, it appears that both natural and managed adaptation options are severely limited, and translocation to montane areas further north (in the UK or elsewhere) may be the option of last resort.

Biodiversity and Ecosystem Services Sector: Summary

Climate change is likely to lead to changes in biodiversity which would not only affect the environment but would also have knock-on impacts for society and the economy. In most cases it was not possible to quantify the magnitude of these changes, but the following conclusions were drawn from the CCRA analysis:

- Increased soil moisture deficits and drying could have severe adverse effects on key habitats including blanket bog and other wetland habitats (BD1).
- Increases in coastal flooding and erosion are projected that would cause loss and damage to coastal habitats (BD2, BD7).
- Climate change could lead to a spread of pests and diseases although these need to be understood on an individual level before reliable projections can be made (BD3, BD4).
- Many species may not be able to track their changing climate space but other species would gain additional climate space. Loss or damage to some species could affect the integrity of whole ecosystems (BD5).
- The potential impact of climate change on soil organic carbon could be important but is currently not well understood (BD8).
- Species migration patterns are likely to change, with serious implications for the designated site network (BD9).
- Increasing air temperatures could lead to stratification of water bodies and adverse impacts on aquatic habitats (BD10).
- The risk of wildfire could increase in hotter, drier conditions. Some key habitats are sensitive to fire, and this could lead to a significant loss of biodiversity (BD12).
- Adverse impacts on water quality are projected to occur, leading to a decline in ecological status in warmer drier summers (BD13).
- A reduction in water availability for biodiversity is projected to occur due to a reduction in summer precipitation and increasing water demands from other sectors, particularly people and agriculture (BD14).
- Agricultural intensification is a potential threat to biodiversity because of the additional pressures it would place on the environment including a loss of nutrients and changes in land use (BDr1).
- The risk of drought is projected to increase and future extreme droughts are likely to be more severe than droughts experienced to date (BDr2).
- An increase in flood defence structures could increase the separation between water bodies and their floodplains with adverse impacts for biodiversity (BDr3).
- Asynchrony between a species breeding cycle and its food supply could lead to ecological disruption (BDr4).
- Migration of species to higher altitudes could lead to significant changes in biodiversity and landscape in the Welsh uplands (BDr5).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.3 Water

Low summer river flows

Risk metric WA2 in the CCRA analysis (Wales analysis)

The change in low river flows provides a direct indication of the impact of climate change on the bio-physical system, and affects biodiversity as well as human activity such as agriculture.

The risk metric used in the CCRA analysis is the Q95 flow, which is the flow that is exceeded 95% of the time. Compared with the 1961-90 baseline, the analysis indicates that the Q95 flows could reduce by:

- 10 to 20% by the 2020s (range 30% to an increase of 10%)
- 20 to 30% by the 2050s (range 5% to 40%), and
- 30 to 40% by the 2080s (range 10% to 50%).

The projections are for the p50 Medium Emissions scenario. The ranges in brackets are approximate values for the most extreme climate change scenarios used in the analysis (p10 to p90 Medium Emissions for the 2020s and p10 Low Emissions to p90 High Emissions for the 2050s and 2080s).

Change in household water demand and public water supply-demand balance

Risk metrics WA4 and WA5 in the CCRA analysis (Wales analysis)

The availability of water is projected to reduce in warmer drier summers, thus constraining the amount of water available for public water supplies. The CCRA analysis indicates that Deployable Outputs in Wales could reduce by about 5% by the 2020s, 10 to 20% by the 2050s and 20 to 30% by the 2080s.

The CCRA analysis indicates that domestic demand may increase by about 2% by the 2020s, 4% by the 2050s and 5% by the 2080s. The 'Principal' population growth projections are increases of 9% by the 2020s, 17% by the 2050s and 24% by the 2080s. Combining these figures with the projections for per capita domestic demand gives overall increases in water demand of about 10% by the 2020s, 20% by the 2050s and 30% by the 2080s. These estimates do not take account of such factors as changes in consumer attitudes to water and the more widespread use of water saving technology.

Whilst it is projected that the total amount of rainfall may not change significantly, the distribution between winter and summer is likely to change. Overall it is estimated that the supply demand balance in the three UKCP09 river basin regions in Wales (Dee, Severn and West Wales) could change from a surplus of about 160MI/day at present to a deficit of nearly 200MI/day by the 2050s and a deficit of over 400MI/day by the 2080s under the p50 Medium Emissions scenario with no population growth and assuming that no adaptation is carried out.

The availability of water in Wales is projected to reduce, particularly in the summer. It is provisionally estimated in the CCRA analysis that about 40% of the population of Wales might be affected by a shortage of water by the 2020s rising to over 90% by the 2080s.

Water Framework Directive Environmental Flow Indicators

Risk metric WA7 in the CCRA analysis (Wales analysis)

This is discussed under reference number WAR1 below.

Combined Sewer Overflow spill frequency

Risk metric WA10 in the CCRA analysis (Wales analysis)

Increases in the frequency and intensity of rainfall events are likely to lead to increases in sewer flooding. Flood water from sewers is often combined with foul sewer flows and also causes environmental pollution.

The risk metric used to assess the increase in sewer flooding in the CCRA analysis is the spill frequency from Combined Sewer Overflows (CSOs), which allow excess sewer flows to be discharged (into watercourses).

Analysis of UKCP09 Weather Generator outputs was used for this metric to estimate the frequency of heavy rainfall events that may cause CSO spills for the Medium Emissions scenario by the 2080s. This analysis was completed for Cardiff, and involved simply counting the number of storms of different rainfall depths up to a total storm depth of 60 mm. The results are shown in Figure B.1.

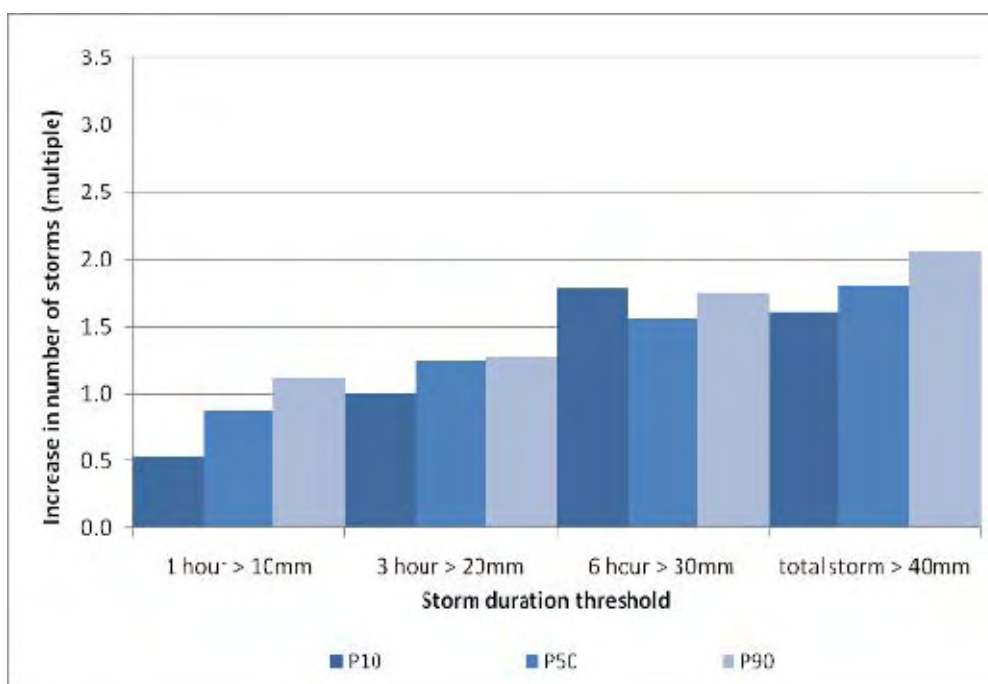


Figure B.1 Change in frequency of heavy rainfall events for Cardiff

These results indicate little change in very short duration storms but the frequency of bigger storms (>30mm in 6 hours and >40mm total rainfall) could increase by between 50% and 100% by the 2080s.

Impacts of major drought on water availability

Reference number WAr1 (Wales analysis)

Major drought events have not been specifically addressed in the CCRA analysis. However their impacts on water availability and supply would be significant in Wales where there is a predominance of surface water flow.

Risk metrics that contribute to an understanding of the impacts of major drought events include the following:

- WA1 Relative aridity
- WA2 Change in Q95 flows

WA7 Number of sites meeting Water Framework Directive Environmental Flow Indicators

WA8 Number of sites with unsustainable abstraction

WA1, WA7 and WA8 are not included in the Wales Tier 2 list.

Projections for these metrics have been produced for the three UKCP09 river basin regions in Wales (Dee, Severn and West Wales). The projections given below are for the p50 Medium Emissions scenario. The ranges in brackets (where shown) are approximate values for the most extreme climate change scenarios used in the analysis (p10 to p90 Medium Emissions for the 2020s and p10 Low Emissions to p90 High Emissions for the 2050s and 2080s).

WA1 Relative aridity

The relative aridity projections indicate that the average relative aridity could increase to about 1.0 in the 2020s, 1.8 in the 2050s and over 2.5 in the 2080s. This means that an average year could be similar to 2003 (which had a dry summer) by the 2050s and the major drought year of 1921 by the 2080s.

The projections for the p90 High Emissions scenario in the 2080s is an average relative aridity of about 4.7 in Wales and England (compared with a 1921 value of 2.59). This indicates that future major droughts could be very severe events, far more so than droughts experienced to date.

WA2 Change in Q95 flows

Compared with the 1961-90 baseline, the CCRA analysis indicates that the Q95 flows may reduce by:

- 10 to 20% by the 2020s (range 30% to an increase of 10%)
- 20 to 30% by the 2050s (range 5% to 40%), and
- 30 to 40% by the 2080s (range 10% to 50%).

WA7 Number of sites meeting Water Framework Directive Environmental Flow Indicators

Flow reductions would also have an adverse impact on water quality. The projected number of sites that could fail to meet Water Framework Directive (WFD) Environmental Flow Indicators (EFIs) compared with the 1961-90 baseline is as follows:

- About 40% by the 2020s (range 85% to an increase of 5%)
- About 85% by the 2050s (range 20% to 90%), and
- About 90% by the 2080s (range 60% to 92%).

The EFIs provide an estimate of the physical habitat required to achieve good ecological status. It is clear that very severe reductions in the number of sites achieving the EFIs are projected.

WA8 Number of sites with unsustainable abstraction

The reduction in number of sites with sustainable abstraction from the 1961-90 baseline is projected to be:

- About 40% by the 2020s (range 65% to an increase of 10%)
- About 55% by the 2050s (range 30% to 75%), and

- About 65% by the 2080s (range 50% to 80%).

It is clear from the above data for metrics WA2 and WA8 that average water availability is likely to reduce.

Hydropower potential

Reference number WAr2 (not analysed)

In view of the likely future need for more renewable energy, the potential for hydropower could be of particular importance in Wales, a country of relatively high rainfall and steep topography. Hydropower potential has not been assessed in the CCRA analysis.

However some general statements regarding the effects of climate change on hydropower potential can be made:

- Mean precipitation is projected to increase in the winter. The projected increases compared with the 1961-90 baseline under the p50 Medium Emissions scenario values are about 7% by the 2020s (range -2% to 16%), 14% by the 2050s (range 2% to 31%) and 19% by the 2080s (range 3% to 43%).
- Mean precipitation is projected to reduce in the summer. The projected reductions compared with the 1961-90 baseline under the p50 Medium Emissions scenario values are about 6% by the 2020s (range 22% to an increase of 11%), 17% by the 2050s (range 36% to an increase of 6%) and 20% by the 2080s (range 44% to an increase of 6%).
- The projected effect of climate change on annual precipitation is that it could increase or decrease typically by up to about 5%.
- River flows are projected to increase in the winter and reduce in the summer. Peak flood flows are projected to increase by about 13% by the 2020s, 20% by the 2050s and 30% by the 2080s compared with the 1961-90 baseline.

Thus the overall availability of water for hydropower generation is not projected to change by a large amount but the seasonality could change with higher generation potential in winter. This is normally the time of greatest demand for electricity, and therefore climate change might have a beneficial effect on hydropower potential.

Increase in chlorine depletion

Reference number WAr3 (not analysed)

Chlorine depletion is caused by greater microbial action as a result of temperature rise and reduces the effectiveness of the treatment of potable water by chlorination. This impact was identified in the CCRA Tier 1 list but was not scored sufficiently highly to be considered for analysis in Tier 2. Whilst the likelihood was considered to be high, the urgency (i.e. the need for short term action) was scored as low.

Increase in Cryptosporidium

Reference number WAr4 (not analysed)

Increases in the number of incidents of cryptosporidium in water are linked with the combination of intense rainfall events followed by sustained high temperatures. This impact was identified in the CCRA Tier 1 list but was not scored sufficiently highly to be considered for analysis in Tier 2. In particular, the scores for both likelihood and urgency were low.

However cryptosporidium in water was identified at the Cardiff workshop to be a key issue. It is understood that changes in rainfall are already increasing the number of incidents, with impacts on water treatment requirements and land use practices.

Impacts on private water supplies

Reference number WAr5 (not analysed)

Private water supplies are understood to be a particular concern because of the relatively high dependence on private supplies, particularly in rural areas. These supplies are often dependent on one source, normally from surface water. They therefore have limited resilience and flexibility to respond to changes in rainfall and watercourse flows. It is also difficult to identify alternative water supplies in small local systems.

There is a further concern that these supplies do not form part of the overall picture of water sector resilience, in contrast to water company supplies that are carefully monitored and managed.

Climate change impacts on private water supplies are generally expected to be more severe than that for public supplies because of local variability in rainfall and the other factors outlined above. For example, the projected reduction in summer rainfall of 17% by the 2050s would severely reduce water availability from existing private supplies.

Water Sector: Summary

Climate change is likely to lead to changes in water availability and supply, particularly during projected hotter, drier summers. The CCRA analysis concluded the following:

- Q95 flows are projected to become lower, by of the order of 10 to 20% by the 2020s, and 30 to 40% by the 2080s compared with the 1961-90 baseline (WA2).
- The availability of water in Wales is projected to reduce in summer. It is provisionally estimated that about 40% of the population of Wales might be affected by a shortage of water by the 2020s rising to over 90% by the 2080s (WA4).
- The number of river sites that meet WFD Environmental Flow Indicators is projected to reduce, by of the order of 40% by the 2020s rising to 90% by the 2080s compared with the 1961-90 baseline (WA7).
- Flooding from CSOs is projected to increase, causing additional flooding and pollution. Projections for Cardiff suggest an increase of over 50% in overflow frequency by the 2080s (WA10).
- The risk of summer droughts is projected to increase and future droughts could be more severe than those experienced to date (WAr1).
- The number of river sites with sustainable abstraction is projected to reduce, by of the order of 40% by the 2020s and 65% by the 2080s compared with the 1961-90 baseline (WAr1).
- The overall availability of water for hydropower generation may not change significantly but there is projected to be more in winter and less in summer (WAr2).
- Chlorine depletion in water may increase as a result of temperature rise although this has not been analysed in the CCRA (WAr3).
- Cryptosporidium in water may increase although this has not been analysed in the CCRA (WAr4).
- Private water supplies could be affected by changes in water availability although this has not been analysed in the CCRA (WAr5).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.4 Flooding and Coastal Erosion

Tidal flooding

Risk metrics FL 1, FL 2, FL 4, FL 6, FL 7 and FL 8 in the CCRA analysis (Wales analysis)

60% of the population live in coastal areas and 75% of the coastline is protected and designated for environmental importance. In addition, there are many caravan sites in flood risk areas and concerns regarding the implications of rising sea levels for some coastal communities.

Tidal flooding is therefore a high priority. As flood protection is provided for the main coastal communities, including for example Cardiff, the number of properties at significant likelihood of tidal flooding is limited (about 23,000)¹⁴. However as the sea level rises this number is projected to rise to between about 40,000 and 100,000 by the 2080s.

The CCRA analysis includes the following projections for tidal flooding:

- Number of people at significant likelihood of flooding (metric FL1)
- Number of residential properties in the highest 20% of deprived areas at significant likelihood of flooding (metric FL2)
- Number of residential properties at significant likelihood of flooding (metric FL6a)
- Expected Annual Damage (EAD) of residential properties at risk (metric FL6b)
- Number of non-residential properties at significant likelihood of flooding (metric FL7)
- EAD of non-residential properties at risk (metric FL7b)
- Transport links at significant likelihood of flooding (metric FL8)
- Area of agricultural land at risk of flooding (metric FL4).

The results for **tidal flooding** are summarised in Tables B.1 (people, properties and transport) and B.2 (agricultural land). Table B.1 shows the range of results for the emissions and population growth scenarios used in the CCRA, and Table B.2 shows results for the p50 Medium Emissions scenario.

The results indicate that the number of people and properties at risk of tidal flooding is projected to increase by a factor of between 1.5 and 4 by the 2080s. Although the amounts of sea level rise are relatively modest (just over 0.3m by the 2080s), the increased frequency of defence overtopping means that some properties in defended areas that are not at 'significant likelihood of flooding' at present would become at 'significant likelihood of flooding' in the future.

The areas shown in Tables B.2(a), (b), and (c) for flooding of agricultural land correspond to flood depths of 0.5m or greater. The total area at risk of flooding would be greater than this.

Whilst the increase in overall area of agricultural land at risk of tidal flooding is about 40% by the 2080s, the area of land that floods very frequently (once in 3 years or more frequently) is projected to rise by a factor of about 4.

¹⁴ Where 'significant likelihood' is an annual probability of flooding of 1.3% (1 in 75 years on average) or greater.

The overall area of agricultural land currently at risk of tidal flooding represents about 1% of all agricultural land (rising to about 1.7% by the 2080s assuming no increase in overall area of agricultural land).

Table B.1 People, properties and transport at significant likelihood of tidal flooding

Metric	Description	Projections for 'significant' likelihood of flooding			
		Baseline (2008)	2020s	2050s	2080s
FL1	People (thousands)	42	55-80	65-120	65-160
FL2	Vulnerable properties (thousands)	6	8-12	10-18	10-26
FL6a	Residential properties (thousands)	16	25-35	25-50	25-65
FL6b	Residential properties (EAD £m)	49	60-80	60-160	60-260
FL7a	Non-residential properties (thousands)	7	10-15	10-25	10-30
FL7b	Non-residential properties (EAD £m)	37	50-60	50-110	60-160
FL8	Motorway (km)	14	14	14-15	14-15
	A-roads (km)	235	240-260	260-280	270-290
	Other roads (km)	325	330-350	350-400	390-410
	Rail (km)	219	230-240	240-260	240-260

Table B.2(a) Area of agricultural land at risk of tidal flooding only (km²)

Epoch	Annual flood probability (%) for land grades 1, 2 and 3 (mainly arable and horticulture)			Annual flood probability (%) for land grades 4 and 5 (mainly grazing)			Total
	<33% (1 in 3 years)	33% - 20%	20% - 10%	<33% (1 in 3 years)	33% - 20%	20% - 10%	
Baseline (2008)	12	6	32	19	7	27	103
2020s	13	6	36	19	7	29	109
2050s	13	42	10	20	35	9	129
2080s	61	6	4	60	7	8	146

Table B.2(b) Area of agricultural land at risk of both tidal and river flooding (km²)

Epoch	Annual flood probability (%) for land grades 1, 2 and 3 (mainly arable and horticulture)			Annual flood probability (%) for land grades 4 and 5 (mainly grazing)			Total
	<33% (1 in 3 years)	33% - 20%	20% - 10%	<33% (1 in 3 years)	33% - 20%	20% - 10%	
Baseline (2008)	4	3	12	24	10	33	86
2020s	4	3	12	25	11	34	90
2050s	6	14	3	33	38	11	105
2080s	21	3	4	76	9	14	127

Table B.2(c) Overall area of agricultural land at risk of tidal flooding (km²)

(Sum of Tables B.2(a) and B.2(b))

Epoch	Annual flood probability (%) for land grades 1, 2 and 3 (mainly arable and horticulture)			Annual flood probability (%) for land grades 4 and 5 (mainly grazing)			Total
	<33% (1 in 3 years)	33% - 20%	20% - 10%	<33% (1 in 3 years)	33% - 20%	20% - 10%	
Baseline (2008)	16	9	44	43	17	60	189
2020s	17	9	48	44	18	63	199
2050s	19	56	13	53	73	20	234
2080s	82	9	8	136	16	22	273

Coastal and tidal flooding also has important implications for coastal habitats. This is discussed in the Biodiversity Sector (metric BD7).

River flooding

Risk metrics FL 1, FL 2, FL 4, FL 6, FL 7 and FL 8 in the CCRA analysis (Wales analysis)

Whilst river flooding is a serious risk both at present and in the future, the steep topography and predominance of coastal communities mean that it is not as important in Wales as in some other parts of the UK. However a risk of particular concern is the link with upland land use and management, as changes here may lead to changes in runoff and therefore flood flows.

The metrics calculated for **river flooding** are the same as those calculated for tidal flooding, and are listed in Tables B.3 and B.4. Table B.3 shows the range of results for the emissions and population growth scenarios used in the CCRA, and Table B.4 shows results for the p50 Medium Emissions scenario.

The areas shown in Table B.4 for flooding of agricultural land correspond to flood depths of 0.5m or greater. The total area at risk of flooding would be greater than this.

Table B.3 People, properties and transport at significant likelihood of river flooding

Metric	Description	Projections for 'significant' likelihood of flooding			
		Baseline (1961-90)	2020s	2050s	2080s
FL1	People (thousands)	65	80-135	65-170	85-210
FL2	Vulnerable properties (thousands)	6	8-16	6-20	8-26
FL6a	Residential properties (thousands)	25	30-55	25-70	35-85
FL6b	Residential properties (EAD £m)	56	60-120	50-170	60-210
FL7a	Non-residential properties (thousands)	17	20-30	20-40	20-50
FL7b	Non-residential properties (EAD £m)	55	60-130	60-200	70-320
FL8	Motorway (km)	8	8-10	8-12	9-12
	A-roads (km)	553	590-670	550-730	600-750
	Other roads (km)	1212	1300-1450	1250-1630	1320-1640
	Rail (km)	222	240-270	220-300	240-300

The results show an increase in the number of people and properties at risk of river flooding by a factor of between 1.3 and 3 by the 2080s compared with the 1961-90 baseline. The corresponding increase in river flood flows is projected to be about 28%.

Table B.4 Area of agricultural land at risk of river flooding (km²)

Epoch	Annual flood probability (%) for land grades 1, 2 and 3 (mainly arable and horticulture)			Annual flood probability (%) for land grades 4 and 5 (mainly grazing)			Total
	<33% (1 in 3 years)	33% - 20%	20% - 10%	<33% (1 in 3 years)	33% - 20%	20% - 10%	
Baseline (1961-90)	34	34	41	39	86	98	332
2020s	44	37	40	58	106	90	375
2050s	71	37	38	129	87	99	461
2080s	80	37	42	157	80	105	501

The overall area of agricultural land at risk of river flooding is projected to increase by about 50% by the 2080s compared with the 1961-90 baseline but the area of land that floods very frequently (once in 3 years or more frequently) could increase by a factor of about 2 to 3.

The overall total area of agricultural land at risk of river flooding represents about 2% of all agricultural land (rising to 3% by the 2080s assuming no increase in overall area of agricultural land).

River and tidal flooding: summary

The overall number of properties at risk of river and tidal flooding is estimated to be about 220,000, which is about 11% of all properties. Of these, about 65,000 properties are at significant likelihood of flooding.

The overall impacts of climate change on people and property at risk of river and tidal flooding is summarised in Table B.5, based on the results of the CCRA analysis.

Table B.5 People and properties at significant likelihood of river and tidal flooding

Description	Baseline	Projections			Notes (Figures are present day estimates)
		2020s	2050s	2080s	
People (thousands)	106	135-215	130-290	150-370	Total population 3 million
Residential properties (thousands)	41	55-90	50-120	60-150	Total number of residential properties 1.26 million
Non-residential properties (thousands)	24	30-45	30-65	30-80	Total number of non-residential properties 0.7 million (estimate)
Total properties (thousands)	65	85-135	80-185	90-230	Total number of properties 2 million
Residential properties (EAD £m)	105	120-200	110-330	120-470	
Non-residential properties (EAD £m)	92	110-190	110-310	130-480	
Total properties (EAD £m)	197	230-390	220-640	250-950	

The results indicate that there could be a relatively large increase in flood risk for relatively small increases in river flows and sea level. Many of the people and properties at risk are in areas currently protected by flood defences. Relatively small increases in sea levels or river flows are likely to have a large impact on the frequency of flooding in these areas.

This is because the chosen threshold of significant likelihood (1.3% annual probability of flooding or greater) is just below the standards of protection provided by the defences (typically 1% annual probability for river defences and 0.5% annual probability for tidal defences). Thus a relatively small increase in river flow or sea level will cause overtopping of defences and an increase in flood risk.

Surface water ('pluvial') flooding

Reference number FLr1 (not analysed)

This affects risk metrics FL 1, FL 2, FL 4, FL 6, FL 7 and FL 8 in the CCRA analysis, but no suitable data were available for analysis

It is estimated that there are about 230,000 properties at risk of surface water flooding, about 12% of all properties. Whilst this is a very large number (and similar to the total number of properties at risk from river and tidal flooding), there are currently no projections available on how this number might increase in the future.

The CCRA analysis does not therefore cover future projections for surface water flooding. It is intended to develop projections for future surface water flooding which should be available for the next CCRA in 2017. However, information is available that provides an indication of how the risk might change in the future.

The main driver of surface water flooding is storm rainfall. The UKCP09 projections indicate that mean winter rainfall might increase by up to 30% by the 2050s and between 3% and 60% by the 2080s ([Section 2.3.3](#)). Mean summer rainfall is projected to reduce but little change is projected for the wettest days in summer. These projections indicate that surface water flooding might increase, particularly as a result of increases in winter rainfall.

In addition, an analysis of UKCP09 Weather Generator outputs was undertaken to estimate the frequency of heavy rainfall events that may cause CSO spills. This analysis was completed for Cardiff, and simply counted the number of storms of different rainfall depths up to a total storm depth of 60 mm.

The results for Cardiff indicate that the frequency of heavy rainfall events (>40mm) could almost double by the 2080s leading to an increase in the frequency of surface water flooding ([Appendix B.3](#), metric WA10).

Overall it can be concluded that surface water flooding is a serious problem that is likely to increase. The projections of increases in mean winter rainfall and a potential doubling of the frequency of heavy rainfall events suggest that the increase could be significant.

Damage to critical infrastructure

Risk metric FL10 (water infrastructure) in the CCRA analysis (not analysed)

Risk metrics FL11 and FL12 (electricity, hospitals and schools) in the CCRA analysis (Wales analysis)

Critical infrastructure in the floodplains includes:

- Water supply and distribution
- Water treatment
- Electricity generation and distribution
- Hospitals
- Other medical facilities including health centres and GPs surgeries
- Schools
- Facilities for the emergency services including fire stations and police stations
- ICT equipment including communications centres, cables and transmission masts.

Tidal flooding of critical infrastructure is a particular concern as there are many strategic sites near the coast. There is also a concern regarding the interdependency between services and knock-on effects.

Much of the infrastructure listed above will be described in future national property datasets, but the information available for the CCRA was limited. In the CCRA analysis it was however possible to estimate numbers of power stations, major electricity sub-stations, hospitals and schools at significant likelihood of flooding. The results are

shown in Tables B.6 and B.7 are for the range of emissions scenarios used in the analysis, based on the current locations of infrastructure.

No information on future projections was available for water supply and distribution infrastructure (metric FL10) but Table B.8 shows that about two thirds of water pumping stations and treatment works are at significant likelihood of flooding, and this proportion is likely to increase under conditions of increased future flooding.

Table B.6 Electricity infrastructure at significant likelihood of flooding

Metric	Description	Projections for 'significant' likelihood of flooding			
		Baseline ¹	2020s	2050s	2080s
FL11	Power stations: Total capacity in MW				
	- River	0	0	0-1750	1750
	- Tidal	1950	2650	2650	2650
	- Total	1950	2650	2650-4400	4400
	Percentage of current generating capacity	20	30	30-50	50
	Major sub-stations: Number				
	- River	4	4	4	4
	- Tidal	8	8-9	9-10	10
	- Total	12	12-13	13-14	14

¹Baseline: 1961-90 river flooding; 2008 tidal flooding

About 20% of power generation capacity in Wales is in flood risk areas, although the analysis does not take account of local defences that could provide a locally higher standard of protection to the power stations. This could rise to about 30% by the 2020s and about 50% by the 2080s, although there is an ongoing programme of constructing new stations and de-commissioning older stations. Information on the locations of power stations and sub-stations was obtained from the National Grid and included in the flood modelling database.

Table B.7 Hospitals and schools at significant likelihood of flooding

Metric	Description	Projections for 'significant' likelihood of flooding (% increase)			
		Baseline ¹	2020s	2050s	2080s
FL12a	Hospitals: Percentage of total number (108)				
	- River	7	7-12	7-13	7-13
	- Tidal	4	4-5	5	5
	- Total	11	11-16	12-18	12-18
	Hospital beds: Percentage of total number (13350)				
	- River	10	10-16	10-16	10-16
	- Tidal	1	1-2	2	2
	- Total	10	10-18	11-18	11-18
FL12b	Primary schools: Percentage of total number (1478)				
	- River	7	8-9	7-10	8-11
	- Tidal	4	4-5	5-6	5-6
	- Total	11	12-14	12-16	13-17
	Secondary schools: Percentage of total number (223)				
	- River	7	7	7-9	7-9
	- Tidal	4	4	4	4
	- Total	11	11	11-13	11-13
	Primary and secondary schools: Percentage of total number (1700)				
	- River	7	8-9	7-10	8-11
	- Tidal	4	4-5	5	5
	- Total	11	12-14	12-15	13-16
	Primary and secondary school pupils: Percentage of total number (440,000)				
	- River	6	6-7	6-8	7-9
	- Tidal	5	5-6	6	6
	- Total	11	11-13	11-15	13-15

¹Baseline: 1961-90 river flooding; 2008 tidal flooding

Data in Table B.8 has been abstracted from 'Flooding in Wales' (Environment Agency 2009) for critical infrastructure not covered by the above analysis, to provide an indication of the magnitude of the risk.

Table B.8 Critical infrastructure: present day risk

Infrastructure	Percentage at risk of river or tidal flooding	
	Significant likelihood	0.1% (1 in 1000-year) floodplain
Water pumping stations and treatment works	67	82
All electricity infrastructure including small installations	7	22
Communications stations	N/A	19
Police, fire and ambulance stations	8	19
Surgeries and health centres	5	18
Caravan parks	14	24

Ability to obtain flood insurance for residential properties

Risk metric FL13 in the CCRA analysis (Wales analysis)

There is a concern that as the number of properties at risk of flooding increases it may become more difficult to obtain insurance for properties in flood risk areas. This was explored in the CCRA analysis by looking at the number of residential properties at significant likelihood of flooding. This likelihood was selected because the Association of British Insurers (ABI) has used it in the statement of principles outlined below.

The current ABI statement of principles includes the following:

Until 30 June 2013, ABI members commit to:

- Continue to make flood insurance for domestic properties and small businesses available as a feature of standard household and small business policies if the flood risk is not significant (this is generally defined as no worse than a 1.3% or 1 in 75 annual probability of flooding or greater).
- Continue to offer flood cover to existing domestic property and small business customers at significant likelihood of flooding providing the Welsh Government or its key partners have announced plans and notified the ABI of its intention to reduce the risk for those customers below significant within five years. The commitment to offer cover would extend to the new owner of any applicable property subject to satisfactory information about the new owner.

The estimated number of properties at significant likelihood of tidal and river flooding is listed in Table B.9 under the p50 Medium Emissions scenario and the Principal population growth scenario.

Table B.9 Properties at significant likelihood of tidal and river flooding

Metric	Description	Projections for 'significant' likelihood of flooding			
		Baseline ¹	2020s	2050s	2080s
FL6a	Residential properties (thousands)				
	- River	25	30-55	25-70	35-85
	- Tidal	16	25-35	25-50	25-65
	- Total	41	55-90	50-120	60-150
FL6b	Residential properties (EAD £m)	105	120-200	110-330	120-470
FL7a	Non-residential properties (thousands)				
	- River	17	20-30	20-40	20-50
	- Tidal	7	10-15	10-25	10-30
	- Total	24	30-45	30-65	30-80
FL7b	Non-residential properties (EAD £m)	92	110-190	110-310	130-480

¹Baseline: 1961-90 river flooding; 2008 tidal flooding

Thus the number of residential properties at significant likelihood of tidal and river flooding could rise from about 41,000 (baseline) to between 60,000 and 150,000 by the 2080s. The total number of residential properties is currently about 1.26 million.

Similarly, the number of non-residential properties at significant likelihood of tidal and river flooding could rise from about 24,000 (baseline) to between 30,000 and 80,000 by the 2080s. There are currently about 700,000 non-residential properties.

About 65,000 residential and non-residential properties at significant likelihood of river and tidal flooding are below the flood probability threshold used by the Welsh Government and the ABI, about 3.5% of all properties in Wales. By the 2020s this number could rise to between 85,000 and 135,000 properties.

Agricultural land and BAP habitats lost to coastal erosion

Risk metric FL14a (agricultural land) in the CCRA analysis (Wales analysis)

Risk metric FL14b (BAP habitats) in the CCRA analysis (not analysed for Wales)

Coastal erosion is currently not considered to be a major issue although beaches are affected both by sea level rise and erosion. However there are potentially severe risks in the longer term including:

- Loss of beach area.
- The long-term sustainability of some coastal communities may require review over the next few decades. It is possible that in some places communities would become unsustainable and that a policy of managed retreat may need to be adopted.
- Damage to coastal habitats. This is discussed in the Biodiversity Sector (metric BD2).

The CCRA analysis assumed that coastal defences for urban areas would be maintained but erosion could occur elsewhere. The analysis did not use the recent

National Coastal Erosion Risk Maps (NCERM) as these were not available when the work was carried out. The results include initial estimates on the impacts of coastal erosion on agricultural land, summarised in Table B.10. The data are considered to be very approximate. Improved data has been prepared by the Environment Agency but not yet released.

Table B.10 Area of agricultural land at risk from coastal erosion (p50 Medium Emissions scenario)

Agricultural land grade	Land affected (ha) by epoch		
	2020s	2050s	2080s
1	0	0	0
2	12-15	45-70	90-130
3	100-120	340-560	680-1000
4	70-90	270-440	560-820
5	75-100	330-530	690-980
Total	250-330	980-1600	2000-3000

The total area of agricultural land is about 1.6 million hectares of which the vast majority (1.5 million hectares) is grass and rough grazing (generally land grades 4 and 5). The above estimates indicate that between 0.1% and 0.2% of agricultural land could be lost to coastal erosion by the 2080s.

Flood risk for Scheduled Ancient Monument sites

Risk metric FL15 in the CCRA analysis (Wales analysis)

The potential loss of sites of archaeological or cultural importance is important in some parts of Wales. In order to assess this impact, the CCRA analysis identified the area of Scheduled Ancient Monument sites at significant likelihood of flooding. The baseline area is about 600ha and future projections for the emissions scenarios used in the analysis are as follows:

- 2020s: 600-800ha
- 2050s: 600-900ha
- 2080s: 700-900ha

About 40% of these areas are at risk from river flooding and about 60% from tidal flooding.

Fluvial flooding (contaminated sites and flash flooding)

Reference number FLr2 (not analysed)

Wales has some particular problems related to fluvial flood risk. The topography is generally undulating, and there are many flashy rivers where large floods can occur with little or no warning. There are also many brownfield sites from former industries, where flooding can lead to pollution.

These site specific issues have not been assessed in the CCRA, where the flood analysis is based on high level national information.

Increase in combination flooding

Reference number FLr3 (not analysed)

The combination of flooding from different sources is of concern, particularly in the following locations:

- Coastal areas, where river flooding and surface water flooding can occur at the same time as high tidal water levels. The north Wales coast is understood to be particularly vulnerable to flooding from this cause.
- River valleys, where runoff from surface water and tributaries occurs at the same time as high water levels in the main rivers.

These have not been assessed in the CCRA analysis but these combinations are likely to increase as the sea level rises and if the frequency and severity of rainfall events increases.

Increase in tide-locking of drainage outfalls

Reference number FLr4 (not analysed)

Tide locking of drainage outfalls is a particular concern as the majority of the population lives on the coast. This was identified in the CCRA Tier 1 list but has not been analysed separately. The impacts of tide locking will be affected by sea level rise, leading to longer closure periods for tide flaps, and increases in storm rainfall, leading to higher fluvial flows during tidelock periods. For these reasons it is likely that flooding from tidelock could increase.

Flooding and Coastal Erosion Sector: Summary

Climate change is projected to lead to increased flooding from sea level rise, increased winter rainfall and more intense storms. The CCRA analysis concluded the following:

- Flood risk in Wales is higher than in other UK countries in terms of the proportion of people, property and infrastructure at risk of flooding. This reflects the fact that most of the population is located either near the coast or in river valleys.
- The number of people and properties at risk of river and tidal flooding may increase by between 10% and 100% by the 2020s, and by between 50% and 250% by the 2080s compared with the baseline (1961-90 for river flooding and 2008 for tidal flooding) (FL1, FL6, FL7).
- There are of the order of 220,000 properties at risk of river and tidal flooding, about 11% of all properties. This includes about 65,000 properties that are at significant likelihood of flooding (1.3% chance per year or greater) (FL6, FL7).
- It is estimated that about 12% of all properties are currently at risk of surface water flooding, and this number is likely to increase. However surface water flooding was not analysed in the CCRA (FLr1).
- The area of agricultural land at risk of river and tidal flooding is projected to increase by about 50% by the 2080s compared with the baseline. The area of agricultural land that floods very frequently (once in 3 years or more frequently) could increase by a factor of about 2 to 3 (FL4).
- About 22km of motorways, over 2,300km of other roads and over 400km of railway lines are estimated to be at significant likelihood of river and tidal

flooding. These figures could increase by between 10% and 35% by the 2080s (FL8).

- About 20% of power generation capacity in Wales is estimated to be at significant likelihood of flooding. This could rise to about 30% by the 2020s and about 50% by the 2080s if the same sites continue to be used for power generation (FL11).
- It is estimated that there are about 11% of hospitals (with 10% of hospital beds) at significant likelihood of flooding. This could rise to between 12% and 18% by the 2080s (FL12a).
- It is estimated that there are about 11% of schools at significant likelihood of flooding. This could rise to between 13% and 16% by the 2080s (FL12b).
- About 65,000 residential and non-residential properties are below the flood probability threshold used by the Welsh Government and the ABI, about 3.5% of all properties in Wales. By the 2020s this number could rise to between 85,000 and 140,000 properties (FL13).
- It is projected that between 0.1% and 0.2% of agricultural land could be lost to coastal erosion by the 2080s (FL14a).
- There are estimated to be about 600ha of Scheduled Ancient Monument sites at significant likelihood of flooding. This could rise to between 700ha and 900ha by the 2080s (FL15).
- Flash flooding and fluvial flooding of contaminated sites could increase although this has not been analysed in the CCRA (FLr1).
- Flooding from a combination of different sources could increase with climate change, particularly in coastal areas (including tide locking) and river valleys although this has not been analysed in the CCRA (FLr2, FLr3).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.5 Agriculture

Change in crop yield

Risk metric AG1 in the CCRA analysis (Wales analysis)

Crop yields are affected by a range of factors, some of which are climate related (particularly temperature and precipitation). Increasing temperatures are generally likely to lead to increases in yield provided that water does not become a constraint. The CCRA analysis investigated crop yields for wheat, potatoes and sugar beet. In 2009 Wales had about 20,000ha of wheat and 2,600ha of potatoes (Welsh Agricultural Statistics 2009¹⁵).

The analysis for wheat indicates that yields might increase by about 40% by the 2020s, 70% by the 2050s and 100% by the 2080s. Water is an important yield component and, as yields increase, the ability of the crop to exploit the available water resource could become a major determinant of final yield in future.

In addition to increases in mean growing season temperature, yields are likely to increase even further with improvements in wheat varieties and some gains due to higher CO₂ concentrations.

It is projected that potato yields might reduce by about 2% by the 2020s, 5% by the 2050s and 6% by the 2080s for rainfed yield. In contrast, future potential yields without restrictions in water or fertiliser availability, have been reported to increase by 13-16%. These increases are principally due to increased radiation and temperature levels and elevated CO₂ concentration effects.

Considering all the available evidence, it is very likely that yields would be maintained or improved in future, provided that water does not become a constraint. There is likely to be an increased demand for water abstraction for irrigation and a potential northwards shift in production if more water is available in these regions. The CCRA analysis has also identified a range of new crops that would be suited to the projected future climate (metric AG9).

Flood risk to agricultural land

Risk metrics AG2 and FL4 in the CCRA analysis (Wales analysis)

The CCRA analysis included an assessment of the area of agricultural land at risk from river and tidal flooding. The Agricultural Land Classification (ALC) was used to estimate the areas of agricultural land at risk of river and tidal flooding with annual frequencies of less than 33% (1 in 3 years on average), 33% to 20% (1 in 3 to 1 in 5 years on average) and 20% to 10% (1 in 5 to 1 in 10 years on average) for ALC grades 1 to 3 (horticulture/arable) and 4 and 5 (grassland/grazing).

The analysis did not cover flooding from surface water or groundwater, or waterlogging, as suitable data were not available. The results are summarised in Table B.11 for river and tidal flooding, using the figures from Tables B.2 and B.4.

¹⁵ <http://wales.gov.uk/topics/statistics/headlines/agric2009/hdw200905131>

Table B.11 Area of agricultural land at risk of river and tidal flooding (km²)

Epoch	Annual flood probability (%) for land grades 1, 2 and 3 (mainly arable and horticulture)			Annual flood probability (%) for land grades 4 and 5 (mainly grazing)			Total
	<33% (1 in 3 years)	33% - 20%	20% - 10%	<33% (1 in 3 years)	33% - 20%	20% - 10%	
Baseline¹	50	43	85	82	103	158	521
2020s	61	46	88	102	124	153	574
2050s	90	93	51	182	160	119	695
2080s	162	46	50	293	96	127	774

¹Baseline: 1961-90 river flooding; 2008 tidal flooding

The analysis covers areas with 0.5m depth of inundation or greater. The total area with a flood depth of 0m or greater was calculated to be 1,330km² by the 2080s using the same analysis approach (about 70% higher than the total given above).

The proportion of agricultural land that has a 10% annual probability of flooding (1 in 10 years on average) or greater is projected to rise from about 3% (baseline) to about 5% in the 2080s. Grades 1, 2 and 3 land that floods regularly (>33% chance per year or 1 in 3 years on average) is projected to rise from about 50km² to over 150km². For grades 4 and 5, the corresponding figures are from about 80km² to about 300km².

Land that is flooded regularly (particularly from the sea) becomes untenable for normal agricultural use. Grassland and rough grazing that is flooded regularly from the sea may also become unusable.

The CCRA analysis also provided estimates of the costs of flood damage to agriculture based on data from the 2007 flood, which affected the River Severn and other catchments in central and southern England. It was estimated that the agricultural losses were in the range of about £1000 to £1600/ha for arable land, and £200 to more than £1000/ha for grassland and livestock.

Risk of crop pests and diseases

Risk metric AG3 in the CCRA analysis (UK analysis)

Plant pests and diseases were investigated in the CCRA analysis using 'marker' diseases for sugar beet (beet mild yellow virus, BMV) and wheat (yellow rust). Long-term historical data are available for these diseases. However it was not possible to derive any simple robust climate risk metrics for these crop impacts. It is possible that improvements in crop agronomy coupled with the development and use of agrochemicals has significantly reduced disease expression. This has in effect buffered the effects of inter-annual climate variability on disease prevalence.

Similarly, for potatoes, although an industry blight monitoring and eradication programme has been in place for many years, neither suitable data nor the derivation of a suitable metric was possible. Other pests include increasing populations of deer and squirrels.

Recent research shows that many pests and pathogens are robust and able to adapt to change. There is therefore little doubt that any opportunities resulting from climate change would be exploited by them. However the interactions between crops, pests and pathogens are complex and currently poorly understood in the context of climate change. More mechanistic inclusion of pests and pathogen effects in crop models

would lead to more realistic projections of crop production at regional scales and assist in the development of robust climate change risk assessments.

Drier soils (due to warmer and drier summer conditions)

Risk metric AG4 in the CCRA analysis (Wales analysis)

UK-level changes in aridity using Potential Soil Moisture Deficit (PSMD) as an agroclimate index suggest mean increases of approximately 40% for the 2020s, rising to over 100% by the 2080s for the UK under a p50 Medium Emissions scenario, although there is considerable uncertainty in these values.

It is projected that the PSMDmax is likely to rise from the present day value of 170mm to about 370mm by the 2080s (range 150mm to 670mm for the p10 Low Emissions and p90 High Emissions scenarios respectively).

The combined changes in rainfall and evapotranspiration are likely to increase aridity levels and hence the need for supplemental irrigation, particularly on high value crops where continuous supplies of premium quality is the driving force in production. It is likely that many crops that are currently irrigated would require more frequent and higher seasonal application depths. It is also likely that for some crops rainfed production may become yield limiting and irrigation would be necessary to maintain current production levels.

Any increases in demand for agricultural irrigation would be influenced by local water resources availability, which is projected to become much scarcer in summer. Growers may adapt through developing better approaches to water management, investing in new application technologies and water storage and/or moving production to areas with suitable land and access to reliable water supplies.

Increase in water demand for irrigation of crops

Risk metric AG5 in the CCRA analysis (Wales analysis)

Agricultural water abstraction in Wales and England constitutes a very small proportion (1-2%) of total abstraction but is concentrated in the driest years, in the driest catchments and at the driest times of year when resources are most under pressure.

By combining historical abstraction data from the Environment Agency with data on agroclimate, future average increases in agricultural water demand of approximately 15% for the 2020s, rising to 25% (2050s) and 50% (2080s) were projected, but with a wide uncertainty band (-20% to 110% in the 2080s).

By the 2050s and 2080s it is likely that there would be significant increases in water abstraction for crops as changes in agroclimate and increasing aridity combine with increased demands for food production.

Projections presented in the CCRA analysis for agricultural abstractions are as follows:

- Present day: 8.7Ml/day
- 2020s: 36% increase (range -15% to 90%)
- 2050s: 90% increase (range 25% to 160%)
- 2080s: 115% increase (range 45% to 200%)

Whilst the overall amounts are modest compared to water availability, the increases are large and would occur during periods of greatest water stress.

Increase in water demand for livestock

Risk metric AG6 in the CCRA analysis (not analysed)

Currently water abstraction for utilisation by livestock agriculture is relatively small and is predominantly related to watering and washing of livestock and their production systems (e.g. housing). However a much larger amount of water is used for the irrigation of crops that contribute (wholly or partially) to livestock diets (grass and cereals). It has been estimated that about half of agricultural water abstractions are related to livestock.

However, details of the exact use of water in all these circumstances were not available and it has therefore not been possible to provide projections for livestock water use. It is likely that the major water abstraction issue for livestock is the need for access to drinking water for livestock and the potential need to use more water for cooling animals and cooling plant mechanisms (e.g. milking parlours).

Reduction in milk production and dairy herd fertility due to heat stress

Risk metrics AG7(a) – Heat stress impact on dairy milk production, and AG7(b) - Heat stress impact on loss of dairy fertility (UK analysis)

Livestock product quality is of particular importance for Welsh agriculture, particularly Welsh lamb and beef. Factors that affect product quality include quality of feed supply and pasture, physiological impacts (including intake, fertility and health) and stress factors on livestock.

The CCRA analysis covered the effects of thermal humidity and heat stress on dairy milk production in the UK. The analysis was related to the average change in climate and did not include extreme weather events that may result in higher numbers of heat stress losses (heat wave and drought).

Overall, the current UK climate does not result in losses from dairy system production or pose a major risk to dairy production and this is likely to continue into the 2020s. By the 2050s a small loss in milk production due to heat stress is projected, about 3 million kg/annum under the p50 Medium Emissions scenario, which is less than 0.01% of current UK milk production. There would however be costs related to declines in herd fertility.

In the longer term, consequences are projected to become more significant, particularly for scenarios representing more humid and hotter conditions.

The analysis on loss of dairy fertility indicates further pressures on dairy production and that there may be additional costs over and above lost milk production in the longer term under the hot and more humid climate scenarios in the 2050s and 2080s.

In summary, the CCRA analysis indicates that impacts on milk production would be small but impacts for meat production have not been investigated.

Heat stress effects on dairy cows including livestock deaths

Risk metric AG8 in the CCRA analysis (UK analysis)

Livestock stress factors include heat stress, cold stress and adverse weather. The CCRA analysis includes an assessment of heat stress on livestock, which indicates small and largely insignificant increases in the number of days of heat stress for typical dairy herds. For example, under the p90 High Emissions scenario for the 2080s, the model indicates a maximum of 3 days per annum when livestock would be classified as stressed. Consequently the expected number of deaths from heat stress is considered negligible.

Opportunities to grow new crops

Risk metric AG9 (UK analysis)

Changing agroclimatic and soil conditions would also influence land suitability, both for existing crops and the potential for new crops. In this context, a wide range of crops could potentially be grown in the UK depending on how future changes in rainfall and temperature affect land suitability.

There is thus scope for many new crops to enter production and change the composition of agricultural land use including, for example, new food crops, new energy crops (for biogas, biomass or bioethanol production), new pharmaceutical crops (drugs or cosmetics), and new industrial crops (e.g. for biopolymers, biolubricants, oil, fibre, paper and pulp).

The CCRA includes a summary of new crops that could potentially be grown in the UK and their geographical suitability is provided. This includes over 30 food crops, about 20 'pharmaceutical' and 'industrial' crops, and 5 energy crops (for potential energy production). Examples of crops that could be grown in Wales in the future include Elder, Garlic, Juniper, Lupin and Rocket.

Changes in grassland productivity

Risk metric AG10 (Wales analysis)

Wales has about 1.4 million hectares of permanent grass and rough pasture used for grazing (about 85% of all agricultural land). Experimental evidence shows that grass production can increase in response to higher temperatures and CO₂ concentrations, both singly and especially in combination, as long as other factors affecting grass growth including water and nutrient supply, particularly nitrogen availability, are non-limiting.

One of the study areas was lowland west Wales (Carmarthen/ Dyfed), which is representative of some of the most productive grassland in the UK, with a long grass-growing season and oceanic conditions. Two cases were assessed: intensive management of grassland (mainly for silage) and grassland herbage for lowland beef and dairy production. The projections for increases in yield are:

Epoch	Intensive management	Grassland herbage	Comments
Baseline yield (tonnes/ha)	15.0	10.5	
2020s	+6% to +14%	+12% to +20%	
2050s	+10% to +32%	+15% to +35%	32% maximum ceiling yield for intensive management (20t/ha)
2080s	+14% to +32%	+20% to +35%	35% maximum ceiling yield for herbage (14t/ha)

In west Wales under UKCP09 p50 2050s High and 2080s Medium and High Emissions scenarios mean summer temperatures are projected to increase by 2-4°C and summer rainfall is projected to reduce by between 10 and 25% of 'baseline' amounts. These effects might be expected to lead to some short term reductions in grass growth, especially on sites with shallow soils, but the likelihood is that any short-term loss would be offset by growth in spring and autumn.

Other factors that could affect grass growth include an increase in fire risk and soil erosion.

Change in crop stress factors

Reference number AGr1 (not analysed)

Crop stress factors include water stress, frost damage and waterlogging. The effects of drought and the need for supplemental irrigation have been considered in the CCRA analysis but other factors have not been covered.

It is however apparent that increased water stress in the summer and increased waterlogging in the winter would have an impact on agricultural production including silage and forage quality. Waterlogging not only affects yield but also access and trafficability.

Change in livestock pests and diseases

Reference number AGr2 (not analysed)

Pests and diseases are one of the factors that affect livestock product quality. This impact has not been assessed in the CCRA analysis although it is important in Wales which has a large livestock population, particularly sheep.

Impacts on pollination (crop yield)

Reference number AGr3 (not analysed)

Pollination is clearly an important process in agriculture related to crop yield, although the impacts of climate change on pollination are unclear. This has not been investigated in the CCRA analysis.

Increased countryside recreation

Reference number AGr4 (not analysed)

Warmer temperatures may lead to increased countryside recreation. This has the potential to change the rural economy and create additional stresses on facilities including water supplies. This impact has not been considered in the CCRA analysis.

Agriculture Sector: Summary

Welsh agriculture is dominated by livestock production. Of the 17,100km² of agricultural land, 12,700 km² (75%) is grass and 1,800 km² (10%) is rough pasture. 2,100 km² (12%) is arable and the remainder consists of agricultural holdings (most of which is woodland).

Any changes in climate are likely to lead to changes in agriculture, both positive and negative. Some of the opportunities include increases in crop yield, new cropping opportunities and carbon storage. The main potential adverse impacts include water availability and new pests and diseases. The CCRA analysis concluded the following:

- It is very likely that crop yields will be maintained or improved in future although water and nutrient availability may be a constraint (AG1).
- The proportion of agricultural land that has a 10% annual probability of flooding (1 in 10 years on average) or greater is projected to rise from about 3% (baseline) to about 5% by the 2080s (AG2).
- The area of agricultural land that floods regularly (>33% chance per year or 1 in 3 years on average) could increase by a factor of 3 to 4 times by the 2080s compared with the baseline (AG2).
- Land that is flooded regularly (particularly from the sea) may become untenable for normal agricultural use (AG2).
- Plant pests and pathogens are likely to exploit opportunities resulting from climate change, although the processes are currently poorly understood (AG3).
- The Potential Soil Moisture Deficit is projected to double by the 2080s. Supplementary irrigation is likely to be required, particularly for high value crops (AG4).
- Crop water use is modest compared to water availability but large increases are projected that would occur during periods of greatest water stress (AG5).
- Livestock water use is likely to increase although this has not been analysed in the CCRA (AG6).
- Heat stress on livestock and dairy production is unlikely to be a major issue (AG7 and AG8). The impact of climate change on meat production has not been analysed in the CCRA.
- The types and locations of crops may change as farmers adapt to climate change (AG9).
- It is likely that grassland yield would increase (AG10).
- Increased water stress in the summer and increased waterlogging in the winter are likely to have an impact on agricultural production although this has not been analysed in the CCRA (AGr1).
- Livestock pests and diseases could affect livestock product quality and are therefore of particular concern. This has not been analysed in the CCRA (AGr2).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.6 Forestry

Forest extent affected by pests and diseases

Risk metric FO1 in the CCRA analysis (UK analysis)

Pests and diseases are regarded as a priority climate change impact. The CCRA analysis considers the aerial extent of woodland that is affected by pests and pathogens, taking 'affected' to mean that the prevalence of pests or pathogens is sufficiently severe to cause a reduction of productivity, timber quality and/or a change in forest management practice.

Whilst there is no clear evidence linking pests and pathogen occurrence with climate variables, it is widely recognised that climate is a major controlling influence on the spread of pests and pathogens. In the CCRA analysis the impacts of pests and pathogens have been assessed by investigating the relationship of a sample pest and a sample pathogen to climate. These are:

- Forest extent affected by red band needle blight
- Forest extent affected by green spruce aphid

The results show that the impact of climate change is greater for red band needle blight than for green spruce aphid. Red band needle blight is likely to reach the high impact level by the 2050s and very high impact by the 2080s, whereas the projected impact of green spruce aphid is low by the 2050s and low to medium by the 2080s.

It was roughly estimated that red band needle blight might affect more than 50% of pine forest in Great Britain by the 2050s and all pine forest by the 2080s. Similarly, it was estimated that the amount of spruce forest in Great Britain affected by green spruce aphid might double by the 2080s from the present day area.

Loss of forest productivity due to drought

Risk metric FO2 in the CCRA analysis (UK analysis)

Drought influences tree health, growth and productivity. Ultimately, drought can cause tree mortality, often when in combination with other stresses such as pests and pathogens. The CCRA analysis relates soil moisture deficit (as an indicator of dry conditions) to the percentage of severely defoliated trees.

The loss of productivity due to drought has been calculated based on the Potential Soil Moisture Deficit and aridity index. It was found that both of these indicators have a similar influence on defoliation and productivity.

The results indicate that there could be a 10% loss of yield under present day conditions, rising to about 18% by the 2080s (range 10% to 30% for different scenarios).

Change in potential yield

Risk metric FO4 in the CCRA analysis (Wales analysis)

Potential yield has been modelled using climate and soil information for important commercial tree species on the Forestry Commission managed public forestry estate in Wales. Results for a high emissions scenario in 2050 and 2080 show an increase in productivity for some species in Wales but a decline in other species. The rate of change appears greatest after 2050 for most species.

Sitka spruce represents about 70% of the total timber yield in the assessment for Wales. Estimated changes in yield for Sitka spruce are an increase of about 20% by

2050 and an overall increase of about 10% by 2080 (and thus a decline between 2050 and 2080).

Twelve species make up the remaining 30% of the yield. The overall change in yield for these species is projected to be an increase of about 4% by 2050 but an overall decline of about 25% by 2080.

Increase in erosion and landslips

Reference number FOr1 (not analysed)

Erosion and landslip events have been particularly evident in recent years in damage caused to transport infrastructure. Erosion and landslips is a particular risk for Welsh forests because many forests are on hillsides. The risk of these events is related to a number of factors including land slope angle and type, soil type, soil water content and land use. Most erosion and landslip events follow periods of extreme rainfall.

Forests and woodland can help reduce soil loss by intercepting rainfall and therefore protecting the surface, by removing water from the site through evapotranspiration, and through the enhanced soil strength provided by roots. However, when trees are harvested or die, the subsequent root decomposition leads to decreased cohesion and therefore increased risk of soil loss, compounded by the removal of the protection provided by tree cover.

An additional threat is from windthrow of trees on steep slopes. If soil-root plates are overturned during wind storms, a large volume of soil is displaced down slope and is exposed to further erosion. For these reasons, although trees growing on steep slopes provide a substantial benefit to soil stability, their management requires particular care to maintain their protective function.

In Wales, where climate projections indicate that winter rainfall will increase, erosion and landslips would be expected to increase in frequency. This may be exacerbated by increased growth rates of trees and increased vulnerability to wind throw from higher water tables and increased storm frequency.

Unless forest management is adjusted to take climate change factors into account on vulnerable forested slopes, the risk of soil loss from erosion and landslip events will increase over the next century. This impact has not however been assessed in the CCRA analysis.

Impacts associated with phenology

Reference number FOr2 (not analysed)

Growing seasons including nursery stock are likely to change as the temperature rises and rainfall patterns change. For example, changes in the timing of frosts would affect the growing season. This would affect tree growth and the annual cycle of forest management. This impact has not been assessed in the CCRA analysis.

Increase in waterlogging

Reference number FOr3 (not analysed)

Increased rainfall alone will not necessarily increase the occurrence of waterlogging, which depends on the balance between rainfall, evaporation, drainage and runoff.

Upland forests in the UK, which include most of the commercial productive conifer plantations, have soils that are predominantly not free draining. A high proportion of these soil types commonly have water tables at a depth below the surface that fluctuates throughout the year and may be close to the surface for parts of the year, usually the winter months.

If rainfall increases, these seasonally fluctuating water tables will approach closer to the surface, and for longer periods. For this reason, woodland creation on soils prone to waterlogging usually relies on some form of artificial drainage.

The anaerobic conditions in waterlogged soils do not permit growth of roots of most tree species, and the active parts of roots that have grown in soil that becomes waterlogged will die (although roots of some conifer species have been found to tolerate waterlogging if they are fully dormant in the winter).

Root death or dieback resulting from waterlogging reduces or limits the rooting depth of trees. As rooting depth is closely related to the anchorage strength of root systems, trees that have limited rooting depth on waterlogged soils will be less wind-stable than trees on free draining soils, and therefore have an increased risk of wind damage.

Where roots are killed by a rising water table, the soil will lose the cohesion benefit of the roots. This loss, in combination with the reduced strength of saturated soil, will make waterlogged forest soils considerably more prone to erosion and landslides.

An additional risk to trees from rooting depth that is limited by seasonally high water tables is that on sites that dry out in summer months, roots may be unable to reach available water for parts of the growing season, leading to increased water stress. In addition, waterlogging is implicated in the spread and attack of some important root pathogens.

There is a risk that waterlogging in forests will increase in wetter winters, although the extent and magnitude of this impact has not been assessed in the CCRA.

Change in soil organic carbon

Risk metric BD8 in the CCRA analysis (UK analysis, see Biodiversity Sector)

Whilst it is recognised that change in soil organic carbon is an important issue, there is considerable uncertainty regarding the potential impact of climate change on soil organic carbon.

This impact has been assessed in the Biodiversity Sector in relation to blanket bog (metric BD8).

Increased risk of wildfires

Risk metric BD12 in the CCRA analysis (Wales analysis, see Biodiversity Sector)

It is likely that the risk of forest fires may increase as a result of warmer drier summers. This impact has been assessed in the Biodiversity Sector (metric BD12). It is provisionally estimated that the risk of wildfires might increase by 30 to 50% by the 2080s.

Forestry Sector: Summary

There are about 290,000ha of forests in Wales, representing about 14% of the total land area. The CCRA analysis concluded the following:

- Pests and diseases could affect large proportions of different woodland types as climatic conditions change (FO1).
- Drought could seriously affect tree productivity. There could be a 10% loss of yield under present day conditions, rising to about 18% by the 2080s (FO2).
- The yield of forest trees is likely to change as the climate changes, with increases for some species and a decline for others. An overall increase in yield is projected by 2050 followed by a decline in yield between 2050 and 2080 (FO4).
- Erosion and landslips may increase as a result of wetter winters although this has not been analysed in the CCRA (FO1).
- Forest productivity and biodiversity may be adversely affected by changes in growing seasons and breeding/hatching cycles, although this has not been analysed in the CCRA (FO2).
- Increased waterlogging is likely to occur in wetter winters leading to tree damage and a reduction in timber yields, although this has not been analysed in the CCRA (FO3).
- The risk of wildfires is likely to increase, with adverse consequences for timber production and biodiversity (BD12).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.7 Health

Summer mortality due to higher temperatures

Risk metric HE1 in the CCRA analysis (Wales analysis)

As temperatures increase the number of premature deaths as a result of heat related illnesses (cardio-vascular and respiratory diseases) may also increase, particularly during summer months.

It is estimated that the annual number of premature deaths could range from about 60 to 350 by the 2050s and from about 70 to 1,000 by the 2080s. The current baseline figure is about 40 deaths per year.

Summer morbidity due to higher temperatures

Risk metric HE2 in the CCRA analysis (Wales analysis)

Temperature increases during the summer months are also likely to cause more heat related illnesses. This was assessed in the CCRA analysis based on the increase in the number of hospital admissions as a result of heat related illnesses.

It is estimated that the number of patient days per year caused by heat related illnesses could range from about 6,000 to 30,000 by the 2050s and be of the order of 10,000 to 100,000 by the 2080s, although only tentative estimates were given in the CCRA. The current baseline figure is estimated to be about 4,000 patient days per year.

Extreme weather event (flooding and storms) mortality

Risk metric HE3 in the CCRA analysis (UK analysis)

Flood risk is projected to increase as a result of climate change. This could lead to a potential increase in the mortality rates of people affected by flooding.

The limited number of extreme flood events leading to death means that it is not possible to give a geographical breakdown of death due to extreme event flooding or storms. However, on a UK scale, mortality due to extreme flooding and storms is projected to increase annually from a current baseline of about 20 by between 20 to 40 by the 2050s and 30 to over 60 by the 2080s. This includes the effects of wave action on the coast.

Thus, whilst extreme weather event mortality is perceived to be an important impact, the magnitude is small. Arguably the stress related impacts associated with extreme weather events are more widespread and have a more severe effect on society.

Mortality and morbidity due to summer air pollution (ozone)

Risk metric HE4 in the CCRA analysis (Wales analysis)

Ground-level ozone is a secondary pollutant, which means that it is not directly emitted from pollution sources but is formed by a series of chemical reactions between nitrogen oxides, volatile organic compounds and oxygen in the presence of sunlight. Ozone also has important impacts on the productivity of natural vegetation.

Ground-level ozone can directly affect human health. Acute exposure to ozone may cause irritation to the eyes and nose and very high levels can cause damage to the airway lining. There can be a noticeable increase in ground-level ozone during periods of anticyclonic weather conditions associated with low winds, increased sunlight and warm temperatures.

It was estimated in the CCRA analysis that the number of premature deaths due to ground-level ozone by the 2080s could increase by approximately 40 to 300 above the present average number of about 600, dependent on levels of emissions in any particular year. For respiratory hospital admissions this range is between 100 and 1000 above the present number of about 1,900.

Decline in winter mortality due to higher temperatures

Risk metric HE5 in the CCRA analysis (Wales analysis)

As temperatures increase the number of premature cold-related deaths avoided is likely to increase. This therefore represents a potential benefit of climate change.

The number of premature cold-related deaths avoided due to increasing temperatures is likely to vary regionally depending on local conditions. The CCRA analysis indicates that premature deaths avoided annually could be of the order of 300 to 2,000 by the 2050s for the principal population scenario. The current baseline figure is about 1,800 to 3,500 deaths per year.

Decline in winter morbidity due to higher temperatures

Risk metric HE6 in the CCRA analysis (Wales analysis)

In winter months as temperatures increase there could be a reduction in the number of hospital admissions due to cold related illnesses. This therefore represents another potential benefit of climate change. However it is difficult to link individual hospital admissions to cold related illnesses. An assessment based on existing literature and research concluded that cold related morbidity can be tentatively determined by multiplying the cold related mortality deaths summarised above by 102.

Extreme weather event (flooding and storms) injuries

Risk metric HE7 in the CCRA analysis (UK analysis)

Injuries due to flooding or storms, defined as injuries sustained during an event that requires medical attention involving a hospital admission, are predicted to increase at a rate of 20 times that for flood event deaths. Injuries in the UK are projected to increase by between 400 and 700 per year by the 2050s and between 500 and 1,300 per year by the 2080s. The present day baseline is estimated to be about 400 injuries per year.

Sunlight / UV exposure

Risk metric HE9 in the CCRA analysis (UK analysis)

As exposure to UV radiation is increased, levels of skin cancers and cataracts would be expected to increase. The amount of UV radiation that reaches the surface of the earth is dependent on a number of factors, the main one of which is the amount absorbed by the stratospheric ozone layer.

Changes in sunlight / UV exposure as a result of climate change could lead to additional melanoma and non melanoma skin cancer cases. However changes as a result of climate change are extremely difficult to quantify. The rate of recovery of the stratospheric ozone layer as a result of reduction in emissions of certain chemicals would affect UV exposure levels in the UK. However, changing social and behavioural patterns (e.g. time spent outdoors) are probably the main driving factor in incidence of melanoma and non-melanoma skin cancer cases.

The many factors that affect the development of skin cancer mean that it is not currently possible to provide reliable projections of future numbers of cases or resultant deaths. These factors include changes in social behaviour and improved treatments.

Effects of floods/storms on mental health

Risk metric HE10 in the CCRA analysis (UK analysis)

As flooding increases and storm conditions change due to climate change, there is likely to be an increase in the number of people suffering mental health problems as a result. This not only covers issues associated with direct flooding but also the prospect of when flooding might next occur.

A number of adverse psychiatric effects and illnesses can be experienced in the aftermath of extreme flood and storm events. In the CCRA analysis the mental health effect was measured by the number of people who go from a general health questionnaire (GHQ-12) score of below 4 to a score of 4 or above as a result of a flood event. It is estimated that climate change could increase these numbers for the UK from a baseline of about 3,000 per year by approximately 4,300-6,900 per year by the 2050s, and 5,400-8,100 per year by the 2080s. These figures apply to present day population.

Whilst mental health provides an indicator of the impacts of extreme weather events on people, there are wider effects including damage and loss to homes and employment. This metric does however provide an indication of the number of people whose health is likely to be severely affected by flooding in the future.

Change in water quality and water-borne diseases

Reference number HEr1 (not analysed)

Impacts on coastal water quality have been considered in the CCRA analysis in relation to disease hosts and pathogens (metric MA2). Whilst a quantitative analysis was not possible, it was concluded that:

- there is a potentially significant risk of a decline in water quality resulting from increasing frequency of extreme precipitation and increasing water temperatures, and
- there could be a significant increase in the number, seasonality and severity of marine-acquired infections as sea surface temperatures rise.

Fresh water quality in relation to health impacts has not been specifically investigated in the CCRA analysis. Water quality is likely to be affected by an increase in the number and magnitude of floods, and a reduction in watercourse flows in the summer.

Estimates have been made of increases in the frequency of sewer flooding and associated pollution, based on CSO spill frequency (metric WA10). The projections indicate that spill frequencies could increase by 50 to 100% by the 2080s.

Estimates have also been made of changes in low river flows and environmental flow indicators (metrics WA2 and WA7, which are not included in the Wales Tier 2 list). These indicate that the magnitude of low flows would significantly reduce in warmer drier summers, and that there would be a large decline in the number of watercourses achieving good ecological status.

These impacts would contribute to increasing stress on the water system and an increasing chance of water quality problems leading to water-borne diseases.

Reduction in winter air pollution (opportunity)

Reference number HEr2 (not analysed)

There are currently high levels of respiratory problems in Wales during the winter. Winter air pollution episodes are likely to decline in frequency and intensity partly as a result of warmer temperatures. Higher winter temperatures are expected to result in reduced atmospheric stability and consequently less air pollution stagnation events.

Although warmer and potentially windier winters are likely to result in a reduction in winter air pollution, projections of winds over the current century are uncertain and are unlikely to change noticeably. The likely decrease in winter air pollution episodes will be associated with a proportional decrease in mortality and morbidity.

Apart from climatic effects, winter air pollution episodes are also likely to further decline due to projected reductions in atmospheric emissions (e.g. traffic-related) of particulate matter (PM₁₀), nitrogen oxides (NO_x) and Volatile Organic Compounds (VOCs) due to future tightening of both fuel and vehicle emission legislation. The effect of the projected changes in atmospheric emissions on winter air pollution is likely to be much larger than any effects associated with changing climatic conditions.

Social inequalities

Reference number HEr3 (not analysed)

A social vulnerability assessment was made in the CCRA analysis to identify health impacts on vulnerable groups, but this has not been specifically applied in the analysis for individual metrics.

However socio-economic conditions and the socio-economic position of individuals do influence the type and severity of health impacts. Extreme weather events also affect social cohesion, particularly in rural areas. There is therefore a concern that the impacts on vulnerable groups should be identified wherever possible.

The CCRA analysis has not attempted to assess the impacts of climate change on specific vulnerable groups. However this is recognised as an important issue that should be addressed in future cycles of the CCRA. One reason for this is the concern that climate change impacts could have very serious long-term impacts on people who are already on the margins of society.

Any further vulnerability assessment should take account of the differences in socio-economic conditions across Wales.

Health Sector: Summary

Wales has a population of about 3 million people. This is projected to rise to about 3.7 million by the 2080s (range 2.6 to 5.0 million). The CCRA analysis investigated the consequences of climate change for human health and concluded the following:

- The annual number of premature deaths from extreme heat in summer could rise from a present day figure of 40 to about 60 to 350 by the 2050s and about 70 to 1,000 by the 2080s (HE1).
- The number of patient days per year caused by heat related illnesses could range annually from about 6,000 to 30,000 by the 2050s and be of the order of 10,000 to 100,000 by the 2080s. The present day figure is about 4,000 (HE2).

- Deaths and injuries from floods and storms (including wave action on the coast) are projected to increase although the overall numbers are modest (HE3, HE7, UK figures).
- The number of premature deaths caused by ground-level ozone could increase by about 40 to 300 by the 2080s, and the number of respiratory hospital admissions could increase by about 100 to 1,000. The current numbers of deaths and hospital admissions are about 600 and 1,900 respectively (HE4).
- Premature deaths avoided annually because of higher winter temperatures could be of the order of 300 to 2,000 by the 2050s. The number of additional hospital days avoided due to cold related illnesses was estimated to be about 100 times the number of premature deaths avoided (HE5, HE6).
- Changes in sunlight / UV exposure as a result of climate change could lead to additional melanoma and non melanoma skin cancer cases (HE9).
- The number of people suffering from mental health problems as a result of flooding is projected to more than double by the 2050s (HE10, UK figures).
- Whilst mental health provides an indicator of the impacts of extreme events on people, there are wider health effects caused by damage and loss to homes and employment (HE10).
- There could be a significant increase in the number, seasonality and severity of marine-acquired infections as sea surface temperatures rise, although this has not been analysed in the CCRA (HEr1).
- Freshwater quality (including rivers and lakes) is likely to be adversely affected by an increase in the number and magnitude of floods and by lower flows in the summer. The potential increase in health risks has not been analysed in the CCRA (HEr1).
- Current levels of winter respiratory problems could reduce as temperatures increase although this has not been analysed in the CCRA (HEr2).
- Health effects of climate change are likely to have the greatest impact on vulnerable people, particularly those in difficult socio-economic conditions. However this has not been analysed in the CCRA (HEr3).
- Some health facilities are at risk of flooding including hospitals, health centres and GPs practices. Disruption to services could therefore occur during extreme weather conditions (hospitals assessed in the Floods and Coastal Erosion Sector, metric FL11).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.8 Built Environment

Increased subsidence risk due to rainfall changes

Risk metric BE2 in the CCRA analysis (UK analysis)

Changes to the present shrink swell pattern of clay soils are expected as a result of climate change due to wetter winters and hotter drier summers. Older buildings and buildings with shallow foundations are at greatest risk. Modern buildings (post-1970) have better foundations, but given the low replacement rate a substantial proportion of buildings would remain at risk.

Subsidence is generally not a serious problem in Wales. The main area of risk is in the clay soils of south east Wales. For the UK as a whole, the number of subsidence claims is projected to rise by up to 7% by the 2020s, 17% by the 2050s and 20% by the 2080s (under the p50 Medium Emissions scenario).

Overheating of buildings

Risk metric BE3 in the CCRA analysis (Wales analysis)

Historically within the UK, building design has been driven by the need for indoor thermal comfort in winter and, more recently, by a desire for energy efficiency. The risk of summer overheating has not been regarded as a problem. This is in contrast to other regions of the world, such as the Mediterranean, where the vernacular architecture is adapted to minimise the impact of summer heat through the use of small windows, exposed thermal mass and external shading devices.

The risk of overheating varies from building to building. Nevertheless, there is evidence that some types of building in the UK, such as highly insulated lightweight buildings and buildings with heavily glazed facades, are already vulnerable to summer overheating. With increasing temperatures and a higher incidence of summer heatwaves, the risk of overheating is projected to increase for all buildings.

An increase in the frequency of mean average daily temperatures exceeding 26°C would increase the risk of overheating in buildings, although the CCRA analysis indicates that this risk is relatively low in Wales. The threshold for overheating of 26°C is projected to increase from a present day average of 3 days/year to between 1 and 13 days by the 2020s, between 2 and 46 days by the 2050s (median value 13 days), and between 3 and 94 days by the 2080s (median value 25 days).

Whilst not an immediate problem, the results indicate that overheating could become a problem within the lifetime of buildings constructed today and therefore this should be taken into account in the design of new buildings.

Effectiveness of green space for cooling

Risk metric BE5 in the CCRA analysis (UK analysis)

Green and blue infrastructure such as parks, open spaces, rivers and water bodies has a dual function in combating the risks associated with temperature increases in urban areas. Firstly the inherent cooling capacity of green and blue infrastructure reduces the heat vulnerability of the surrounding area. Secondly, it provides valuable climate refuges, to which local residents can go for temporary respite from extreme heat.

More arid conditions are likely to reduce the capacity of green space to provide cooling benefits within urban environments. In the CCRA analysis this was represented by a reduction in the effective area of green space. It is projected that the effective area may reduce by about 15% (range 0 to 40%) by the 2050s and over 30% (range 2% to 80%) by the 2080s.

Reduction in energy demand for heating – opportunity

Risk metric BE9 in the CCRA analysis (Wales analysis)

Warmer winter temperatures should reduce the demand for heating. There may however be an increase in the demand for cooling in summer as temperatures rise, and this is covered in the Energy Sector (metric EN2).

Currently winter energy efficiency is the focus of both new-build design and retrofit/refurbishment programs. However, with future warmer winters, a reduction in heating demand is expected. This reduced requirement for space heating provides an opportunity for changes in building design although good levels of insulation would still be required in colder spells and can also help to reduce overheating in summer.

The demand reduction is estimated to be about 15% by the 2020s, rising to 25% by the 2050s and 40% by the 2080s (under the p50 Medium Emissions scenario with no population growth). However the projected increases in population mean that the overall heating demand may show little change.

Damage from heat/drying

Reference number BEr1 (not analysed)

Damage from heat and the consequent drying of buildings is expected to increase as the temperature rises. This impact was identified in the CCRA analysis but no robust evidence was identified to enable an assessment to be undertaken.

Increase in soil erosion and landslips

Reference number BEr2 (not analysed)

The incidence of soil erosion and landslips is likely to increase as a result of wetter winters causing more slope instability and drier summers causing more drying of soils and erosion. This is a particular concern as there are a relatively large number of settlements in valleys or on hillsides, particularly in south Wales. This impact has not however been assessed in the CCRA.

Change in household water demand and the water supply-demand balance

Risk metrics WA4 and WA5 in the CCRA analysis (Wales analysis)

These metrics are covered under the Water Sector. A large decrease in the water supply-demand balance is projected. Thus there is likely to be pressure on water supplies in the future for existing as well as new development. Meeting the projected increase in water demand against a background of reducing Deployable Outputs may present a major adaptation challenge. It is likely that there will be an increased requirement for water storage facilities as there are limited sources of groundwater in Wales. There are also cross border issues as Wales supplies water to parts of England.

Increase in properties at risk of flooding

Risk metrics FL6 and FL7 in the CCRA analysis (Wales analysis)

There are about 357,000 properties at risk of flooding, about 1 in 6 of all properties in Wales (Environment Agency 2009). The total number of properties at risk from river and tidal flooding is about 220,000 (about 11% of all properties) and the total number at risk from surface water flooding is about 230,000 (about 12% of all properties). There is overlap between these figures: about 97,000 properties are at risk from surface water flooding and river or tidal flooding. It is likely that these numbers will increase as a result of climate change.

The number of residential and non-residential properties at significant likelihood from tidal and river flooding both now and in the future has been estimated in the CCRA Floods Sector analysis (metrics FL6 and FL7), and the results are summarised in Table B.9. The Expected Annual Damages (EAD) of residential and non-residential properties at risk from tidal and river flooding is projected to increase from a baseline of about £200 million to between £200 million and £400m by the 2020s, rising to between £250 million and £900 million by the 2080s (at today's prices). This provides an indication of the annual cost of flood damage.

Other sources of flood damage include rain and wind related impacts on existing buildings. The projected increase in the intensity of storms may lead to an increase in flood damage to buildings caused by overloading of roof drainage systems and failure of window seals, etc. This impact has not been assessed in the CCRA analysis.

Flood risk for Scheduled Ancient Monument sites

Risk metric FL15 in the CCRA analysis (Wales analysis)

The potential loss of sites of archaeological or cultural importance is important in some parts of Wales. In order to assess this impact, the CCRA analysis identified the area of Scheduled Ancient Monument sites at significant likelihood of flooding. The results are summarised in the Floods and Coastal Erosion Sector (metric FL15).

However this analysis does not cover the majority of buildings of historic or cultural importance including listed buildings.

Built Environment Sector: Summary

There are estimated to be about 2 million buildings in Wales including 1,260,000 residential properties. The conclusions of the built environment sector analysis were as follows:

- The number of subsidence claims in the UK is projected to rise as a result of changes to the shrink swell pattern of clay soils (BE2).
- Whilst not an immediate problem, the results indicate that overheating could become a problem within the lifetime of buildings constructed today and therefore this should be taken into account in the design of new buildings (BE3).
- The capacity of green space to provide cooling benefits within urban environments is likely to reduce as temperatures rise. A reduction in the effective area of green space in the UK of about 15% is projected by the 2050s rising to over 30% by the 2080s (BE5).
- Heating energy demand per property in the winter is projected to reduce. However projected increases in population mean that the overall heating demand may show little change (BE9).
- Damage from heat and the consequent drying of buildings is expected to increase as the temperature rises although this has not been analysed in the CCRA (BEr1).
- The incidence of soil erosion and landslips is likely to increase although this has not been analysed in the CCRA. This is a particular concern as there are a relatively large number of settlements in valleys or on hillsides (BEr2).
- Household water demand is projected to increase as a result of increases in aridity and total population although change in consumer behaviour may be able to mitigate this increase (WA4).
- There may be a reduction in water availability. Current projections indicate a potential deficit in the supply-demand balance from about the 2020s onwards (WA5).
- About 1 in 6 of all properties are estimated to be at risk of some form of flooding. It is likely that the number of properties at risk will increase as a result of climate change (FL6/7).
- The Expected Annual Damages (EAD) of residential and non-residential properties at risk from tidal and river flooding is projected to be between £200 million and £400m by the 2020s, rising to between £250 million and £900 million by the 2080s (FL6/7).
- Flood risk to cultural heritage is projected to increase although the CCRA analysis is limited to SAM sites and does not cover impacts on listed buildings and other buildings of cultural importance (FL15).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.9 Transport

Disruption to road traffic due to flooding

Risk metric TR1 in the CCRA analysis (UK analysis)

Disruption and delay to road and rail traffic is a major consequence of flooding, and is projected to increase as flooding increases. The consequences are wide ranging and include disruption to people (including key workers) getting to and from work, breakdown of supply chains and disruption to emergency services, including those responding to flood emergencies.

Wales is particularly vulnerable to transport disruption because many of the main transport connections are either on the coast, where they are prone to both tidal and fluvial (i.e. rivers and other watercourses) flooding, or in valleys where they are prone to fluvial flooding. The Flooding and Coastal Erosion Sector provides an estimate of the lengths of road and rail at risk of flooding both now and in the future (metric FL8).

The widespread flooding of major and minor roads in July 2007 in Wales and England gives a guide to the scale and costs of the risks involved. It has been estimated that the cost of transport disruption was of the order of £100m at today's prices (range of uncertainty £22m to £174m) and the probability of this type of event is likely to increase with climate change.

By the 2080s, the qualitative estimate in the CCRA indicates that an event of comparable cost to the summer 2007 flood might occur every year (or multiple events of the type experienced in the 2000 floods).

Landslide risks on the road network

Risk metric TR2 in the CCRA analysis (UK analysis)

The length of roads currently under some kind of threat from landslides in the UK runs into thousands of kilometres. The incidence of soil erosion and landslips is likely to increase as a result of wetter winters causing more slope instability, and drier summers causing more drying of soils and erosion. This is a particular concern in Wales as there is a relatively large number of transport corridors in valleys.

The main impacts of landslides on roads and railways include damage to infrastructure and disruption to transport. The CCRA analysis includes an assessment of the lengths of road potentially impacted by landslides based on the detrimental effect of increased rainfall on soil stability. No account is taken of potential land management practices that could reduce the risk, or the costs of disruption and delay to transport.

Data for Wales on landslide risk was not identified in the CCRA analysis, and projections have only been produced for England, Scotland and Northern Ireland. It is understood that the Welsh Government is currently in the process of initiating surveys and data collection relating to the country's geotechnical assets.

The data for England suggests that about 0.2% of roads are at severe risk of landslides, and about 2% at medium risk. These proportions may double by the 2080s based on the results of a very simple qualitative analysis.

The effects of erosion and landslides on the rail network have not been assessed. This would affect rail lines in cuttings and on embankments. It is estimated that there are about 5,000km of rail lines in cuttings and a further 5,000km on embankments in the UK.

Bridge scour can affect road and rail networks and there has been one bridge failure per year on average in the UK from this cause. This number could potentially increase

as a result of increases in river flood flows, although it was not possible to quantify the potential increase in the CCRA.

Rail buckling risk

Risk metric TR5 in the CCRA analysis (UK analysis)

Rail temperatures would increase as summer air temperatures rise. This means that more rail buckles could occur in future summers. The current average number of rail buckles in Wales is about 2 per year and the cost is estimated to be about £40,000/year. In the hot summer of 2006 there were 6 rail buckles in Wales.

The CCRA analysis indicates that the number of rail buckles could increase by a factor of 3 to 5 by the 2080s.

Other components of the railway network that could be at risk from climate change include expansion of structures such as bridges caused by higher temperatures, although this has not been considered in the CCRA analysis.

Reduction in cold weather working/travelling (opportunity)

Reference number TRr1 (not analysed)

Whilst a general trend of warming winter temperatures is to be expected, the problems involving cold weather will not be eliminated. Indeed as the winters 2009/10 and 2010/2011 have shown, it is essential to remain prepared for severe winter weather. However, such events will decline in frequency, very low freezing temperatures will be less common and the winter season will be shorter. As a result, winter disruption across all modes of transport should be reduced.

This is a potential benefit of climate change especially in the uplands where communities are regularly cut off by snow in the winter. It would also reduce the difficulties of cold weather working and potentially lead to reduced maintenance costs.

The road network is the most sensitive mode to severe winter weather and here, complacency will perhaps become the biggest issue. There is a general sense that the UK is underprepared for snow-related problems and the danger is that in a climate of cost-cutting, winter maintenance budgets may become an easy target.

This could cause significant problems as the number of marginal nights (where the temperature is close to freezing and untreated road surfaces are at the most dangerous) may not reduce over the forthcoming century. This, coupled with general driver complacency caused by a lack of experience of driving in such conditions, may cause an increase in accidents and subsequent disruption on the road network.

In addition, the number of times the temperature passes zero could increase, resulting in more freezing/thawing cycles and an increase in damage to road surfaces. These impacts have not been analysed in the CCRA.

Increased demand for transport

Reference number TRr2 (not analysed)

Travel demand has increased significantly over the last few decades. Road traffic has increased by 85% since 1980 and air travel between, or from, UK airports has quadrupled in the same period. Much of this growth is linked with disposable income and, despite the current economic climate, both mid and long term trends indicate that demand will continue to rise.

Transport demand is likely to change in the future for a number of reasons, some of which are climate related. For example, it is possible that demand for tourism could increase with warmer summers and milder winters. Seaside resorts would be warmer

and access to Welsh hills and mountains would be less restricted by snow and ice. As a result there could be an increase in transport demand in these areas.

Other factors that could change the way in which the climate affects transport are changes in social behaviour, economic conditions and policies. Social and economic changes are a significant control on transport demand and therefore the nature of infrastructure required to satisfy the demand.

Improvements in technology may reduce the need for transport, for example if more people work from home or local centres, taking advantage of potential improvements in ICT systems. Demand would also be reduced if a modal shift occurred from private to public transport as part of sustainable development.

The transport system should adapt to these changes but there is concern that increased capacity may be difficult to achieve. Reasons for this include lack of space in transport corridors and difficult terrain. This impact was identified in the CCRA but has not been analysed.

Increase in coastal erosion risk for transport

Reference number TRr3 (not analysed)

There is a danger of increased coastal erosion due to a combination of sea level change and higher frequency extreme events leading to flooding and increasingly damaging wave action. In affected areas there are two options:

1. Protection (e.g. reinforced defences)
2. Planned Retreat (i.e. re-route affected roads and railways).

There are a number of important road and rail links on the coast in Wales, some of which are in exposed locations. Whilst this risk has not been assessed in the CCRA, it should be reviewed when new National Coastal Erosion Risk Map (NCERM) becomes available from the Environment Agency.

Problems may also be encountered at ports and harbours but there is not considered to be a significant problem at airport locations in Wales.

Transport Sector: Summary

Road and rail transport are more vulnerable to a changing climate than air transport and water transport. This is because road and rail infrastructure has been designed to work in the existing UK climate whereas air and water transport have international networks and aircraft and ships operate in a range of global climates. Airports and sea ports are vulnerable to climate change but the impacts are generally small.

As most transport needs are provided by roads, most of the CCRA analysis has concentrated on road transport. There is an increasing number of passengers using rail travel. This could lead to the provision of more services on a fixed infrastructure, which in turn could lead to more weather and climate related train delays.

The UKCIP/BESEECH socio-economic scenarios suggest that the mix of road, rail, air and water transport is likely to change in the future although road transport is likely to remain the most important (UKCIP/BESEECH, 2005).

Climate change could lead to an increase in transport disruption as a result of more extreme weather and flooding. The conclusions of the CCRA analysis are as follows:

- Disruption and delay to road and rail traffic due to flooding is projected to increase. By the 2080s a flood event equivalent to that of summer 2007 might occur every year. The cost of transport disruption in summer 2007 was about £100 million in Wales and England (TR1).
- The incidence of landslips is likely to increase. This is a particular concern as there are a relatively large number of transport corridors in valleys. The number of roads and railways at risk of landslides may double by the 2080s (TR2, England figures).
- The number of rail buckles could increase by a factor of 3 to 5 by the 2080s due to rising temperatures. There are currently about 2 rail buckles a year in Wales (TR5).
- Higher winter temperatures are likely to reduce disruption and delay caused by snow and ice although this has not been analysed in the CCRA. However travel problems in winter will continue to occur, for example damage caused by the freeze/thaw cycle (TRr1).
- It is likely that demand for transport will change in the future for a number of reasons including consequences of climate change, for example increased tourism. It may be difficult to provide the required infrastructure in some areas for topographic reasons although this has not been analysed in the CCRA (TRr2).
- Coastal erosion risk to transport infrastructure is projected to increase although this has not been analysed in the CCRA (TRr3).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.10 Energy

Energy infrastructure at risk of flooding

Risk metrics EN1 and FL11 in the CCRA analysis (Wales analysis)

The main risk that flooding poses to the energy sector concerns electricity transmission and primary distribution substations, as overhead lines, underground cables and gas pipelines are unlikely to be affected. Given their location near rivers or on the coast, a number of power stations may also become at risk of flooding if they are not effectively defended.

Loss of power can have severe and widespread consequences, affecting large numbers of homes and businesses. Loss of power can also affect other essential services including water supply and ICT.

There was insufficient information on the substations to extrapolate the risk of flooding to possible capacity losses. However estimates made by the Energy Network Association indicate that the risk of energy supplies to people being affected by tidal, river and pluvial flooding of substations is 'very high' (ENA, 2011).

Flooding of electricity sub-stations and power stations is covered in the CCRA analysis in the Floods and Coastal Erosion Sector (metric FL11). It is estimated that about 12 major sub-stations (400kV to 132kV transformation) are currently at significant likelihood of flooding (4 river and 8 tidal), rising to about 14 by the 2080s.

As stated in [Section B.4](#), about 20% of power generation capacity in Wales is in flood risk areas. This could rise to about 30% by the 2020s and about 50% by the 2080s, although there is an ongoing programme of constructing new stations and de-commissioning older stations.

Energy demand for cooling

Risk metric EN2 in the CCRA analysis (Wales analysis)

As temperatures rise, the demand for cooling (for air conditioning, IT infrastructure, etc) is also likely to rise. In some cases this can be offset by mitigation measures such as changes to building design, but the scope of this is limited due to the existing building stock.

Cooling Degree Days (CDD) are used as a common climatic indicator of the demand for cooling services and is a measure of the average temperature's departure from a certain base temperature. In this UK analysis, CDD is defined as the day-by-day sum of the mean number of degrees by which the air temperature is more than a value of 22°C.

The number of CDD in Wales is projected to increase from a baseline of less than 25 (1961-90) to between 25 and 50 by the 2050s and between 25 and 100 by the 2080s, with the largest increase in south east Wales.

The demand for cooling was also estimated in terms of energy demand for the UK as a whole. Projections indicate that cooling demand could change from a current level of about 25TWh per year (25,000GWh) to between 20 and 60TWh per year by the 2020s and between 15 and 150TWh per year by the 2050s.

Heating demand is likely to continue to exceed cooling demand by the 2050s. Domestic heating demand is projected to reduce from a current level of 340TWh per year to about 250TWh per year by the 2050s for the UK (metric BE9 in the Built Environment sector).

Heat-related damage/disruption to energy infrastructure

Risk metric EN3 in the CCRA analysis (UK analysis)

There is a concern that increasing temperatures could cause increases in heat related damage to energy infrastructure. However the CCRA analysis suggests that current energy infrastructure is generally resilient to significant warming since similar infrastructure is operational in other (hotter) countries. Problems that might occur in the future are likely to be dealt with by autonomous adaptation.

It was therefore concluded that heat damage/disruption to energy infrastructure is not a major climate change risk.

Risk of restrictions in water abstraction for energy generation

Risk metric EN4 (UK analysis)

Water is required for cooling of power stations. As temperatures rise, the temperature of cooling water will also rise. The consequences include a potential increase in the temperature of water discharged from the cooling process, or an increase in the amount of water used, or both.

This metric is concerned with water abstraction. The consequences for discharges of cooling water are covered under metric EN8 below. The impact has been assessed for the UK in terms of the number of sites with unsustainable abstraction for power stations located on rivers, and the impact of warmer water for power stations located on the coast. The major power stations that require cooling water (coal, gas and nuclear) in Wales are on the coast and therefore this summary is limited to coastal sites.

If the amount of cooling water used is unchanged but the discharge temperature is not permitted to increase, the amount of cooling will reduce resulting in a reduction in power generation. It is more likely that either the temperature of discharged water will increase (discussed in EN8 below) or, if this is not possible, the capacity of the cooling system would have to be increased. This might involve major modifications to power stations.

Electricity turbine efficiency

Risk metric EN6 (not analysed)

The efficiency of thermal power stations may be affected by increases in temperature. High temperatures result in lower air density, which may reduce the amount of air drawn into a turbine and consequently the amount of fuel burnt. This would lead to a reduction in turbine-based power generation. How much this may affect thermal power station outputs is currently unknown; further research would have to be undertaken to assess this.

Power station cooling

Risk metric EN8 (not analysed)

The efficiency of thermal power stations depends upon the temperature interval of the steam/gas upstream and downstream. Water is the most effective cooling medium and therefore either river or sea water is extracted in this process. Both increased air and river or sea water temperatures would result in a decrease in the efficiency of a thermal power station.

Additionally, water can only be extracted and discharged at or below regulated threshold temperature values. Increased temperatures may result in these thresholds being met more frequently. This could be reduced by changing the cooling system used or reducing the total electricity production.

The major thermal power stations that require cooling water (coal, gas and nuclear) in Wales are on the coast and therefore this summary is limited to coastal sites. If the temperature of discharge water increases, the principal issues for coastal water quality in terms of temperature increase relate to:

- Specific environmental sensitivities, for example the potential for thermal barriers to limit fish movement into an estuary.
- The interaction of oxygen concentration and temperature: warmer water at standard air pressure will hold less oxygen than it would at lower temperature.
- The interaction of temperature, dissolved oxygen levels and ammonia toxicity where there is potential for impact upon a protected feature or for the development of water conditions that create barriers to the passage of migrating or juvenile fish.

These impacts have not been assessed in the CCRA, although both the EU Shellfish Directive and guidance on marine protected sites recommend maximum allowable increases of 2°C for shellfish waters and conservation areas. It is recognised that this limit is likely to be exceeded by global warming alone eventually, although this change would be gradual and uniform thus allowing for natural adaptation.

It is likely that a site-specific analysis would be necessary to carry out a quantitative analysis on this risk since it is likely to depend on many local factors.

During heat waves and drought periods, the use of cooling water may be restricted if limit values for temperature are exceeded, which may lead to reduced capacity or even temporary plant closures. The ability to provide quantitative information is therefore also dependent on the ability for climate projections to capture climatic conditions such as droughts and hot spells, which is a limitation of the UKCP09 projections.

Some of the previous literature has identified a potential fall in thermal (fossil) power station efficiency with temperature due to a combination of these effects. The literature reports some very simple indications that for a temperature increase of 1°C, coal and gas power output may decrease by 0.6% due to the thermal efficiency loss, with potentially higher decreases for nuclear power stations.

Energy transmission capacity losses due to heat - overground

Risk metric EN10 in the CCRA analysis (UK analysis)

Increases in temperatures could affect the efficiency of electrical transmission and distribution systems resulting in the de-rating of equipment and reduction in capacity. This in turn would mean that it is more costly for the supplier to deliver the same amount of energy to a customer, thus increasing the cost of energy provision.

Currently transmission and distribution capacity losses can be 3% and 10% respectively in the summer. The CCRA analysis indicates that distribution and transmission equipment could suffer additional capacity de-rating of between about 1.7% and 10% by the 2050s.

Energy Sector: Summary

Power stations in Wales can generate about 9GW of energy, about 10% of the overall UK generation capacity. Potential climate change impacts for the energy sector include disruption caused by increased flooding, changes in demand and effects of heat.

The conclusions of the CCRA analysis are summarised below. Some of the outcomes of the analysis are uncertain given the current transition to a low carbon economy, both in terms of generation and demand.

- It is estimated that there are about 12 major sub-stations at significant likelihood of flooding (4 river and 8 tidal), rising to a total of about 14 by the 2080s (EN1).
- About 20% of Welsh energy generation capacity is in areas at significant likelihood of tidal and river flooding, rising to about 50% by the 2080s assuming the location of infrastructure does not change (EN1).
- In the short term there is a “very high” risk that customers in the UK could be affected by energy supply disruption arising from river, tidal and pluvial flooding (EN1).
- The number of Cooling Degree Days in Wales could rise from less than 25 at present to between 25 and 100 by the 2080s.
- Cooling demand for buildings could change from a current level of about 25TWh per year to between 15 and 150TWh per year by the 2050s. However it is likely that winter heating demand would continue to be higher than summer cooling demand in the 2050s (EN2).
- Heat damage to energy infrastructure and the resulting disruption is not a major climate change risk (EN3).
- Water abstraction for cooling of power stations would increase as temperatures rise (EN4).
- Electricity turbine efficiency would reduce as temperatures rise although this has not been analysed in the CCRA (EN6).
- Efficiency of power station cooling processes would reduce as temperatures rise although this has not been analysed in the CCRA (EN8).
- Distribution and transmission equipment could suffer an additional capacity de-rating because of higher temperatures, of about 2% to 10% by the 2050s (EN10, UK figures).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.11 Business, Industry and Services

Climate risks to investment funds

Risk metric BU1 in the CCRA analysis (UK analysis)

The financial services sector accounts for less than 5% of Gross Domestic Product and employs about 2.6% of the workforce in Wales. It is possible that small percentage changes in the rate of return for investments that lack climate resilience could cause significant monetary losses.

This could arise if the effects of climate change on investment performance are underestimated, climate change risk management processes are inadequate, or climate change risks are underestimated. These in turn could lead to reduced financial performance, with consequences for investors and insurers.

The more extreme potential impacts of climate change, such as an increased risk of flooding, may result in significant financial impacts to specific companies or ventures in companies' investment portfolios. The potential magnitude and uncertainty associated with future extreme weather events means that this could be a major impact with large financial consequences.

Whilst this consequence is possibly one of the largest risks to the UK from climate change, it has not been possible to identify suitable information to undertake quantitative analysis within the CCRA.

Monetary losses due to tourist assets at risk from flooding

Risk metric BU2 in the CCRA analysis (UK analysis)

As the sea level rises, the area of beaches and other natural coastal assets is likely to reduce. In addition, the combination of higher sea levels and wave action is likely to increase damage to natural and man-made assets including tourist visitor attractions and facilities. It is estimated that there are about 33,000 buildings within the tourism and leisure sector in the UK that are within Flood Zone 3 (High Risk¹⁶).

There are many coastal towns that rely on tourism and over 300km of beaches in Wales. It is estimated in the CCRA analysis that 1 to 7km² of beach area could be lost as a result of sea level rise by the 2050s, and 2 to 12km² by the 2080s (about 2% to 8% of total beach area). This change would increase pressure for space on some beaches, particularly if tourism increases.

The change in number and value of tourist buildings and facilities at risk of flooding has not been assessed in the CCRA, but the number of non-residential properties at risk of tidal flooding is given in Table B.1. If it is assumed that this is representative of tourist buildings, the results indicate that the number at significant likelihood of tidal flooding could increase by about 40% to 100% by the 2020s, and by 40% to 400% by the 2080s.

The CCRA analysis has not considered coastal erosion impacts on tourism.

Risk of restrictions in water abstraction for industry

Risk metric BU3 in the CCRA analysis (Wales analysis)

Industrial abstraction occurs in all River Basin Districts in Wales and the effects of drier summers would reduce summer water availability, although more water would be available in wetter winters. The CCRA analysis indicates that, whilst climate change

¹⁶ 1% annual flood probability on rivers (1 in 100 years on average) and 0.5% annual flood probability for tidal flooding (1 in 200 years on average)

could affect the access of the industrial sector to water, industrial demand is a small proportion of overall water demand.

It is possible that adaptive measures or changes in regulatory controls could have more of a day-to-day impact on industrial abstractions than any absolute changes in water availability.

Risk of business disruption due to flooding

Risk metric BU4 in the CCRA analysis (Wales analysis)

The financial impact of business and industry assets at risk of flooding includes direct damage to assets and business interruption during and following a flood.

A major concern in the business sector is that many businesses are vulnerable to disruptions caused by extreme weather events, particularly flooding. For example, less than one in three businesses have a contingency plan to cover business interruption and many businesses are under-insured against flood risk. Actual recovery times are often longer than expected, causing severe disruption to business.

Many business properties were flooded during the summer 2007 floods, resulting in damage to premises, equipment and fittings, and loss of stock. They also suffered disruption of business. It is estimated that about 8,000 business premises were affected in Wales and England, and the overall economic costs associated with business impacts caused by the 2007 floods were estimated as £740 million. This corresponds to an average of nearly £100,000 per business.

The CCRA analysis includes Expected Annual Damages (EAD) caused by river and tidal flooding for non-residential properties (metric FL7b in the Floods and Coastal Erosion Sector). This is projected to increase from a baseline value of about £100 million to between £100 million and £300 million by the 2050s and between £130 million and £500 million by the 2080s. This includes all types of non-residential properties and therefore is greater than the value for properties just associated with business. It does not however include the costs of business interruption.

Businesses in Wales have a relatively high risk from tidal flooding compared to the rest of the UK because of the long coastline relative to size, and the fact that many businesses are located near the coast.

Loss of productivity due to ICT disruption

Risk metric BU5 in the CCRA analysis (UK analysis)

ICT is an integral and vital part of the operations of all types of businesses, with over 80% of businesses in the UK being 'heavily dependent' on ICT systems. Any disruption to these systems could therefore have a major impact on business. Climate change could potentially disrupt ICT systems, with increases in rainfall, flooding and temperature affecting parts of the systems.

It has not been possible to provide an estimate of the number of days that might be lost due to disruption to ICT owing to a lack of suitable information. Overall it appears from the information available that the risk of major ICT disruption due to climate change is relatively low for large businesses, as they are often based in large urban centres and have flexibility in managing their ICT systems.

However the risks for smaller companies (including SMEs) and remote workers are greater, particularly if they are located in rural locations and other relatively remote areas where they may be dependent on single electricity and telecommunications connections.

Perhaps the greatest risks are the currently unknown impacts of climate change. For example, fires arising from excessive heat or flood damage to critical components could lead to major failures. A major flood event covering a large geographical area could affect many elements of the system leading to widespread failures. Failure of electricity supplies would have a direct impact on ICT systems. These types of major disruptions to ICT would affect all businesses, and it may take some time to restore services.

Mortgage provision threatened due to increased flood risk

Risk metric BU6 in the CCRA analysis (Wales analysis)

This impact relates to the reduction in potential revenue that may be realised by mortgage lenders, both in terms of the opportunity to provide new mortgages and in terms of the risks to existing mortgages from an increasing number of uninsurable properties. Clearly, there is also an important risk for homeowners, although this is a separate impact.

It is estimated in the CCRA analysis that there are currently more than 40,000 residential properties at significant likelihood of flooding. This is projected to rise to between 50,000 and 120,000 by the 2050s and to between 60,000 and 150,000 by the 2080s.

The overall mortgage fund value of properties that are estimated to be at significant likelihood of flooding is of the order of £3.1 billion by the 2050s and £3.3 billion by the 2080s (at today's prices, p50 Medium Emissions). It is estimated that the value of mortgage fund value at risk would be about £110 to 500 million in the 2050s and £140 to 530 million in the 2080s (at today's prices, p10 Low Emissions to p90 High Emissions).

In practice, any changes to insurance and mortgages would be gradual. The consequences might include withdrawal of insurance or increases in insurance premiums. The estimates in the CCRA analysis are therefore likely to be upper bound estimates of the potential impact.

Insurance industry exposure to flood risks

Risk metric BU7 in the CCRA analysis (UK analysis)

The insurance sector is highly sensitive to weather extremes and there is the potential that insurance costs could rise due to the greater chance of flood damage resulting from climate change.

It is estimated that annual insurance pay out costs for flooding in the UK could increase from a present day annual average of £200 to £300 million, to about £1 billion by the 2080s (at today's prices). This would be affected by future policies adopted by the insurance industry regarding the provision of flood insurance and the Welsh Government regarding flood risk management.

Expansion of new or existing tourist destinations - opportunity

Risk metric BU8 in the CCRA analysis (UK analysis)

Future climate change is likely to cause major changes in the distribution of tourists around the world and different trends for tourism, both in the UK and overseas. Based on modelling studies, future climate change is likely to make countries at higher latitudes and altitudes more attractive as a tourist destination, due to the poleward shift in the "Tourism Comfort Index" (TCI). Specific consequences of climate change include:

- Decline in numbers of UK outbound tourists visiting the Mediterranean during summer months.
- Increase in domestic tourism within the UK.
- Increase in overseas tourists visiting Britain during summer months.

Consequently climate change represents an opportunity for tourism in Wales. Not only would the summer tourist season become more attractive, but also the tourist seasons would change with an increase in tourists during the spring and autumn.

It is however difficult to make quantitative projections of future tourism because additional factors including the national economy, change in consumer spending levels, exchange rates and world events all play a role in holiday decisions. Studies referenced in the Business, Industry and Services Sector report suggest that the British Isles might experience a 3% to 18 % increase in bed nights by the 2080s, depending on which scenario is used.

A particular concern related to increases in tourism is the increasing pressures that could occur on tourist destinations including the physical capacity to accommodate tourists and the ecological capacity beyond which unacceptable changes could occur. The projected increase in incidence of severe weather events (e.g. flooding, heat waves and drought) could also affect tourism.

Decrease in output for businesses due to supply chain disruption

Risk metric BU9 in the CCRA analysis (UK analysis)

In recent years, lean supply chains have become the standard. Businesses have invested considerable effort in maximising efficiency by delivering products to the customer with minimal waste. This is achieved by streamlining operations across all links in the supply chain, from procurement and manufacturing to warehousing and transportation. Leanness has brought efficiency and cost savings, but it has also resulted in increased risk of disruption.

Climatic factors have the potential to disrupt UK businesses' supply chains by affecting availability of natural resources and raw materials, or by causing distribution delays because of disruption to transport. Raw materials include agricultural produce for the UK and overseas, as well as minerals, oil, timber and other non-agricultural materials.

The climate is also a factor in market demand for goods. If extreme weather events affect key suppliers, and no alternate supply is available, then supply chains are severely interrupted. Each of these risks is likely to increase as the climate changes.

Supply chain disruptions are costly to business. Disruptions negatively affect company stock price, return on assets, and return on sales. Businesses do not tend to recover quickly from supply chain disruptions and share prices can be adversely affected.

Increase in energy use for machine cooling systems

Reference number BUr1 (not analysed)

As temperatures rise, there would be a need for increased cooling for machinery, particularly the heavy industry areas in south Wales. This in turn would lead to an increase in energy demand. Failure to provide increased cooling could lead to a loss of efficiency in machine performance.

Some industrial areas are close to conservation areas, and the environmental impacts of increased cooling include increases in waste water temperatures from the cooling process. This could have adverse impacts on biodiversity.

This impact has not been assessed in the CCRA analysis.

Difficulties with disposal of solid/liquid wastes due to low flows

Reference number BUR2, partially covered by risk metric WA2 in the CCRA analysis (not analysed)

Disposal of solid and liquid wastes using processes involving river flows (for example, dilution) could become more difficult in the future due to projected reductions in river flows during the summer. Metric WA2 in the Water Sector shows that low flows could get significantly lower as a result of climate change.

This impact has not been assessed in the CCRA analysis.

Increase in infrastructure disruptions (including gas/electricity)

Reference number BUR3 (not analysed)

Failures of essential services including electricity, gas and water would have a direct impact on business. The CCRA analysis has identified potential increased risks to critical infrastructure, but does not include an estimate of the overall impact that this could have for business.

Business, Industry and Services Sector: Summary

Climate change impacts in the Business, Industry and Services Sector include direct damage caused by extreme weather events, losses due to business disruption and adverse impacts on financial performance. Many small businesses are particularly vulnerable as they may not have adequate resources to recover from a major climate event. The conclusions of the CCRA analysis are as follows:

- Climate change may have a major impact on investment performance with severe consequences for the financial sector. This would be exacerbated if management processes are inadequate or climate change risks are underestimated (BU1).
- Beaches and coastal resorts in Wales are a major tourist attraction. Sea level rise could cause the loss of beach area and other coastal assets. It is projected that about 3 to 12% of total beach area could be lost by the 2080s (BU2, UK figures).
- The number of tourist facilities at risk of flooding is projected to increase, and floods could become more frequent (BU2).
- Whilst climate change could affect the access of the industrial sector to water, industrial demand is a relatively small proportion of overall water demand (BU3).
- Expected Annual Damages to non-residential properties are projected to double by the 2050s (BU4).
- The overall impact of flooding on business can be estimated from the summer 2007 floods in Wales and England, where about 8,000 business premises were affected at an overall economic cost of about £740 million (BU4).
- Businesses in Wales are at a relatively high risk of tidal flooding because many businesses are located near the coast (BU4).
- The risk of major ICT disruption due to climate change is relatively low for large businesses but smaller companies (including SMEs) and remote workers are more vulnerable and their risks are greater (BU5).

- Mortgage lenders may be affected by the increasing number of properties that have difficulty obtaining insurance because of increases in flood risk (BU6).
- Annual insurance pay out costs for flooding in the UK could increase by a factor of 3 to 5 by the 2080s, depending on future policies adopted by the insurance industry regarding the provision of flood insurance and the Welsh Government regarding flood risk management (BU7, UK figures).
- There are opportunities for increased tourism as a result of warmer summers and longer tourist seasons (BU8).
- Extreme events are likely to cause an increase in supply chain disruption, which can have severe adverse impacts on businesses (BU9).
- Cooling requirements for industrial machinery could increase although this has not been analysed in the CCRA (BUr1).
- Disposal of solid and liquid wastes due to low flows in watercourses could become more difficult although this has not been analysed in the CCRA (BUr2).
- Increases in the impacts of failure of essential services on business have not been analysed in the CCRA (BUr3).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

B.12 Impacts not covered by other sectors

Increase in emergency response to extreme climate events (including floods)

Reference number CSr1 (Wales analysis)

The need for emergency response to extreme weather events would increase if the projected increases in the magnitude and frequency of extreme weather events occur. This includes preparing for emergencies, responding in an emergency, and recovery after the event. Recovery can be a major and often underestimated task.

The CCRA analysis does not include an assessment of this risk although it does include a general assessment of the increase in flood risk (in the Flooding and Coastal Erosion Sector) and heat related effects (Health Sector).

The effort required to respond to floods could increase by 2 to 3 times by the 2080s. However there are no baseline costs available from which to estimate future projections of cost and effort. The response and recovery costs for the 2007 flood exceeded £250 million. This is about 14% of the property damage cost of £1.78 billion (Environment Agency 2010b).

If this ratio were to be applied to Expected Annual Damages values for Wales, the response and recovery cost could rise from a baseline of £28 million per year to between £35 million and £120 million for Wales by the 2080s if no adaptation measures are implemented.

The data from the 2007 floods show that local authority and temporary accommodation costs represented the vast majority of the response and recovery costs. Costs to the emergency services were relatively small.

The frequency of heatwaves could increase by a factor of 10 by the 2080s. In this case a heatwave is defined as events where a threshold temperature in the national Heatwave Plan is exceeded for 2 or more days. There could be a corresponding increase in the demand for emergency services, particularly the Health Service. The number of patient days due to heat related illnesses per year in Wales is projected to increase from about 4,000 to between 10,000 and 100,000 by the 2080s (metric HE2).

Increase in emergency response to increase in grassland and forest fires

Reference number CSr2 (UK analysis)

Emergency response to fires would increase in the future if the projected increase in fires occurs. These fires place a heavy burden on the Fire and Rescue Service, and may lead to an increase in resource requirement in the future.

An analysis carried out in the CCRA indicates that there could be an increase in grassland and heath fires of between 100% and 180% by the 2080s, from 72,000 per year to between 150,000 and 200,000 for the UK as a whole (CCRA, 2011). Assuming that the number of other fires does not change, this would represent about 30% of all fires attended by the Fire and Rescue Service compared with 15% at present.

These estimates are based on temperature only and do not consider rainfall. In addition, fires related to temperature tend to be confined to limited periods, placing a very high degree of stress on the Fire and Rescue Service. For example, in the hot summer of 2003 there were about 150,000 grassland and heath fires representing 25% of all fires, twice the annual average.

How particular areas cope with several high priority impacts

Reference number CSr3 (not analysed)

This impact has not been specifically assessed in the CCRA analysis. Examples include:

- the overall effects of increased temperatures and changes in rainfall patterns on agriculture and communities in the upland areas of Wales; and
- the overall effects of warmer temperatures, sea level rise, reduced summer rainfall and increased winter rainfall on tourist resorts on the coast.

Increase in outdoor leisure, sport and tourism: opportunities and risks

Reference number CSr4 (not analysed)

Outdoor leisure and tourism is likely to increase as a result of changes in the climate. For example, warmer drier summers could lead to changes in lifestyles with more outdoor activities and a longer tourist season. This impact has not been assessed in the CCRA.

Impacts not covered by other sectors: summary

- The need for emergency response to extreme weather events including floods, heat waves and fires is likely to increase (including preparation, response and recovery after the event) (CSr1, CSr2).
- Combinations of climate change impacts are potentially important but have not been analysed in the CCRA (CSr3).
- Outdoor leisure and tourism is likely to change as a result of changes in the climate although this has not been analysed in the CCRA (CSr4).

The above summary is presented by the order of metric/reference numbers and does not imply any prioritisation of impacts.

Appendix C Human welfare value

A monetisation exercise has been carried out as part of the CCRA to provide an indicative cost per year of potential economic, environmental and social consequences that may have an effect on human welfare.

C.1 Introduction

Climate change adaptation decisions that are designed to reduce climate change risks inevitably involve making trade-offs concerning the use of scarce economic resources. To the extent that economic efficiency is an important criterion in informing such decision-making, it is useful to express climate change risks in monetary terms, so that they can be:

- Assessed and compared directly (using £ as a common metric); and
- Compared against the costs of adaptation measures to reduce such risks.

For the CCRA, a monetisation exercise has been undertaken to allow an initial comparison of the relative significance of different risks within and between sectors. Since money is a metric with which people are familiar, it may also serve as an effective way of communicating the possible extent of climate change risks in Wales and help raise awareness.

It is important to note, however, that this exercise focuses on the effect on overall human welfare for Wales (described in more detail in the section below). The intrinsic value of elements of the natural environment is not captured, nor is the variation in social vulnerability within Wales considered. Therefore, the indicative 'value rankings' determined by this exercise do not always represent all factors that make a particular risk significant. In other words, the value rankings provided here should be considered as partial representations of the overall significance of these metrics, and additional non-quantified dimensions of these consequences need to be considered. These other dimensions are discussed and taken into consideration in the overall categorisation of risks provided in the main body of this report.

C.2 Method

Where possible, an attempt has been made to express the size of individual risks (as described in this report) in monetary terms as a cost per year. The aim is to express the risk in terms of its effects on human welfare, as measured by the preferences of individuals in the affected population. The total value to society of any risk is taken to be the sum of the values of the different individuals affected. This distinguishes this system of values from one based on 'expert' preferences, or on the preferences of political leaders.

Individual preferences are expressed in two, theoretically equivalent, ways. These are:

- The minimum payment an individual is willing to accept (WTA) for bearing the risk; or
- The maximum amount an individual is willing to pay (WTP) to avoid the risk.

However, due to the availability of data, it has sometimes been necessary to use alternative approaches (e.g. repair or adaptation costs) to provide indicative estimates.

A variety of methods have been used to determine these costs. In broad terms, these methods can be categorised according to whether they are based on:

- Market prices (MP)
- Non-market values (NMV) or
- Informed judgement (IJ)

Informed judgement has been used where there is no quantitative evidence and is based on extrapolation and/or interpretation of existing data.

In general terms, these three categories of method have differing degrees of uncertainty attached to them, with market prices being the most certain and informed judgement being the least certain. It is important to stress that the confidence and uncertainty of risks differs. Therefore, care must be taken in directly comparing the results. A further caveat is that whilst an attempt has been made to use the best monetary valuation data available, the matching-up of physical and monetary data is to be understood as an approximation only.

In general, the approach adopted for Wales is consistent with that taken in the UK level sector reports and a detailed description of the data considered in the valuation of each risk is provided in these reports. Details of the monetary valuation approach applied to the CCRA as a whole can be found in the CCRA Method Report (Defra, 2010b).

However, in cases where a specific valuation approach was adopted for Wales, a description of the chosen method is outlined in the sections below. In each case, a justification is given for the approach taken.

Valuations have generally been scaled from the UK analysis to the Wales context, but account is also taken of differences between the Wales context and the UK as a whole. Where potential climate change consequences have been quantified at the Wales scale these have been applied.

Understanding the Valuation Rankings

Valuations are based on projections for the Medium Emissions scenario, central estimate (p50) for the 2050s with no socio-economic changes.

Valuations are ranked as Low (L), Medium (M) or High (H), based on a logarithmic scale of increasing value.

A negative ranking signifies a cost (or financial loss); a positive ranking signifies a saving (or financial benefit).

In general, the following ranges are applied: Low - less than £10 million per year; Medium - £10 to £100 million per year; High - over £100 million per year. However, there are exceptions; for example, if a large proportion of a business that is vital for the sustainability of a region is affected then this would result in a High ranking even if the total cost was less than £100 million per year.

It is important to note that the valuation exercise has only been undertaken for those risks that have been identified as being sufficiently important to assess as part of this first risk assessment for Wales. Furthermore, it has not been possible to provide monetary valuation for some risks. Therefore, the sum of the valuations does not provide the total cost in human welfare terms of projected climate change. The valuation exercise only provides a means of identifying the relative significance of these selected risks.

C.3 Climate change impacts on the natural environment (terrestrial)

Methods

The results for the Biodiversity Sector risks are based on informed judgement; given the generally indirect ways in which these impact on human welfare these estimates are highly uncertain, as emphasised by the use of question marks in the valuation column of the summary table below. As a consequence of this uncertainty, and in the absence of better empirical evidence, it is inappropriate to scale these results on any basis. This conclusion is supported by the fact that location-specific components are likely to be less significant in the welfare valuation of these risks.

Discussion

Table C.1 draws together all the monetary estimates by use of a cost ranking. Impacts BD5 and BD14 have the highest cost rankings.

Impact BD5 relates to the changes in species geographical coverage when they are unable to track changing climate space. Whilst the changing climate envelopes imply that there is likely to be a mix of species that gain and lose as a result of climate change, and an accompanying array of associated welfare effects that are location-specific, the welfare impacts are likely to be most immediately in the form of amenity effects, but in parallel with longer lasting changes in regulating and supporting systems.

Impact BD14 relates to water availability for the natural environment taking account of changes in demand and projected changes in rainfall. The loss of moisture in the summer could potentially have widespread welfare effects resulting from greater aridity and loss of biodiversity.

It should be emphasised that the uncertainty surrounding the other risks relating to the terrestrial natural environment is high and these may well justify a similar cost ranking.

Table C.1 Monetary valuation of climate change impacts on the natural environment (terrestrial)

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Changes in soil organic carbon	BD8	-M?	UK	L	Informed Judgement	Based on informed judgement in UK Sector report
Ecosystem risks due to reduction in water quantity	BD14	-H?	Wales	L		Based on Water Sector metric WA7 (Environmental Flow Indicators)
Water quality and pollution risks	BD13	N/A	N/A	N/A		Not assessed
Biodiversity risks due to warmer rivers and lakes	BD10	-L	UK	L		Based on informed judgement in UK Sector report
Risks to species and habitats due to drier soils	BD1	-M	UK	L		No direct valuation. Based on consequences in UK Sector report
Increased risk of wildfires	BD12	-L to -M?	UK	L		Based on cost of response to fires in UK Sector report
Risk of pests to biodiversity	BD3	-M	UK	L		Based on informed judgement in UK Sector report
Risk of diseases to biodiversity	BD4	-M?	UK	L		Based on informed judgement in UK Sector report
Species unable to track changing climate space	BD5	-H?	UK	L		Based on informed judgement in UK Sector report
Change in species migration patterns	BD9	-M?	UK	L		Based on informed judgement in UK Sector report

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.4 Climate change impacts on the natural environment (coastal)

The cost rankings given in Table C.2 below are all based on informed judgement and therefore have high uncertainty attached. Changes in species migration are suggested to constitute the highest ranked cost for the same reasons as the terrestrial natural environment. Fragmentation of habitats is less of a problem on the coast compared with inland. The confidence is, however, very low.

Table C.2 Monetary evaluation of climate change impacts on the natural environment (coastal)

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Risks to species and habitats due to coastal evolution and flooding	BD2/7	-L?	UK	L	Informed judgement	Based on results in UK Sector report
BAP habitats lost due to coastal erosion	FL14b	-L	UK	L	Informed judgement	Based on results in UK Sector report
Changes in species migration patterns	BD9	-M?	UK	L	Informed judgement	Qualitative risk assessment based on results in UK Sector report. Ranking given here only relates to small number of indicator species. Total effects likely to be much greater
Expansion of new or existing tourist destinations	BU8	N/A	N/A	N/A	-	Adverse impacts of tourist pressure. Not assessed

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.5 Climate change impacts on the natural environment (marine)

Increases in disease from pathogens and disease hosts are unlikely to have significant impacts in Wales. This is because of existing controls, which mean that the impacts are likely to be rather limited.

The costs of Harmful Algal Blooms (HABs) are not known, but informed judgement based on studies of the costs of HABs suggests that these costs may be relatively low in the Welsh case. Based on data to 1998, ECOHARM identifies an impact of HABs on UK mussel aquaculture of between £2.2 million to £4.6 million (€2.54 million and €5.28 million) (ECOHARM, 2003). This does not include climate change attribution, but it may give an indication of the potential scale of the costs.

For ocean acidification costs, the results of the UK sector study were scaled on the basis of the value of shellfish catch¹⁷ in England and Wales. This was then adjusted using the relative catch of the 3 largest ports (giving 32% of the England and Wales total). This gives cost estimates as shown in Table C.3.

¹⁷ Source: <http://marinemanagement.org.uk/fisheries/statistics/documents/monthly/2010/may.pdf>.

Table C.3 Mid-point annual costs of ocean acidification (Wales)

£m, no socioeconomic change

	Shellfish	Mollusc	Aquaculture	Total
2020s	0.7	0.2	0.1	1.0
2050s	3.8	1.0	0.3	5.2
2080s	8.3	2.2	0.7	11.2

The complexity of the challenge in the valuation of projected shifts in fish species is considerable. This is because in some cases, for example for the Plaice and Cod species, the shift moves the catch closer to UK ports, whereas in other cases, for example Haddock, the catch is projected to move further away from the UK. The analysis also highlights the potential for species shift across international boundaries, with associated implications for fishing quotas.

In the UK sector report, expert judgement was used to suggest that the overall cost would be low, between £1 million to £9 million per annum. It seems appropriate to suggest that the costs for Wales would also be low.

For the case of invasive species, the UK sector analysis considered the case of the eradication of the Carpet Sea Squirt from marinas in the UK, suggesting that the costs could rise to £72 million for the whole of the UK by the 2080s. Given that 9% of berths are in Wales¹⁸, this suggests costs of up to £5 million for Wales by the 2080s, assuming a constant number of berths.

The UK sector report studied nine invasive species and concluded that the range of all of them could encompass the UK coast by the 2080s. Whilst the costs have not been estimated, they could be high. Examples are given in the box entitled 'Changes to the Marine Environment' in [Section 4.2.3](#).

Other impacts include effects on recreational users and tourists. The ECOHARM study referred to above uses a contingent valuation survey to elicit preferences and derives impacts of between £185 million and £1,320 million (£215 million and €1,524 million) for the whole of Europe. Clearly the impact on Wales would be a small fraction of this. The ECOHARM study does not consider the impact of climate change explicitly, so these costs may increase in the future.

Based on the above, the likely impacts of climate change on the marine environment in Wales is summarised in Table C.4. The level of confidence in the estimates is generally low. Further work is needed on a number of these areas to produce more robust estimates of the likely consequences.

¹⁸ Based on

[http://www.insights.org.uk/articleitem.aspx?title=Marinas:%20The%20Tourism%20Aspect%20of%20Leisure%20Boating#Market size and value](http://www.insights.org.uk/articleitem.aspx?title=Marinas:%20The%20Tourism%20Aspect%20of%20Leisure%20Boating#Market%20size%20and%20value)

Table C.4 – Monetary valuation climate change impacts on the natural environment (marine)

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Decline in marine water quality	MA2	-L	Wales	L	Informed judgement	Low impact likely because of existing measures to reduce health impacts
Risk of harmful algal blooms	MA1	-L	UK	L	Informed judgement	Impact not quantified in sector report
Increased ocean acidification	MA3	-L to -M	Wales	L	Market Prices	Based on shellfish, molluscs and aquaculture only. Adjustment based on shellfish fishery
Changes in fish catch location	MA4	-L	UK	L	Informed judgement	Assumes species do not cross national boundaries
Northward spread of invasive non-native species	MA6	-M to -H	UK	L	Market Prices/ Informed judgement	Carpet sea squirt only used in valuation. Valuation ranking includes 8 other species identified in CCRA
Expansion of new or existing tourist destinations	BU8	N/A	N/A	N/A		Adverse impact on environment. Not quantified in sector report

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.6 Climate change impacts on agriculture

The most robust estimates are given for crops, where the impacts on grass, sugar beet, wheat and potatoes were estimated in the UK sector report. The impacts on potatoes were negligible when CO₂ fertilisation was taken into account, and no sugar beet is grown in Wales¹⁹, but benefits for grass and wheat²⁰ can be estimated for Wales.

The results are shown in Tables C.5(a) for grass and C.5(b) for wheat. Table 5(a) shows results for the ranges of change projected in the CCRA (i.e. from 11% to 31% by the 2020s and from 22% to 51% by the 2050s). Table 5(b) shows results for all the emissions scenarios explicitly.

The flood impacts have been derived using the extent of agricultural land at risk of flooding in Wales as a basis, combined with the results of the sector analysis which estimates the expected annual damage to agricultural land from flooding.

¹⁹ Source: <http://www.defra.gov.uk/evidence/economics/foodfarm/reports/documents/Sugar.pdf>

²⁰ Based on area harvested in 2010 and change in yield based on sector report. Source of area: <http://www.defra.gov.uk/evidence/statistics/foodfarm/food/cereals/cerealsoilseed.htm>

For pests and diseases, the sector report examined two crop impacts but the results suggested little or no impact of climate, assuming the continued use of pesticides in response to increased pest prevalence. It has therefore not been possible to value this metric.

Table C.5(a) Change in monetary value of grass production in Wales due to climate change (£m, in 2010 prices)

£m per year compared to 1961-1990 climate, 2010 prices, no discounting

	2020s	2050s
Change in monetary value based on grass silage price	35 (11%)	69 (22%)
Change in monetary value based on grassland hay price	95 (11%)	189 (22%)
Change in monetary value based on grass silage price	97 (31%)	160 (51%)
Change in monetary value based on grassland hay price	266 (31%)	438 (51%)

Table C.5(b) Impact on Gross Margins for Wheat per annum due to climate change (Wales)

£m per year compared to 1961-1990 climate, 2010 prices, with adjustments to prices and land use, but no discounting

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				2.2	4.2	6.7	2.9	5.3	8.3
Medium	1.2	2.6	4.3	2.4	4.4	6.8	3.6	6.2	9.5
High				2.2	4.1	6.3	3.9	6.5	9.8

The cost of the impact of changes in mean temperature on livestock mortality was negligible although the estimates do not include extreme weather events (e.g. heatwaves) where mortality may be significant.

Table C.6 gives a summary of the expected scale of damages to agriculture in Wales from climate change. It can be seen that significant benefits are expected in terms of increased crop value, but the uncertainties in modelling of the physical impacts remain considerable.

Table C.6 Monetary valuation of climate change impacts on Agriculture

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Change in crop yield	AG1	+L	Wales	M	Market Prices	Wheat and potatoes considered
Opportunities to grow new crops	AG9	N/A	N/A	N/A		Not assessed
Changes in grassland productivity	AG10	+H	Wales	M	Informed Judgement	85% of agricultural land in Wales is permanent grass
Increase in water demand for crops	AG5	-L to -M	Wales	L	Informed Judgement	Based on consequences in Sector Report and metric WA8. No direct valuation
Increase in water demand for livestock	AG6	Negligible	UK	N/A	Informed Judgement	Relatively low demand for water for livestock
Drier soils	AG4	-M	UK	L	Informed Judgement	Based on consequences in Sector Report. No direct valuation
Increase in flood risk to agricultural land	AG2/FL4	-L to -M	Wales	M	Market Prices	
Agricultural land lost due to coastal erosion	FL14a	-M	Wales	M	Market Prices	
Risk of crop pests and diseases	AG3	N/A	N/A	N/A		No impact identified in sector report – likely because of increased use of pesticides
Effects of heat stress on dairy milk production and herd fertility	AG7	-L	UK	M	Informed Judgement	
Effects of heat stress on dairy livestock	AG8	Negligible	UK	N/A	Informed Judgement	Does not consider extreme events

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.7 Climate change impacts on forestry

To estimate the damage costs due to Red Band Needle Blight the UK estimates were scaled by area of pine forests. The damage costs in the sector study reflect a range of values for ecosystem services in forests assuming a 10% damage to such services caused by the impacts of the pathogens. There are limits to the validity of this scaling, as it assumes an even coverage of impact across the UK. However, adopting this assumption, the annual costs for Wales may be up to £0.4 million by the 2080s.

Table C.7 Estimated Change in damage costs due to Red Band Needle Blight by emissions scenario (Wales)

£million/year, 2010 prices, no uplift or discounting; future climate change (2020s, 2050s, 2080s); assuming current forest stock (no future socio-economic change)

Emission scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				0	0.2-0.4	0.4	0-0.1	0.2-0.4	0.4
Medium	0	0-0.1	0.2-0.4	0-0.1	0.2-0.4	0.4	0-0.1	0.4	0.4
High				0-0.1	0.2-0.4	0.4	0.2-0.4	0.4	0.4

For the costs of Green Spruce Aphid the sector study is used, with scaling for the relative size of Spruce forest in Wales. This gives estimates of the costs as shown in Table C.8. It should be noted that this is based on market prices related to lost timber productivity. The effects on other ecosystem services were judged to be limited.

Table C.8 Estimated Change in damage costs due to Green Spruce Aphid by emissions scenario (Wales)

£million/year, 2010 prices, no uplift or discounting; future climate change (2020s, 2050s, 2080s); assuming current forest stock (no socio-economic change)

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				0-0.2	0-0.2	0.2-0.8	0-0.2	0.2-0.8	0.2-0.8
Medium	0-0.2	0-0.2	0.2-0.8	0-0.2	0.2-0.8	0.2-0.8	0-0.2	0.2-0.8	0.8-2.1
High				0-0.2	0.2-0.8	0.2-0.8	0-0.2	0.2-0.8	0.8-2.1

The impact of yield loss due to drought was valued, as in the UK sector study, on the basis of market prices for soft and hard wood. This leads to estimated costs as shown in Table C.9 of between £0.1 and £0.6 million per year depending on the scenario considered.

Table C.9 Value of Forest Yield Loss due to Drought under different emissions scenarios (Wales)

£million/year, no socio-economic change

Emissions scenario	2020s			2050s			2080s		
	p10	p50	p90	p10	p50	p90	p10	p50	p90
Low				0.0	0.2	0.5	0.04	0.3	0.5
Medium	-0.1	0.1	0.3	0.1	0.3	0.6	0.2	0.4	0.8
High				0.1	0.3	0.6	0.2	0.6	1.0

An overview of the scale of costs associated with climate change in Wales is given in Table C.10. Of those impacts that could be valued, the costs are generally low. Timing of impacts and associated costs are also very uncertain, particularly the costs of red band needle blight and the impacts of drought.

Table C.10 Monetary valuation climate change impacts on Forestry

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Forest extent affected by pests and diseases	FO1	-L	Wales	L	Informed Judgement/ Non-Market Value/ Market Prices	Red band needle blight and green spruce aphid only. Analysis for Wales based on forest area
Loss of forest productivity due to drought	FO2	-L	Wales	L	Market Prices	
Increased risk of wildfires	BD12	-L to -M	UK	L	Informed Judgement	See Table C.1
Decline in potential yield	FO4	N/A	N/A	N/A		Not assessed

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.8 Climate change impacts on Business

Methods

Risk metrics BU3, BU4, BU7, and FL7 are estimated using market prices and non-market values; the cost rankings of the remaining risks are based on informed judgement.

Discussion

Risk metrics BU4 and FL7 both address the exposure of business to flooding. FL7 covers damage to buildings and BU4 includes other forms of disruption to business operations. The total Expected Annual Damages (EAD) attributed to non-residential properties in Wales are presented in Table C.11. These values can be seen to increase significantly over the three time periods though the uncertainty across the climate scenarios is large.

Table C.11 EAD of Non-Residential Properties at significant likelihood of river and tidal flooding (Wales)

£million/year, no uplift or discounting; climate change only; current population (no socio-economic change)

Base line	2020s			2050s					2080s				
	Med p10	Med p50	Med p90	Low P10	Low p50	Med p50	High p50	High p90	Low p10	Low p50	Med p50	High p50	High p90
92	110	140	170	110	150	160	190	230	140	180	200	220	290

Additional business interruption cost are estimated to be £2m, £4m and £6m for the 2020s, 2050s and 2080s, respectively under that the p50 Medium Emissions scenario.

On the basis of these results (and results for metric FL6 which covers residential property) it is estimated that the combined domestic and commercial claims in Wales could increase by between 15% and 100% by the 2020s rising to between 20% and 200% by the 2050s. The increase by the 2080s could be in the range of 50% to a four times increase. The additional average annual total claim for flood related damage is estimated to be of the order of £55m in the 2020s, £110m in the 2050s and £170 million in the 2080s for the p50 Medium Emissions scenario.

However, the overall impact to the industry is unclear, being determined by the balance of pay-out following an event versus the cost of products to consumers (i.e. cost of premiums). The risk is thus fundamentally one of how well the industry understands weather risk (and how this may vary as climate changes). The evidence suggests that the insurance industry is adapting to the challenges arising from climate change.

Metric BU2 estimates the costs of protecting buildings of historical and cultural significance from flooding. In the absence of estimates for Welsh buildings, a scaling is undertaken on the basis of population, reflecting national societal ability and willingness to pay for this type of flood protection. Climate change attributable costs are estimated to be £1 million by the 2050s and £2 million by the 2080s.

However these costs are not representative of the total damage caused by flooding to tourism related buildings and natural features. For example, the effect of the loss of beach area is not covered and an assessment of damage to listed buildings has not been carried out.

Estimates for metric BU3 are presented in Tables C.12 and C.13, which show the total value of abstractions that may be prevented if catchments switch from being unsustainable to sustainable for industrial users. Table C.12 presents results for abstraction from local catchments whilst Table C.13 presents results for locations downstream of the abstraction. Overall the costs are relatively small.

It is possible that the extent of adaptive measures practised by other sectors (e.g. public water supply) or changes in regulatory controls could have more of a day-to-day impact on industrial abstractors than any absolute changes in water availability. Thus, although constraints on supply as a result of climate change do have the potential to effect industrial use, the wider constraints on water supply will possibly have a larger, albeit more indirect, effect.

Table C.12 Marginal Change in Industrial Abstraction from Sustainable Catchments from Climate change (Wales)

No socio-economic change; local; £m/annum, no uplift or discounting; 2008 risk baseline

	Low Emissions scenario			Medium Emissions scenario			High Emissions scenario		
	p10 (wet)	p50 (mid)	p90 (dry)	p10 (wet)	p50 (mid)	p90 (dry)	p10 (wet)	p50 (mid)	p90 (dry)
2020s	-0.1	0.2	0.2	-0.1	0.2	0.2	-0.1	0.2	0.2
2050s	0.1	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.3
2080s	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.3

Table C.13 Marginal Change in Industrial Abstraction from Sustainable Catchments from Climate change (Wales)

No socio-economic change; downstream; £m/annum, no uplift or discounting; 2008 risk baseline

	Low Emissions scenario			Medium Emissions scenario			High Emissions scenario		
	p10 (wet)	p50 (mid)	p90 (dry)	p10 (wet)	p50 (mid)	p90 (dry)	p10 (wet)	p50 (mid)	p90 (dry)
2020s	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1
2050s	0.0	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
2080s	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.2

Table C.14 highlights that, on the basis of the risks considered, flood risk is likely to be the most significant to business, including industrial and commercial enterprises and insurers.

Impacts on the insurance sector and the finance sector should not be seen as welfare impacts. Rather, they indicate sectors of business vulnerability to climate change and serve to indicate the need for adaptation action.

Table C.14 Monetary valuation climate change impacts on Business

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Increase in non-residential properties at risk of flooding	FL7	-M/H	Wales	M	Market Prices	Scaled from results in UK Sector report. Repair costs used, equating to adaptation costs
Risk of business disruption due to flooding	BU4	-H	Wales	H	Market Prices	Scaled from results in UK Sector report. Double counting with FL7 but includes wider costs (e.g. disruption). Should not be interpreted as welfare impact
Decrease in output for businesses due to supply chain disruption	BU9	-M	UK	L	Informed Judgement	Based on evidence of losses to specific industries
Mortgage provision threatened due to increased flood risk	BU6	-M to -H	Wales	M	Market Prices	Scaled from results in UK Sector report. Double counting with FL6. Should not be interpreted as welfare impact
Insurance industry	BU7	-M?	Wales	M	Market Prices	Should not be interpreted as

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
exposure to flood risks						welfare impact
Risk of restrictions in water abstraction for industry	BU3	-L	Wales	M	Non-Market Values	Scaled from results in UK Sector report. Double-counting with WA8b
Loss of productivity due to ICT disruption	BU5	-L?	UK	L	Informed Judgement	Qualitative risk assessment
Monetary losses due to tourist assets at risk from flooding	BU2	-L to -M	UK	M	Market Prices/ Informed Judgement	Maintenance costs used, equating to adaptation costs. Also, risk assessment not likely to have considered all assets (e.g. beach loss). Therefore likely to be lower bound of true welfare costs
Expansion of new or existing tourist destinations	BU8	N/A	N/A	N/A		Not assessed
Climate risks to investment funds	BU1	-H?	UK	L	Informed Judgement	Scaled from results in UK Sector report. Likely to be double-counting with risks in other sectors such as floods, agriculture, transport and health. Should not be interpreted as welfare impact

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.9 Climate change impacts on buildings and the urban environment

Methods

Risk metrics BE2, BE3, FL6, FL7 and FL13 are estimated using market prices and non-market values. The cost rankings of the remaining risks are based on informed judgement.

Discussion

Quantitative analysis has been undertaken for Wales for the two property related flood risks (FL6 and FL7). The Expected Annual Damages (EADs) attributable to climate change alone for the p50 Medium Emissions scenario for Wales are presented in Table C.15 below. These results are generated on the basis that flood defences are

maintained to present standards. The residential totals are further disaggregated to indicate that whilst approximately 75% of the cost will be borne by household insurance companies, one quarter of the total is attributed to provision of emergency and hospital services (see e.g. Chatterton, 2009).

Table C.15 Climate attributable EADs for property flooding (Wales)

£m, 2010, no uplift or discounting; p50 Medium Emissions scenario; no socio-economic change

	Residential		Non-residential	Total
	Insurance	National		
2020s	25	10	50	85
2050s	55	20	70	145
2080s	75	30	110	215

Metric (BE3) relating to the overheating of buildings may lead to potentially high costs, from reduced productivity and lost work time. This could plausibly be of the order of tens, or even hundreds of millions of pounds annually by later time periods, given the size of the working population potentially impacted, combined with the unit value of a day of lost productivity (£150/day on average).

However care is needed in interpreting these changes, because of the private sector autonomous response to climate change. In the face of rising temperatures, companies would be likely to adjust the working environment (e.g. through air conditioning), to avoid falls in productivity and in direct response to occupational health legislation and guidance. The indicative results above are therefore likely to be an over-estimate of the actual costs likely to occur in the future.

The quantitative results for subsidence risk (metric BE2) are identified as being low as subsidence is not a large problem in Wales. The impact of the risk relating to green spaces (metric BE5) is judged likely to incur economic costs indicatively of £0 – 10 million a year in the time periods considered.

Table C.16 summarises the monetary valuation relating to the built environment for Wales. Clearly, the property related flood risks are the largest, whilst overheating of buildings is also sizeable. The flood risk valuations are considered to have less uncertainty compared to the other risk metrics, since they are based on quantitative modelling.

Table C.16 Monetary valuation climate change impacts on the Built Environment

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Increase in properties at risk of flooding	FL6 / 7	-H	Wales	M	Market Prices	Scaled from results in UK Sector report. Repair costs used, equating to adaptation costs
Insurance availability for residential properties	FL13	-M	Wales	M	Market Prices	Double counting with FL6. High original valuation but industry may adapt to change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Flood risk for SAM sites	FL15	-L	Wales	L	Informed Judgement/ Non-Value Markets	Relies on crude quantitative assessment
CSO spill frequency	WA10	-L	Wales	L	Informed Judgement	Qualitative risk assessment. Scaled from results in UK Sector report
Overheating of buildings	BE3	-M	UK	L	Market Prices	Assumes no autonomous adaptation or use of cooling (energy), thus values are considered high for actual future baseline. Values loss in workers productivity. Strong overlap (double counting) with increased energy use metric
Increased subsidence risk	BE2	-L	Wales	L	Market Prices	Range reflects climate projections only and relates to summer rainfall
Effectiveness of green space for cooling	BE5	-L	UK	L	Informed Judgement	Qualitative risk assessment

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.10 Climate change impacts on infrastructure

Methods

Risk metrics TR5, WA4, and BE9 are estimated using market prices and non-market values. The cost rankings of the remaining risks are based on informed judgement. Whilst WA4 results are generated from quantitative physical estimation for Wales, the remaining results have been scaled to the Welsh context from the UK level sector analysis.

Discussion

There are a number of risk metrics concerned with damage to transport infrastructure resulting from the projected increases in frequencies in extreme weather events under climate change. The outcome of the assessment shows that cost of disruption from floods (metric TR1) is expected to be low. For TR2 (erosion and landslides), the cost ranking is low in the 2050s but may increase to medium for the p90 medium and high emission projections in the 2080s. Metric TR5 (rail buckling from heat) is considered

likely to have a low cost ranking under all emissions scenarios, across the three time periods.

The risk metrics selected for water relate to the issue of meeting water demands, given changing supply conditions under climate change. Table C.17 spatially disaggregates the results on the basis of Welsh UKCP09 river basins and shows the impacts of climate change alone on water supply deficits (£m/annum) in each of the basins, when population is held constant at current levels.

From these results it is clear that the largest deficits are borne in the Severn River basin, although a large proportion of this is in England. The cost rankings for Wales, in total, are considered to be medium overall. The deficits would be exacerbated under projected increases in future population. There is however considerable uncertainty, as reflected in the range of results under the different climate change scenarios in a given time period.

Table C.17 Annual Water Supply-Demand deficits in UKCP09 river basins
£m, 2010 prices; considers climate change impacts on Deployable Outputs; current population; 150/day per capita consumption; no water transfer between regions

River Basin	Time Period	Low emissions			Medium emissions			High emissions		
		p10 (wet)	p50 (mid)	p90 (dry)	p10 (wet)	p50 (mid)	p90 (dry)	p10 (wet)	p50 (mid)	p90 (dry)
Dee	2020s	0.0	0.0	-0.9	0.0	0.0	-1.0	0.0	0.0	-0.9
	2050s	0.0	-0.9	-2.2	0.0	-1.3	-2.7	-0.3	-1.7	-2.7
	2080s	-0.2	-1.5	-2.7	-0.8	-2.0	-2.8	-1.2	-2.0	-2.8
Severn	2020s	0.0	-0.3	-5.1	0.0	-0.2	-5.6	0.0	-0.3	-5.3
	2050s	0.0	-5.4	-12.8	-0.5	-7.5	-15.7	-2.0	-9.5	-17.6
	2080s	-1.3	-8.7	-17.6	-4.8	-12.7	-17.9	-7.8	-12.9	-18.2
Western Wales	2020s	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.4
	2050s	0.0	-0.5	-3.1	0.0	-1.0	-3.8	0.0	-1.6	-4.6
	2080s	0.0	-1.5	-4.7	0.0	-3.2	-7.0	-1.0	-5.0	-8.7
Total	2020s	0.0	-0.3	-6.4	0.0	-0.2	-6.9	0.0	-0.3	-6.6
	2050s	0.0	-6.9	-18.1	-0.5	-9.8	-22.2	-2.3	-12.7	-25.0
	2080s	-1.5	-11.8	-25.1	-5.6	-17.9	-27.7	-10.0	-19.9	-29.8

Metrics WA4 and WA5 do not provide quantitative estimates of the additional risks relating to non-connected households and businesses. As a result, it is not possible to make quantitative estimates of the welfare costs associated with these risks. An informed judgement has been made as to the potential order of magnitude that this implies, additional to the costs estimated for WA4; these do not alter the overall ranking.

Valuations for metrics relating to energy use (BE9 and EN2) are based on market prices and generate a low cost ranking in the 2020s and a medium ranking in the 2050s and 2080s. Note, however, that whilst BE9 (reduction in heating demand) constitute welfare benefits, EN2 (increase in cooling demand) constitute welfare costs.

Valuation of metrics relating to infrastructure damage due to extreme weather events (EN1, EN3 and EN10) rely on informed judgement, in the absence of a quantitative physical risk assessment. The risks of outages as a result of substations at risk of flooding (EN1) are judged to be low in the 2050s rising possibly to medium in the 2080s. The risk to power stations is judged to warrant a low cost ranking in the 2020s and 2050s, and a low/medium in the 2080s, although this is highly uncertain.

Table C.18 summarises the results for infrastructure in Wales. It shows that there are clearly significant welfare impacts associated with water resources and energy provision. However, the uncertainty associated with these rankings, and the absence of

socio-economic change, suggests that the full range of results including all climate and socio-economic scenarios need to be considered in planning adaptation.

Table C.18 Monetary valuation climate change impacts on Infrastructure

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Transport						
Increase in flooding of road and rail	FL8	-L	Wales	L	Informed Judgement	Links with Transport and overlaps with TR1. Double-counting if summed
Disruption to road traffic due to flooding	TR1	-L	UK	L	Informed Judgement	Road sector only. Qualitative risk assessment
Landslide risks on the road network	TR2	-L	UK	L	Informed Judgement	Road sector only. Qualitative risk assessment
Rail buckling risk	TR5	-L	Wales	L	Market Prices	Includes time delay and repair costs. Repair cost estimates equate to adaptation costs
Water						
Change in household water demand	WA4	-M	Wales	M	Market Prices	The welfare impact derives from the supply-demand imbalance captured in WA5
Water infrastructure at risk of flooding	FL10	N/A	N/A	N/A	-	Not assessed. No data
Energy						
Power stations and sub-stations at risk of flooding	FL11	-L	Wales	L	Informed Judgement	Included in Energy (EN1)
Energy infrastructure at risk of flooding	EN1	-L to -M	Wales	L	Informed Judgement	Assumes no autonomous (private sector) adaptation. No direct valuation
Restrictions in water abstraction for energy generation	EN4	N/A	N/A	N/A	-	Not assessed

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence Ranking	Estimation Method	Notes
Reduction in energy demand for heating	BE9	+M	Wales	L	Market Prices	Climate change only for current stock. Not including existing policy, thus probable over-estimate. No rebound effects included, which may reduce benefits significantly
Energy demand for cooling	EN2	-M	Wales	L	Informed Judgement	Low impacts due to existing winter peak capacity in the UK (thus within summer reserve margin). Does not include potential issues of summer maintenance regime, or summer peak (extremes)
Heat-related damage/ disruption to energy infrastructure	EN3	-L	UK	L	Informed Judgement/ Market Prices	Only includes costs of extra energy provision. Additional investment costs of air conditioning units would add to these costs significantly
Energy transmission capacity losses	EN10	-L	Wales	L	Informed Judgement	Adaptation cost (cost of upgrading) based on sector report
Electricity turbine efficiency	EN6	N/A	N/A	N/A	-	Not assessed
Power station cooling	EN8	N/A	N/A	N/A	-	Not assessed

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.

C.11 Climate change impacts on health and well-being

Methods

All risk metrics, apart from HE9 and FL2, are estimated using market prices and non-market values. The cost rankings of the HE9 and FL2 are based on informed judgement.

Discussion

Table C.19 shows the monetary value of additional mortality impacts from heat in Wales (metric HE1) under the Medium Emissions scenario, given current population. No acclimatisation or increased adoption of air conditioning is assumed.

It is clear from the table that as climate change develops over the course of the century the size of the heat-related mortality risks increase, so that the welfare cost in the 2080s is more than four times higher than that in the 2020s, whilst doubling between the 2050s and 2080s.

Table C.19 Valuation of Life Years Lost (heat) for the Medium Emissions and Principal population scenario (Wales)

£m, annual, 2010 prices; no acclimatisation

2020s			2050s			2080s		
p10	p50	p90	p10	p50	p90	p10	p50	p90
0.1	0.3	0.6	0.4	0.8	1.6	0.7	1.5	3.1

The monetary value of reduced mortality impacts from cold under the three climate scenarios is estimated to range from £15 million to £30 million per year by the 2050s based on the principal population scenario. No acclimatisation is assumed. The benefits identified under this metric are greater than the adverse impacts under HE1 and HE2.

The monetary totals for climate-induced flood related deaths in the UK (metric HE3) are presented in Table C.20. Current levels of flood defences are assumed in the risk assessment. The welfare impacts of these fatalities increase further into the future, and across the climate scenarios from low to high.

Table C.20 Monetary Valuation of Additional Flood Related Deaths due to Extreme Event Flooding and Storms (UK)

£m, annual, 2010 prices; future climate change with current population

2020s			2050s					2080s				
Med.	Med.	Med.	Low	Low	Med.	High	High	Low	Low	Med.	High	High
P10	p50	P90	p10	p50	p50	p50	p90	p10	p50	p50	p50	p90
0.4	1.1	1.6	0.7	1.7	2.0	2.3	3.1	1.4	2.5	2.9	3.5	5.8

Table C.21 shows the valuation of additional flood related injuries due to extreme events such as flooding and storms (HE7), assuming current population.

Table C.21 Monetary Valuation of Additional Flood Related Injuries due to Extreme Event Flooding and Storms (Wales)

£m, annual, 2010 prices; current population

2020s			2050s					2080s				
Med.	Med.	Med.	Low	Low	Med.	High	High	Low	Low	Med.	High	High
p10	p50	p90	p10	p50	p50	p50	p90	p10	p50	p50	p50	p90
0	1	2	1	2	2	2	3	1	2	3	3	6

The annualised results for flooding to hospitals attributable to climate change alone are presented in Table C.22. It is also emphasised that these totals will be higher if more frequent flood events are included in the analysis.

Table C.22 Flood costs to hospitals from climate change (p50 Medium Emissions scenario, Wales)

EAD, £m/year, 2010 prices, no uplift or discounting; no socio-economic change

2020s			2050s					2080s				
1	2	3	4	5	6	7	8	9	10	11	12	13
Medium	Medium	Medium	Low	Low	Medium	High	High	Low	Low	Medium	High	High
p10	p50	P90	p10	p50	p50	p50	p90	p10	p50	p50	p50	p90
0	14	30	7	21	30	42	58	19	39	42	51	70

Table C.23 shows that the highest valuation ranking is the benefits of reduced winter mortality and morbidity. The highest valuations for adverse impacts include hospital flooding risk, impacts on vulnerable people and water supply. However there is considerable uncertainty in these results, even in the absence of alternative socio-economic futures.

Table C.23 Climate change impacts on the Health and Well-being

Medium Emissions scenario (p50, 2050s); no population change

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence ranking	Estimation Method	Notes
Summer mortality due to higher temperatures	HE1	-L	Wales	L	Non-Market Value	Assume no acclimatisation. Does not include urban heat island and heatwave impacts. Does not include benefits of cooling associated with rising energy costs
Summer morbidity due to higher temperatures	HE2	-L	Wales	M	Non-Market Value/Market Prices	Assume no acclimatisation. Does not include urban heat island and heatwave impacts. Adaptation costs (treatment)
Sunlight / UV exposure	HE9	- L?	UK	L	Informed Judgement	Qualitative risk assessment
Decline in winter mortality due to higher temperatures	HE5	+L	Wales	L	Non-market Value	Assume no acclimatisation
Decline in winter morbidity due to higher	HE6	+M	Wales	M	Non-Market Value/Market Prices	Assume no acclimatisation

Impact	Metric	Valuation Ranking	Valuation Coverage	Confidence ranking	Estimation Method	Notes
temperatures						
Extreme weather event (flooding and storms) mortality	HE3	-L	Wales	L	Welfare impact cost (Non-Market Value)	Assumes current flood protection levels
Extreme weather event (flooding and storms) injuries	HE7	-L	Wales	M	Non-Market Value/Market Prices	Adaptation costs equate to medical treatment costs
Number of people at risk of flooding	FL1	N/A	N/A	N/A	-	Incorporated in FL6 in Built Environment. Not assessed separately
Vulnerable people at risk of flooding	FL2	-M to -H	Wales	L	Informed Judgement	Based on potential state support. No direct valuation. This is regarded as important in Wales
Effects of floods/storms on mental health	HE10	-L	UK	L	Non-Market Value/Market Prices	Adaptation costs equate to medical treatment costs
Hospitals at risk of flooding	FL12	-M	Wales	L	Market Prices	1:75 annual risk of flood event assumed
Mortality and morbidity due to summer air pollution (ozone)	HE4	-L	Wales	L	Informed Judgement 2020s, 2050s; Non-Market Value, 2080s	Same as HE1
Public water supply-demand deficits	WA5	-M	Wales	M	Market Prices	Welfare impact derives from the supply-demand imbalance

Note: - signifies a negative impact or loss; + signifies a positive impact or gain.