Final Report **Project UKCC13**

Preparing for a Changing Climate in Northern Ireland

January 2007

Environment & Heritage Service
www.ehsni.gov.uk

UK Climate Impacts Programme

DOE
Department of the Environment
www.doeni.gov.uk

SNIFFER
SCOTLAND & NORTHERN IRELAND FORUM FOR ENVIRONMENTAL RESEARCH

© SNIFFER 2007

All rights reserved. No part of this document may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior permission of SNIFFER.

The views expressed in this document are not necessarily those of SNIFFER. Its members, servants or agents accept no liability whatsoever for any loss or damage arising from the interpretation or use of the information, or reliance upon views contained herein.

The document should be referenced as:

Preparing for a Changing Climate in Northern Ireland, Arkell, B., Darch, G., and McEntee, P (eds), SNIFFER UKCC13 (2007)

Lead authors of chapters in this report were Geoff Darch, Paddy McEntee, Liz Hammock and Guy Mercer (Atkins), Mark Broadmeadow (Forest Research), Jake Piper (Oxford Brookes University), David Viner (University of East Anglia) and Sari Kovats (London School of Hygiene and Tropical Medicine). Contributions were also made by Michael McLarnon, Jayne Walker, Louise McDevitt, Julie Nesbitt, John Box, Jules Wynn and Rob McSweeney (Atkins) and Elizabeth Wilson (Oxford Brookes University).

Project funders

Scotland & Northern Ireland Forum for Environmental Research
Environment and Heritage Service Northern Ireland, Department of Environment Northern Ireland

Dissemination status

Unrestricted

A summary report is also available from www.sniffer.org.uk

Whilst this document is considered to represent the best available scientific information and expert opinion available at the stage of completion of the report, it does not necessarily represent the final or policy positions of the project funders.

Research contractor

This report's contents were produced by:

ATKINS
Atkins Limited
71 Old Channel Road
Belfast
BT3 9DE

Project Management

SNIFFER's project managers for this contract were:
Brendan Forde, Department of Environment Northern Ireland
Barry McAuley, Department of Environment Northern Ireland

SNIFFER's project steering group members were:
Brendan Forde, Department of Environment Northern Ireland
Ivan Gregg, Department of Environment Northern Ireland
Laura McAleese, Department of Environment Northern Ireland
Barry McAuley, Department of Environment Northern Ireland
Gerry Metcalf, UK Climate Impacts Programme
Emily Postan, SNIFFER

SNIFFER
First Floor, Greenside House
25 Greenside Place
EDINBURGH EH1 3AA
Scotland
UK

Company No: SC149513
Scottish Charity: SCO22375

www.sniffer.org.uk

EXECUTIVE SUMMARY

UKCC13: Preparing for a Changing Climate in Northern Ireland

Project funders/partners: SNIFFER, DOENI, EHS

Key words: climate change, impacts, risk, adaptation, public service, Northern Ireland.

Background to research

The climate of Northern Ireland is already changing. Air temperature is rising and the number of hot days is increasing; the proportion of rainfall falling in summer is decreasing, while winters are slightly wetter (EHS, 2004). These changes are expected to accelerate over the coming century. Average temperature may rise by 3°C or more; summer rainfall may fall by up to 50% while winters may be 25% wetter (Hulme et al., 2002). Furthermore, relative sea level may begin to rise.

Although there are ongoing efforts to mitigate climate change, principally by reducing emissions, at least some climate change is now inevitable. Adaptation to climate change – reducing risks and realising opportunities – is therefore required. It is vital that the community and key stakeholders within it have a clear understanding of potential impacts and response strategies. In particular public bodies, with their policy-making, service provision and advisory roles, need to be at the forefront in risk management and the delivery of sustainable development.

This report examines the ways in which Northern Ireland must prepare to meet both the opportunities and threats presented by the impacts of a changing climate. It focuses specifically on the impacts on, and the need for adaptation by, the public sector in Northern Ireland.

Objectives of research

The five main objectives of this study were to:

1. Provide an analysis (updating the 2002 SNIFFER scoping report), based on the themes of Economic Infrastructure, Built Environment, Natural Environment and Social Wellbeing, of climate change impacts upon Northern Ireland, using the UK Climate Impacts Programme 2002 (UKCIP02) scenarios and recent research in the field relevant to Northern Ireland.
2. Produce a risk analysis of identified impacts with estimated likelihood of risk and resource implications.
3. Produce an adaptation strategy for each impact, identifying the public sector bodies responsible for delivery.
4. Provide an analysis of the effect on public services (building on the 2005 EHS guidance), specifically on the key outcomes related to the Government's three priority themes of Economic Competitiveness, Equality and Community Cohesion and Better Public Services.
5. Produce a technical report of climate impacts for use by policy experts. In addition, a separate non-technical summary report has been produced.

Climate change

Current climate, in particular extreme weather, can present difficulties and the examples documented provide some indication of the sensitivity to climate change. For this reason, it is recommended that information on sensitivity to current weather is collated by public sector organisations.

The UKCIP08 climate change scenarios, due in 2008, are not likely to alter the strategic findings of this report. However, significantly more detail will be provided, including probabilistic projections, and this will be particularly useful for detailed technical assessments for key sectors – an essential next step to this report. It is recommended that a brief assessment of the UKCIP08 scenarios is made on their publication, reviewing any changes in projections and highlighting the enhanced data available for stakeholders in Northern Ireland. It is also recommended that outputs of Irish Environmental Protection Agency (EPA) research are reviewed with respect to application in Northern Ireland.

There remain significant uncertainties associated with climate change scenarios and impact assessment and this has been recognised through this study as a significant barrier to planning for adaptation, particularly in funding detailed studies and investments. A large amount of research is currently underway regarding uncertainty and approaches to quantification and it is recommended that detailed assessments review the findings.

Rapid climate change, for example leading to a decline in the North Atlantic Drift, is considered unlikely over the next 100 years. It is recommended that a watching brief is kept on current research in this area and if necessary alternative 'side-swipe' scenarios are investigated to test the resilience of Northern Ireland.

The development and assessment of socio-economic scenarios for Northern Ireland is recommended for use alongside climate change scenarios. These should build on the work being undertaken as part of the UKCIP / Engineering and Physical Sciences Research Council BESEECH study.

Climate change impacts

Climate change impacts have been identified for each sector, with a link made between the climate variable and the receptor. The risk assessment has classified each of the impacts as a threat, opportunity, lost opportunity or benefit. This method is a valuable way to prioritise impacts and adaptive responses, and it is recommended that a risk-based approach is adopted in more detailed impact assessments.

The main impacts of climate change have been considered in terms of the principal sectoral activities in Northern Ireland and are summarised below.

The Natural Environment

Conservation, biodiversity and habitats

Threats to the conservation, biodiversity and habitats of Northern Ireland include:

- Distribution and species composition of habitats will change in response to warmer winters.
- Increase in range of invasive non-native species may threaten ecosystems, in response to warmer temperatures.
- Inter-tidal habitats, salt marshes and mudflats threatened through flooding and erosion.

- Loss of coastal grazing marsh.
- Estuarine and river ecology threatened by tidal flooding.
- Warmer sea temperatures affecting phytoplankton communities – the resulting decline in sand eel populations would adversely affect a wide range of seabirds.

The opportunities that a changing climate could bring to the conservation, biodiversity and habitats of Northern Ireland (e.g. expansion of one species, wetter winters for some habitats) tend to be accompanied by equivalent threats (e.g. loss of another species and drier summers respectively).

Fisheries

Threats to fisheries in and around Northern Ireland include the following:

- Increased frequency of flooding could lead to decreased fish egg survival and washing away of juvenile salmon.
- Lower flows, lower water quality and increased temperatures leading to fish kills.
- Increased temperatures can be lethal for some fish such as salmon.
- The melting of the polar ice pack has cooled the northern Atlantic, reducing the extent of thermally attractive habitat for Salmon.
- Angling affected by disturbance of breeding season of fish.

Opportunities for Fisheries in and around Northern Ireland from a changing climate are limited but warmer waters may provide benefits to aquaculture including higher growth rates and new species.

Agriculture

Threats to agriculture in Northern Ireland include:

- Field drainage issues in wetter weather
- Potential impacts on crop yields
- Potential impacts on animal health

Opportunities for agriculture in Northern Ireland include:

- Potential for growing new crops.
- Reduced cold weather problems including frost damage and a decrease in time that animals need to be kept indoors.

Forestry

Threats to forestry in Northern Ireland include the following:

- Hotter, drier summers will increase water uptake by woodlands, restricting planting in areas with limited water availability.
- Risk of increasing frequency of forest fires, dependent on species and age structure of forest.
- Changing incidence of insect pest and disease outbreaks e.g. increasing impact of the green spruce aphid on commercial plantations of Sitka spruce.
- Extended summer droughts leading to widespread tree mortality.

Opportunities for forestry in Northern Ireland include:

- Higher potential productivity resulting from increased warmth and higher CO_2 levels.
- Changing climatic conditions will alter site suitability of tree species that are currently planted and this may bring benefit in some areas.
- Increased commercial planting as part of a mitigation strategy.

- Expansion of woodland, including riparian woodland, may be required to offset soil erosion and fluvial flooding, to provide shade for fish and amenity for leisure activities.

Water resources

Threats to water resources in Northern Ireland include the following:

- Lower flows may cause problems for users relating to abstraction, ability to dilute effluent, aquatic ecology and recreation.
- Increased temperatures may cause problems with river and reservoir water quality e.g. Dissolved Oxygen depletion, algal blooms, physiological impact on fish.
- Storms may cause more Combined Sewer Overflows, damaging aquatic life.
- Increased rainfall causing erosion of soil and leaching of agrochemical and agricultural wastes with problems for aquatic life, abstractions and river users.
- Reduction in volume of sewer base flow may result in blockages, leading to environmental health and flooding problems.
- Drier, hotter summers will increase demand for water, affecting ability of abstractors to meet requirements.
- Lower summer runoff leading to reduced flushing of estuaries and lakes with implications for shell fisheries, lake ecology and abstractors.
- Higher evaporation and lower inflows leading to reduction in open water storage e.g. Lough Neagh, which may affect marginal habitats and abstraction.
- Increase in pests and change in life cycle of aquatic and land-based organisms.
- Summer storms, following dry periods, may lead to high pollutant loads, damaging aquatic habitats.

Opportunities are limited but increasingly wet winters could provide an opportunity for increased water storage. Business opportunities may arise from increased demand for water efficient products.

The Built Environment

Coastal and flood risk management

Threats to coastal and flood risk management in Northern Ireland include the following:

- Increase in winter fluvial flooding, with impacts on: settlements; farms and agricultural land; natural heritage; transport infrastructure; the economy; and health.
- Increase in flooding, with impacts on: urban infrastructure: buildings (including built heritage), utilities and transport; businesses; the economy; and health.
- Increase in flooding and erosion at the coast, with impacts on: coastal habitats; coastal settlements; coastal transport infrastructure; and agricultural land.

No opportunities or benefits have been identified in relation to coastal and flood risk management; however, there may be opportunities in related areas e.g. new habitat creation projects.

Buildings, construction and planning

Threats to buildings, construction and planning in Northern Ireland include the following:

- Increase in winter flooding, with impacts on: settlements; buildings and built heritage; transport infrastructure; water infrastructure (supply and drainage); the economy; health and comfort; urban green spaces; and construction.
- Increase in summer temperatures and drought, with impacts on: buildings and settlements; infrastructure; green spaces and soil moisture; construction; urban heat island; and waste management.

- Sea level rise leading to an increase in flooding and erosion at the coast, with impacts on: settlements and buildings; infrastructure (transport, water, communications, waste); and coastal urban green spaces.

Economic Infrastructure

Business

Business is sensitive to generic impacts such as flooding as well as weather-related effects on product demand. Threats to business in Northern Ireland include:

- Wetter winters leading to damage of stock and premises, supply chain problems, loss or reputation and insurance and investment issues.
- Problems of exposure to outdoor workers in hotter summers.
- Decline or shift in demand for certain seasonal goods.

However, there will also be opportunities for businesses which can adapt, for example:

- Boost to sales of summer goods e.g. water retention products, drought tolerant plants.
- Opportunity for business growth in outdoor activities and al-fresco retail.
- Increased demand for cooling products.

Insurance

With regards to insurance, climate change is likely to affect customer needs and the nature of cover, while altering the pattern of claims and risk to which insurers are exposed. Threats to insurance in Northern Ireland include:

- Increase in inland and potentially coastal flooding under wetter winter and rise in sea level, leading to an increase in flood-related property claims and business continuity claims.
- Increase in subsidence claims in hotter, drier summers.

No opportunities or benefits have been identified for the insurance sector overall, although there will be opportunities for new products and a reduction in certain claims (e.g. cold-weather related accidents).

Transport

Transport, and in particular roads, are already vulnerable to extreme weather. Threats to transport in Northern Ireland include:

- Wetter winters and inland flooding, leading to: infrastructure damage; problems for emergency services; delays to users; and road safety issues.
- Wetter winters with increased flooding and scour, leading to destabilisation of bridge / embankment foundations.
- Drier summers with drier soils and vegetation, leading to increased risk of fire and increased risk of subsidence (on clay soils).
- Hotter summers with more extreme temperatures, leading to: increased discomfort / exposure for travellers; economic cost of infrastructure damage e.g. road rutting; and respiratory problems associated with deterioration in air quality.

The main opportunity for the sector will be the likely increase in demand for walking and cycling.

Tourism

Tourism will be affected by and will benefit from climate changes both in Northern Ireland and internationally. Specific risks for Northern Ireland include:

- Wetter winters, which will affect outdoor tourism activities.
- Coastal changes, which may cause flooding and degrade beaches.
- Dry summers, which may cause water shortages and be detrimental to the natural environment.

Opportunities for tourism in Northern Ireland include:

- Drier, hotter summers, which will increase domestic tourism opportunities.
- Warmer winters, allowing more year round tourism.
- More outdoor and water based activities due to hotter weather.

Energy

Threats to the energy sector include:

- Heightened risk of subsidence and heave, leaving structures vulnerable to damage or collapse.
- Greater demand for air conditioning in summer, altered demand profile and operational variations by power suppliers. Health implications for those without access to cool buildings.
- Reduced soil moisture content and heightened risk of subsidence in vulnerable areas.
- Greater levels of damage to power supply infrastructure (e.g. trees coming into contact with power lines).

Benefits under climate change include a reduction in winter heating needs and winter fuel poverty.

Social Wellbeing

Health

Threats to health in Northern Ireland include:

- Coastal and riverine floods. Flooding is known to have serious impacts on physical and mental health.
- Hotter summers with increased “heatwave” events, leading to increase in: hospital admissions; respiratory problems; heat-related mortality and morbidity; and occupational heat stress.
- Hotter summers (and milder winters) leading to increased bacterial growth, and activity of pests (flies, rodents).
- Longer summers leading to increased exposure to UV- and its consequent health effects.

Opportunities for health in Northern Ireland include:

- Reduction in cold weather-related mortality and morbidity.
- Potential improvement in public health related to increased opportunities for physical recreation.

Sport and recreation

Threats to sport and recreation in Northern Ireland include:

- Wetter winters will affect outdoor sport and recreation (adverse conditions for play).
- Dry weather may be detrimental to local habitats and species which are vital for nature based recreation
- Reduced soil moisture will affect pitches and sports grounds.
- Increase in storm intensity and frequency may cause the cancellation of outdoor activities.
- Damage to sporting and recreation facilities, for example through flooding and drought.

Opportunities for sport and recreation in Northern Ireland include:

- Drier, hotter summers will allow increased outdoor sport and recreation.
- Increase in water based recreation and sports.
- Warmer winter weather will allow more year round outdoor sport and recreation.

Cross-sector impacts

A number of potential cross-sector impacts have been identified. These relate to:

- Increasing flood risk, with particular implications for the Built Environment and Economic Infrastructure.
- A significant reduction in summer rainfall (and potential reduction in annual rainfall), with consequences for the Natural Environment.
- Warmer summers (with more extreme hot days), causing a mixture of threats and opportunities in different geographical settings.
- The potential for impacts on Biodiversity to affect Fisheries and, therefore, Tourism and Recreation.

Impacts on public services

The implications of each climate change impact on public services in Northern Ireland have been assessed and the relevant public bodies that may be responsible for developing and implementing adaptation measures identified. Some impacts directly affect public buildings, infrastructure and land; others affect processes, services and plans managed by public bodies. For most impacts, more than one Public Service Area and public body responsible for adaptation was identified, highlighting the need for a cross-sector, multi-agency approach to adaptation. Planning (and therefore the Planning Service) has a role in several sectors. The DOE needs to continue its co-ordinating role, to include leadership on raising awareness, monitoring and managing implementation. Strong links will also be required with the Office of First Minister and Deputy First Minister, the lead office on Sustainable Development.

There are a number of climate-sensitive policy outcomes related to Government's priorities and spending plans. In general, climate change impacts will make it more difficult to meet the outcomes of the Government's priority themes, but constraints can be minimised by building climate change adaptation into the action plans for the delivery of these outcomes. This is recognised in the Sustainable Development Strategy, which itself must consider the impacts of climate change in the delivery of each target. By considering climate change impacts now, policies can be 'future proofed' by planning adaptation. In this respect sustainable development can be a useful tool for promoting wider adaptation to climate change and this study will contribute to the key targets identified for climate change adaptation in the Strategy.

Adaptation to climate change impacts

The current approach to adaptation varies between sectors and between organisations within sectors. Some organisations are moving towards adaptation, at least in certain functions or with regards to particular strategies, but many are delaying, adopting a 'wait and see' approach. This latter approach often involves building adaptive capacity, through research and networking. A particular outcome of the 'wait and see' approach to climate change adaptation is that there is generally a lack of sector-specific risk assessments for Northern Ireland. As a result, awareness, willingness to change and general sense of urgency to consider climate change adaptation within sector-specific planning is lacking.

For some sectors, whilst research is being undertaken to assess the potential impacts of a changing climate, this does not appear to be carried through into policy and strategy development. For example, despite the significant amount of climate change impact research in relation to biodiversity, there does not appear to be any clear co-ordination of strategic planning within and between the various bodies responsible to address climate change risks and planning for adaptation. This also means that the links to other sectors, for example between biodiversity, fisheries, tourism and recreation, are potentially missed.

The short-term pressures (resources, funding etc) on a number of sectors, such as health for example, have meant that there is very little political will to address climate change impacts. In other sectors, such as tourism, the business planning process tends to have a much shorter term focus and a more strategic or political response to climate change adaptation will be required.

It is recommended that climate change adaptation is given a higher priority across all sectors and within each of the public bodies identified as being responsible for adaptation.

Potential adaptation strategies have been identified for each of the impacts identified in the study. These are presented below.

The Natural Environment

Conservation, biodiversity and habitats:

- Review of legislation to assess whether it will provide sufficient protection for priority / designated habitats in a changing climate and to identify whether revisions may be required.
- Review of monitoring to assess whether existing systems are sufficiently sensitive to the effects of a changing climate and identify where new systems may be required.
- Education and awareness: particularly focused on the human impact on species and habitats and the scale of the likely impacts of a changing climate.

Fisheries:

- Further research focussing particularly on:
  - those species more valuable to Northern Ireland for both biodiversity and economic reasons; and,
  - potential advantages of new target species in the marine environment.
- Review of the potential impacts on ports or river structures.

Agriculture:

- More detailed assessment of risks and opportunities geographically specific to Northern Ireland agriculture.
- Education and raising awareness: specific to Northern Ireland context and needs to inform and drive new practices.
- Ongoing review of agricultural reform strategies, e.g. CAP reform, to ensure their flexibility in relation to a changing climate.

Forestry:

- Review of how woodlands may help with adaptation across sectors – for example planting in flood plains can reduce downstream flood flows.
- Further research and identification of a strategy for exploiting potential opportunities provided by climate change (including mitigation) for the Northern Ireland forestry sector.
- Development of the Ecological Site Classification decision support system for aiding species selection under climate change scenarios to Northern Ireland to help in long term planning.
- Development of Best Practice guidelines to ensure that forestry and woodland management in Northern Ireland is resilient to climate change. Gaps in current research should be addressed. Forestry sector should use risk assessments to formulate an adaptation strategy.

Water Resources:

- More detailed modelling of impacts on Northern Ireland water resources, addressing long-term impacts on supplies, environment and water quality.
- Further development of adaptive actions already identified, many of which include wider environmental benefits. Some adaptation may be realised through compliance with the Water Framework and Nitrates Directives.
- Ensure risks and adaptation are adequately represented within long term planning for water resources e.g. in schemes such as reservoirs. Adaptation costs can be minimised by maintaining and improving current infrastructure.
- Changes to the planning processes and regulatory framework for the water sector in Northern Ireland will provide opportunities for the development of adaptive planning.

The Built Environment

Coastal and flood risk management:

- More specific modelling of the impacts on flood risk in Northern Ireland.
- Strategic assessment of flood and erosion risks, and specific risk assessments for individual sites and infrastructure projects.
- Evaluation of options such as upstream source control, flood storage and flood-protection, as well as non-structural methods such as flood warning and insurance.
- Specific focus on options for managing coastal change, including construction of sea defences and managed realignment.
- Cross-sector implications: overlaps with biodiversity provide both opportunities and threats that will need further specific risk assessment and adaptive planning.

Buildings, construction and planning:

- Strategic actions: research, raising awareness, consideration of longer-term plans and seeking changes to planning policy.
- Location and urban design actions: adaptation of infrastructure at risk, reduction of flood risk, use of green spaces and sustainable urban drainage systems.
- Building design: Reducing heat gain within buildings, use of green roofs, opportunities for energy and water-efficient new-build houses.

- Historic buildings: Improved management and maintenance of current buildings, development of strategies to adapt to changing climatic conditions.
- Waste management: assess potential impacts, sites at risk and options for effective planning.
- Review regulatory framework and incentives provided for adaptive planning within Northern Ireland.

Economic Infrastructure

Business:

- Increase awareness of climate change threats and opportunities.
- Address the lack of priority given to climate change due to short term business and economic pressures.
- Develop specific tools, guidance and climate data for risk assessments that match business needs, which vary across the sector.
- Embed climate change adaptation into existing risk management and decision support strategies.

Insurance:

- Although the insurance industry is one of the most proactive sectors for climate change research, little research has examined Northern Ireland specifically. Insurers are expert at dealing with risk and insurance could be a valuable tool in managing future weather-related risk.
- As insurers rely on sharing the burden of risk, insurance should be employed alongside other adaptation measures.

Transport:

- Review of current standards for infrastructure such as drainage, earthworks, roads, railways, bridges, sea defences and tunnels and implications of a changing climate.
- New highway infrastructure should include additional capacity to account for climate change, including paying particular attention to storm drainage, culvert sizing and flow attenuation.
- Existing highway infrastructure should be assessed to determine if alterations are necessary.
- Emergency planning should take account changing climatic extremes.
- Although there are limited railways in Northern Ireland, links should be made with research programmes elsewhere in the UK with regards to adaptation measures such as coastal defences, flood risk and embankment stability.

Tourism:

- Detailed sector-specific research into the impact of a changing climate on tourism in Northern Ireland. This should examine the opportunities for increased tourism that may be provided and the strategies and policies required to develop opportunities and adapt to impacts.
- Education: for tourists and operators of their impacts on climate to ensure there are few barriers to the implementation of new adaptation measures and new opportunities are maximised.

Energy:

- Improve the resilience of the electricity transmission network to weather.
- Undertake a risk assessment of power stations in areas that may be vulnerable to flooding.
- Ensure that the growing gas infrastructure is climate-proofed.

- Consider adaptation in the planning of new energy infrastructure, particularly renewables infrastructure, with which there is little experience of weather impacts.
- Undertake research into demand and consumption of energy with respect to climate change and socio-economic scenarios.

Social Wellbeing

Health:

- Sector specific policy review looking at the impacts of a changing climate on health and wellbeing in Northern Ireland and their relation to competing considerations in the Northern Ireland health sector.
- Consideration given to Northern Ireland being included within the UK Heat wave Plan.
- Infectious disease surveillance should be strengthened.
- Registries of extreme events and their impact on the public health should be set up for monitoring purposes.

Sport and recreation:

- Sport and recreation tend to be reactive and strongly dominated by social factors, which make it difficult to effectively plan for climate change. Although generic impacts can be identified, there is a need for further basic research incorporating climate change and socio-economic scenarios, from which future policies can be developed.
- There are significant opportunities for this and related sectors such as health; these will need to be realised through a coordinated approach involving education, transport, health and sector-specific agencies.

It is recommended that the sector-specific adaptation strategies are now taken forward and the risk-based assessment of impacts has provided an indicative prioritisation of the timetable for adaptation. Immediate priority should be given to the most significant impacts; for major threats and opportunity adaptive actions should be undertaken, or at least planned, in the short-term. Given the lag in the climate system, we are already committed to changes projected to about the year 2040 and therefore adaptive actions to initial impacts can be planned and executed with some certainty. Adaptive actions may require detailed sector-specific risk assessments, option appraisal and selection, and development of associated indicators and targets to benchmark progress.

For many adaptation cases there are opportunities for no or low-regret solutions, particularly in relation to improving the ability to cope with current weather-related impacts. There are also win-win opportunities to adapt to several impacts with one action. It will be necessary to re-evaluate impacts where the risk has been classified as unknown, especially where this may lead to a major threat. This will involve review of ongoing research and development of a better understanding of the sensitivity of receptors.

A number of general themes for climate change adaptation are apparent from across the sector- and impact-specific adaptation strategies. These can be grouped under the two main elements of the UK's Adaptation Policy Framework:

Building adaptive capacity:

- Raising awareness.
- Increase training and knowledge.
- Contribute to the development and use of climate change scenarios for Northern Ireland, to include comparison of EPA and UKCIP output.
- Development of socio-economic scenarios for Northern Ireland for use alongside climate change scenarios in detailed impact assessments.
- Review of legislation, regulations, policies and procedures with respect to protection from climate change and provision of incentives for adaptation.
- Contingency / emergency planning.
- Improve monitoring and records of extreme weather events.
- Incorporate climate change into existing models.
- Include climate impacts and adaptation in strategies and plans, with scheme specific risk assessments.
- Consideration of cross-sector implications of responses: threats and opportunities.

Delivering adaptive actions:

- Increase resilience e.g. diversification; buffer zones.
- Accept losses where feasible e.g. coastal realignment.
- Avoid losses e.g. by altering building materials.
- Embrace change e.g. new species and maximising opportunities provided.
- Exploiting opportunities provided by mitigation (e.g. woodland / forestry management).
- Planning for risks and opportunities in new infrastructure projects (water, sewerage, flood risk, transport, construction etc).
- Changes to management and maintenance practices to accommodate changes in climate.
- In building design / construction: managing heat gain; energy, water and environmental efficiencies.
- Enhanced health surveillance and heat-wave response.

Constraints to adaptation include uncertainty about future climate conditions and a lack of funding and human resources. The future is inherently uncertain and decision-making will need to incorporate uncertainty in climate change and socio-economic scenarios, drawing on appropriate techniques and new research. Flexibility and the implementation of no- and low-regret solutions will help avoid unnecessary adaptation. This will be particularly the case in terms of those sectors responsible for the management and development of infrastructure with typically long asset lives and high levels of investment; but it is equally appropriate for the environment / biodiversity sectors. A rise in the profile of climate change adaptation will need to be accompanied by appropriate resources to undertake detailed impact assessments and implement adaptation. In the short-term this may require funding for capacity building, while in the medium to long term funding may be required to deliver adaptive actions.

Next steps: a partnership of stakeholders

This study identifies the main issues that public services in Northern Ireland will need to consider in terms of the impacts and needs for adaptation to a changing climate. Option appraisal and selection, and development of associated indicators and targets should now be undertaken. This is likely to require more detailed quantitative assessment of impacts at the sector and scheme level, which may be guided by the risk assessments completed in this study. However, as the impacts and responses taken for one sector or organisation could significantly affect others, it is recommended that a Northern Ireland climate change partnership is established to facilitate and coordinate stakeholder engagement and consideration of issues within and between sectors. This should provide the foundation for ensuring that Northern Ireland is adequately prepared for the impacts of climate change.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

GLOSSARY OF TERMS

1	**INTRODUCTION**	**1**
1.1	**Background**	**1**
1.2	**Study Aims and Objectives**	**2**
1.3	**Report Structure**	**3**
2	**METHODOLOGY**	**5**
2.1	**Approach**	**5**
2.2	**Preliminary Identification of Impacts and Adaptation**	**5**
2.3	**Consultation with Key Stakeholders**	**6**
2.4	**Risk Assessment**	**6**
2.5	**Adaptation Strategies**	**7**
2.6	**How the Risk Assessments have been used**	**7**
3	**CLIMATE CHANGE**	**9**
3.1	**Recent Climate**	**9**
3.2	**Recent Weather Related Events**	**13**
3.3	**Climate Change Scenarios**	**15**
3.4	**Climate Change Uncertainties**	**17**
3.5	**Rapid Climate Change resulting from feedbacks on the North Atlantic Drift**	**19**
4	**CONSERVATION, BIODIVERSITY AND HABITATS**	**21**
4.1	**Scope**	**21**
4.2	**Background**	**21**
4.3	**The Issue Now**	**21**
4.4	**How Climate Change May Affect The Future**	**22**
4.4.1	Woodlands	23
4.4.2	Wetlands	23
4.4.3	Marine and Coastal Habitats	25
4.4.4	Heathlands	26
4.4.5	Grasslands	27
4.4.6	Limestone pavements	27
4.4.7	Lakes	27
4.4.8	Birds	28
4.4.9	New / invader species	28
4.4.10	Conclusions	29
4.5	**Actions Undertaken or Underway and Key Gaps**	**31**
4.6	**Adaptation Strategies**	**31**
4.7	**Conclusions and Recommendations**	**32**
5	**FISHERIES**	**39**

5.1 Scope **39**
5.2 Background **39**
5.3 The Issue Now **39**
5.4 How Climate Change May Affect the Future **40**
5.4.1 Freshwater fisheries 40
5.4.2 Marine Fisheries 41
5.4.3 Conclusions 42
5.5 Actions Undertaken or Underway and Key Gaps **44**
5.6 Adaptation Strategies **45**
5.7 Conclusions and Recommendations **45**

6 AGRICULTURE **51**
6.1 Scope **51**
6.2 Background **51**
6.3 The Issue Now **52**
6.4 How Climate Change May Affect The Future **53**
6.4.1 Crops 55
6.4.2 Intensive Grass Production 55
6.4.3 Livestock 56
6.4.4 Farm Management 57
6.4.5 Overview 57
6.5 Actions Undertaken or Underway and Key Gaps **59**
6.6 Adaptation Strategies **60**
6.7 Conclusions and Recommendations **60**

7 FORESTRY **67**
7.1 Scope **67**
7.2 Background **67**
7.3 The Issue Now **67**
7.4 How Climate Change May Affect the Future **68**
7.4.1 Impacts on woodland ecosystems 68
7.4.2 Impacts on commercial production forestry 69
7.4.3 Analysis of current knowledge of likely climate change impacts 70
7.4.4 Summary 70
7.5 Actions Undertaken or Underway and Key Gaps **73**
7.6 Adaptation Strategies **73**
7.6.1 Constraints to adaptation 74

8 WATER RESOURCES **81**
8.1 Scope **81**
8.2 Background **81**
8.3 The Issue Now **82**
8.4 How Climate Change May Affect the Future **82**
8.5 Actions Undertaken or Underway and Key Gaps **86**
8.6 Adaptation Strategies **86**
8.7 Conclusions and Recommendations **87**

9 COASTAL & FLOOD RISK MANAGEMENT **91**

9.1 Scope **91**
9.2 Background **91**
9.3 The Issue Now **93**
9.4 How Climate Change May Affect the Future **94**
9.5 Actions Undertaken or Underway and Key Gaps **98**
9.6 Adaptation Strategies **99**
9.7 Conclusions and Recommendations **100**

10 BUILDINGS, CONSTRUCTION AND PLANNING **105**
10.1 Scope **105**
10.2 Background **105**
10.3 The Issue Now **105**
10.4 How Climate Change May Affect the Future **106**
10.4.1 Buildings 106
10.4.2 Urban infrastructure 106
10.4.3 External and internal human comfort 107
10.4.4 Historic buildings 108
10.4.5 Green spaces 108
10.4.6 Planning 108
10.4.7 Waste 110
10.4.8 Summary 110
10.5 Actions Undertaken or Underway and Key Gaps **112**
10.5.1 Building construction and property management 112
10.5.2 Development strategy and planning policy in Northern Ireland 113
10.6 Adaptation Strategies **114**
10.7 Conclusions and Recommendations **116**

11 BUSINESS **121**
11.1 Scope **121**
11.2 Background **121**
11.3 The Issue Now **121**
11.4 How Climate Change May Affect the Future **122**
11.5 Actions Undertaken or Underway and Key Gaps **126**
11.6 Adaptation Strategies **126**
11.7 Conclusions and Recommendations **127**

12 INSURANCE **131**
12.1 Scope **131**
12.2 Background **131**
12.3 The Issue Now **131**
12.4 How Climate Change May Affect the Future **132**
12.5 Actions Undertaken or Underway and Key Gaps **135**
12.6 Adaptation Strategies **135**
12.7 Conclusions and Recommendations **136**

13 TRANSPORT **139**
13.1 Scope **139**

13.2 Background **139**
13.2.1 Northern Ireland Transport System 139
13.2.2 Northern Ireland Transport Policy Context 142
13.3 The Issue Now **143**
13.4 How Climate Change May Affect the Future **144**
13.4.1 General Impacts 144
13.4.2 Impacts on Roads 145
13.4.3 Impacts on Railways 145
13.4.4 Impacts on Aviation 145
13.4.5 Impacts on Shipping and Ports 145
13.4.6 Summary 145
13.5 Actions Undertaken or Underway and Key Gaps **147**
13.6 Adaptation Strategies **148**
13.7 Conclusions and Recommendations **148**

14 ENERGY **153**
14.1 Scope **153**
14.2 Background **153**
14.3 The Issue Now **153**
14.4 How Climate Change May Affect the Future **155**
14.5 Actions Undertaken or Underway and Key Gaps **157**
14.6 Adaptation Strategies **157**
14.7 Conclusion and Recommendations **158**

15 TOURISM, SPORT AND RECREATION **163**
15.1 Scope **163**
15.2 Background **163**
15.2.1 Tourism 163
15.2.2 Sport and recreation 164
15.2.3 The natural environment and climate sensitivity 165
15.3 The Issue Now **165**
15.4 How Climate Change May Affect the Future **166**
15.5 Actions Undertaken or Underway and Key Gaps **171**
15.6 Adaptation Strategies **171**
15.7 Conclusions and Recommendations **172**

16 HEALTH **179**
16.1 Scope **179**
16.2 Background **179**
16.3 The Issue Now **181**
16.4 How Climate Change May Affect the Future **182**
16.4.1 Heatwave planning 183
16.4.2 Emergency preparedness 184
16.4.3 Health Services 184
16.4.4 Social Services 185
16.4.5 Food safety 185
16.4.6 Occupational Health 186
16.4.7 Communicable Disease Surveillance 186

16.4.8 Health Promotion 186
16.4.9 Town planning 187
16.4.10 Summary 187
16.5 Actions Undertaken or Underway and Key Gaps 189
16.6 Adaptation Strategies 189
16.6.1 Infectious disease surveillance 189
16.6.2 Built environment 190
16.6.3 Emergency Planning 190
16.7 Conclusions and Recommendations 190

17 CONCLUSIONS AND RECOMMENDATIONS 195
17.1 Scope 195
17.2 Methodology 195
17.3 Climate Change 195
17.4 Climate Change Risks 196
17.5 Cross-Sectoral Analysis 201
17.6 Impact on Public Services and Priority Themes 202
17.7 Sustainable Development 204
17.8 Adaptation 205

18 REFERENCES 207

19 APPENDICES 219

Appendix A Detailed Methodology 219

Appendix B Climate Change Scenario Maps 231

Appendix C Workshop Report 237

List of Tables

Table 2.1 - Summary of Impact due to Climate Change 8
Table 2.2 - Identification of Adaptation Responses 8
Table 3.1 - Severe Weather-Related Events in Northern Ireland, 1996 to 2006 14
Table 3.2 - UKCIP02 Climate Change Scenarios for Northern Ireland 15
Table 3.3 - Key Climate Change Uncertainties 18
Table 4.1 - Summary of responses from consultation 21
Table 4.2 - Species lost from or gained by Ireland based on the MONARCH 1 model (Harrison et al. 2001) 22
Table 4.3 - Climate Change Impacts: Conservation, Biodiversity and Habitats 30
Table 4.4 - Impacts and Adaptation Summary: Conservation, Biodiversity and Habitats 34
Table 5.1 - Climate Change Impacts: Fisheries 43
Table 5.2 - Impacts and Adaptation Summary: Fisheries 47
Table 6.1 - Crop Areas and Livestock Numbers, 1854-2004 51
Table 6.2 - UK Agriculture and Climate Change 53
Table 6.3 - Climate Change Impacts: Agriculture 57
Table 6.4 - Impacts and Adaptation Summary: Agriculture 62
Table 7.1 - Climate Change Impacts: Forestry 71
Table 7.2 - Summary of Potential Adaptation Strategies 75
Table 7.3 - Impacts and Adaptation Summary: Forestry 77
Table 8.1 - Key Responsibilities for Organisations in the Water Resources Sector 81
Table 8.2 - Percentage change in Q95 by the 2020s, compared to 1961-1990 82
Table 8.3 - Climate Change Impacts: Water Resources 84
Table 8.4 - Impacts and Adaptation Summary: Water Resources 89
Table 9.1 - Key Responsibilities for Organisations Managing the Coast 93
Table 9.2 - Percentage change in mean monthly runoff by the 2020s, compared to 1961-1990 94
Table 9.3 - Climate Change Impacts: Coastal and Flood Risk Management 97
Table 9.4 - Impacts and Adaptation Summary: Coastal & Flood Risk Management 102
Table 10.1 - Climate Change Impacts: Buildings, Construction and Planning 110
Table 10.2 - Impacts and Adaptation Summary: Buildings, Construction and Planning 118
Table 11.1 - Impacts of Climate Change on Industry Sectors 123
Table 11.2 - Climate Change Impacts: Business 124
Table 11.3 - Impacts and Adaptation Summary: Business 129
Table 12.1 - Recent extreme weather events in the UK 132
Table 12.2 - Climate Change Impacts: Insurance 134
Table 12.3 - Impacts and Adaptation Summary: Insurance 137
Table 13.1 - Climate Change Impacts :Transport 146
Table 13.2 - Impacts and Adaptation Summary: Transport 150
Table 14.1 - Climate Change Impacts: Energy 156
Table 14.2 - Impacts and Adaptation Summary: Energy 160
Table 15.1 - Climate Change Impacts: Tourism 168
Table 15.2 - Climate Change Impacts: Sport & Recreation 169
Table 15.3 - Impacts and Adaptation Summary: Tourism 174
Table 15.4 - Impacts and Adaptation Summary: Sport & Recreation 177
Table 16.1 - Annual totals (CDSC (NI) website) for laboratory confirmed reports of select climate-sensitive notifiable diseases in Northern Ireland (passive surveillance) 181
Table 16.2 - Summary of known effects of weather and climate on human health 182
Table 16.3 - Climate Change Impacts: Health 187
Table 16.4 - Impacts and Adaptation Summary: Health 192
Table 17.1 - Climate Change Threats in Northern Ireland 197
Table 17.2 - Climate Change Opportunities and Benefits for Northern Ireland 200

Table 17.3 - Impacts of Climate Change on Climate-Sensitive Outcomes related to Government Priority Themes 203
Table 19.1 - Template Climate Change Impact Tables 223
Table 19.2 - Template Impacts and Adaptation Tables 223
Table 19.3 - Current Weather-Related Effects: Natural Environment ii
Table 19.4 - Current Weather-Related Effects: Built Environment iii
Table 19.5 - Current Weather-Related Effects: Socio-Economics iii
Table 19.6 - Climate Change Impacts: Natural Environment iv
Table 19.7 - Climate Change Impacts: Built Environment v
Table 19.8 - Climate Change Impacts: Socio-Economics vi
Table 19.9 - Non-Climate Risks: Natural Environment vii
Table 19.10 - Non-Climate Risks: Built Environment vii
Table 19.11 - Non-Climate Risks: Socio-Economics vii
Table 19.12 - Actions under Defra's Adaptation Policy Framework xv
Table 19.13 - Adaptation Actions: Natural Environment xv
Table 19.14 - Adaptation Actions: Built Environment xvi
Table 19.15 - Adaptation Actions: Socio-Economics xvi
Table 19.16 - Constraints to Adaptation: Natural Environment xvii
Table 19.17 - Constraints to Adaptation: Built Environment xvii
Table 19.18 - Constraints to Adaptation: Socio-Economics xviii

List of Figures

Figure 1.1 - Relationship between General Themes and Government Priority Themes 3
Figure 2.1 - Task Flow Chart 5
Figure 2.2 - Framework for Classifying Risks and Adaptive Responses 8
Figure 3.1 - Mean Annual Temperature (Armagh Observatory) 9
Figure 3.2 - Number of Hot Days (Armagh Observatory) 10
Figure 3.3 - Number of Cold Days (Armagh Observatory) 11
Figure 3.4 - Annual Rainfall (Armagh Observatory) 11
Figure 3.5 - Winter Rainfall (Armagh Observatory) 12
Figure 3.6 - Summer Rainfall (Armagh Observatory) 12
Figure 3.7 - Annual Mean Tidal Level (Belfast Harbour), 1918-2001 13
Figure 4.1 - Risk Assessment: Conservation, Biodiversity and Habitats 31
Figure 5.1 - Risk Assessment: Fisheries 44
Figure 6.1 - Risk Assessment: Agriculture 58
Figure 7.1 - Risk Assessment: Forestry 72
Figure 8.1 - Risk Assessment: Water Resources 86
Figure 9.1 – Fluvial and Sea Defences 92
Figure 9.2 - Risk Assessment: Coastal and Flood Risk Management 98
Figure 10.1 - Risk Assessment: Buildings, construction and planning 112
Figure 11.1 - Risk Assessment: Business 125
Figure 12.1 - Risk Assessment: Insurance 135
Figure 13.1 - Regional Strategic Transport Network, Northern Ireland 139
Figure 13.2 - Vehicle Kilometres of Travel (VKT) for Class 1 Vehicles (car, taxis and vans) 1993-2003 140
Figure 13.3 - Index of vehicles licensed in NI and GB 1992-2004 140
Figure 13.4 - Method of Travel to Work, Northern Ireland 2004 141
Figure 13.5 - Risk Assessment: Transport 147
Figure 14.1 - Risk Assessment: Energy 157
Figure 15.1 - Risk Assessment: Tourism 170
Figure 15.2 - Risk Assessment: Sport & Recreation 170
Figure 16.1 - Risk Assessment: Health 188
Figure 19.1 - Task Flow Chart 221
Figure 19.2 - The relationship between significant climate and non-climate risk factors and the definition of climate adaptation and climate-influenced decision types 225
Figure 19.3 - Risk Matrix incorporating Stakeholder or Expert Perception on Likelihood (and Impact) 227
Figure 19.4 - Risk Category 227
Figure 19.5 - Potential Adaptive Responses to Risk Categorisation 230
Figure 19.6 - Annual Average Daily Temperature Climate Change Scenarios 233
Figure 19.7 - Summer Precipitation Climate Change Scenarios 234
Figure 19.8 - Winter Precipitation Climate Change Scenarios 235
Figure 19.9 - Risk Matrix: Natural Environment ix
Figure 19.10 - Risk Matrix: Built Environment xi
Figure 19.11 - Risk Matrix: Socio-Economics xii
Figure 19.12 - Sliding Scale Matrix: Natural Environment xiv
Figure 19.13 - Sliding Scale Matrix: Socio-Economics xiv

GLOSSARY OF TERMS

Term	***Meaning / Definition***
ABI	Association of British Insurers
Adaptation	The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits, associated with climate variability and climate change
AMP4	Asset Management Plan 4, the business plan produced by English and Welsh water companies for 2005 to 2010.
APF	Adaptation Policy Framework
ASSI	Area of Special Scientific Interest
BACLIAT	Business Areas Climate Impacts Assessment Tool
BESEECH	Building Economic and Social Information for Examining the Effects of Climate Change
BMTP	Belfast Metropolitan Transport Plan
Building Adaptive Capacity	Covers activities such as research, data collection, change to regulations and awareness raising
CCDeW	Climate Change and Demand for Water
CCFB	Changing Climate For Business
CDSC	Communicable Disease Surveillance Centre
DARD	Department of Agriculture and Rural Development
DCAL	Department of Culture Arts and Leisure
Delivering Adaptation Actions	Involves activities that accept impacts, share impacts, avoid negative impacts or exploit opportunities
DEFRA (Defra)	UK Department for Environment, Food and Rural Affairs
DETI	Department of Enterprise Trade and Investment
DfT	UK Department for Transport
DHSSPS	Department of Health, Social Services and Public Safety
DOE	Department of the Environment
DRD	Department for Regional Development
EA	Environment Agency (England and Wales)
EHP	Environmental Health Professional
EHS	Environment and Heritage Service
EPA	Environmental Protection Agency (Republic of Ireland)
ETS	Emissions Trading Scheme
FCB	Fisheries Conservancy Board

Term	***Meaning / Definition***
GCM	General Circulation Model
HHWS	Heat Health Warning System
HPA	Health Protection Agency
ICZM	Integrated Coastal Zone Management
ITS	Intelligent Transport Systems
MONARCH	Model developed to model impacts of bioclimatic change on a number of critical species, habitats and geomorphological features
NAOI	North Atlantic Oscillation Index
NIAER	Northern Ireland Authority for Energy Regulation
NITB	Northern Ireland Tourist Board
NIR	Northern Ireland Railways
NVC	National Vegetation Classification
NERC	Natural Environment Research Council
ODPM	UK Office of the Deputy Prime Minister
PET	Potential Evapotranspiration
PPS	Planning Policy Statement
RCM	Regional Climate Model
RDS	Regional Development Strategy
Receptor	The entity that may be harmed by a particular set of hazardous events
RTO	Regional Tourism Organisation
RTS	Regional Transportation Strategy
SME	Small Medium Enterprise
SNIFFER	Scottish and Northern Ireland Forum For Environmental Research
SPECIES	Model to simulate change in potential climate space of species at $5km^2$ resolution
SRTP	Sub Regional Transport Plan
SUDS	Sustainable Drainage Systems
THC	Thermohaline Circulation
UKCIP	UK Climate Impacts Programme
UKCIP98	The climate change scenarios published by UKCIP in 1998 (Hulme and Jenkins, 1998)
UKCIP02	The climate change scenarios published by UKCIP in 2002 (Hulme *et al*., 2002)
UKWIR	UK Water Industry Research

1 INTRODUCTION

1.1 Background

The climate of Northern Ireland is already changing. Air temperature is rising and the number of hot days is increasing; the proportion of rainfall falling in summer is decreasing, while winters are slightly wetter (EHS, 2004). These changes are expected to accelerate over the coming century. Average temperature may rise by 3°C (or more in Co. Fermanagh); summer rainfall may fall by up to 50% while winters may be 25% wetter (Hulme et al., 2002). Furthermore, relative sea level may begin to rise and there is likely to be less cloud, a fall in relative humidity, a reduction in soil moisture content and potentially higher winter wind speeds (Hulme et al., 2002).

Current climate change is not without precedence. The climate of the last 2.5 million years has been alternating between cold (glacial) periods and warm (interglacial) periods. For the past 10,000 years we have been in an interglacial period, although there have been smaller variations of climate within this time, including cooler periods such as the 'Little Ice Age' in Europe. These changes in climate are a natural part of the climate system, caused by internal variability and response to external factors such as solar radiation and volcanoes (IPCC, 2001).

Current climate change is a response to recent global warming. Climate modellers are increasingly confident that this warming is not purely a consequence of natural causes. The most recent report of the Intergovernmental Panel on Climate Change (IPCC) concluded that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (IPCC, 2001: 10). Climate modellers cannot simulate recent trends based on natural factors alone. Only when the effects of anthropogenic activity are included do the models agree with observations. Anthropogenic activity includes emissions from burning fossil fuels (e.g. in power stations and cars) and land use change, both of which release greenhouse gases into the Earth's atmosphere.

Greenhouse gases, such as water vapour, carbon dioxide and methane, occur naturally in the Earth's atmosphere. Greenhouse gases allow incoming short-wave solar radiation to reach the Earth, but they absorb most of the long-wave radiation emitted by the Earth in response, some of which is then re-emitted back towards the Earth's surface. This process, termed the greenhouse effect, keeps the Earth's average temperature some 33°C above what it otherwise would be. However, by increasing the concentration of greenhouse gases, more heat is being retained within the Earth's atmosphere and this is causing the climate to change.

There are two basic responses to climate change. Firstly, we can aim to stabilise or reduce the concentration of greenhouse gases in our atmosphere. This is termed mitigation and involves limiting future climate change by reducing emissions and managing land use change. However, as we share one atmosphere, mitigation requires global action to be truly effective, hence the attempts to reach global agreement through the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Secondly, we can deal with the impacts of climate change by preparing for them. This is termed adaptation and involves identifying potential impacts and devising strategies for reducing risks and realising opportunities. Some adaptation will be required regardless of the success of mitigation because lags in the climate system mean that some climate change is unavoidable. For this reason, very different emissions scenarios result in a similar magnitude of warming over the next 40 years (Met Office, 2003).

This report is concerned with adaptation to climate change. It is essential that the community and key stakeholders within it have a clear understanding of potential impacts and strategies for adaptation. Public bodies, with their policy-making, service provision and advisory roles, need to be at the forefront in risk management and can lead the way in delivering sustainable development.

The implications of climate change for Northern Ireland were established in the scoping study published by SNIFFER in 2002. The study involved a literature review and consultation and identified impacts in sectors under three themes: Physical Environment; Living Environment; and Infrastructure and Socio-Economic Development. Sectoral impacts and vulnerabilities were described, along with potential adaptation strategies.

Further advice, specifically for public bodies, was set out in Guidance for Public Bodies on Climate Change Impacts in Northern Ireland (EHS, 2005a). This provides a starting point for considering vulnerability to climate change and establishes four broad responses: be informed; build climate change into corporate plans; coordinate adaptation; and lead by example. Specific measures for adapting to climate impacts are also provided for different services, with public bodies identified.

1.2 Study Aims and Objectives

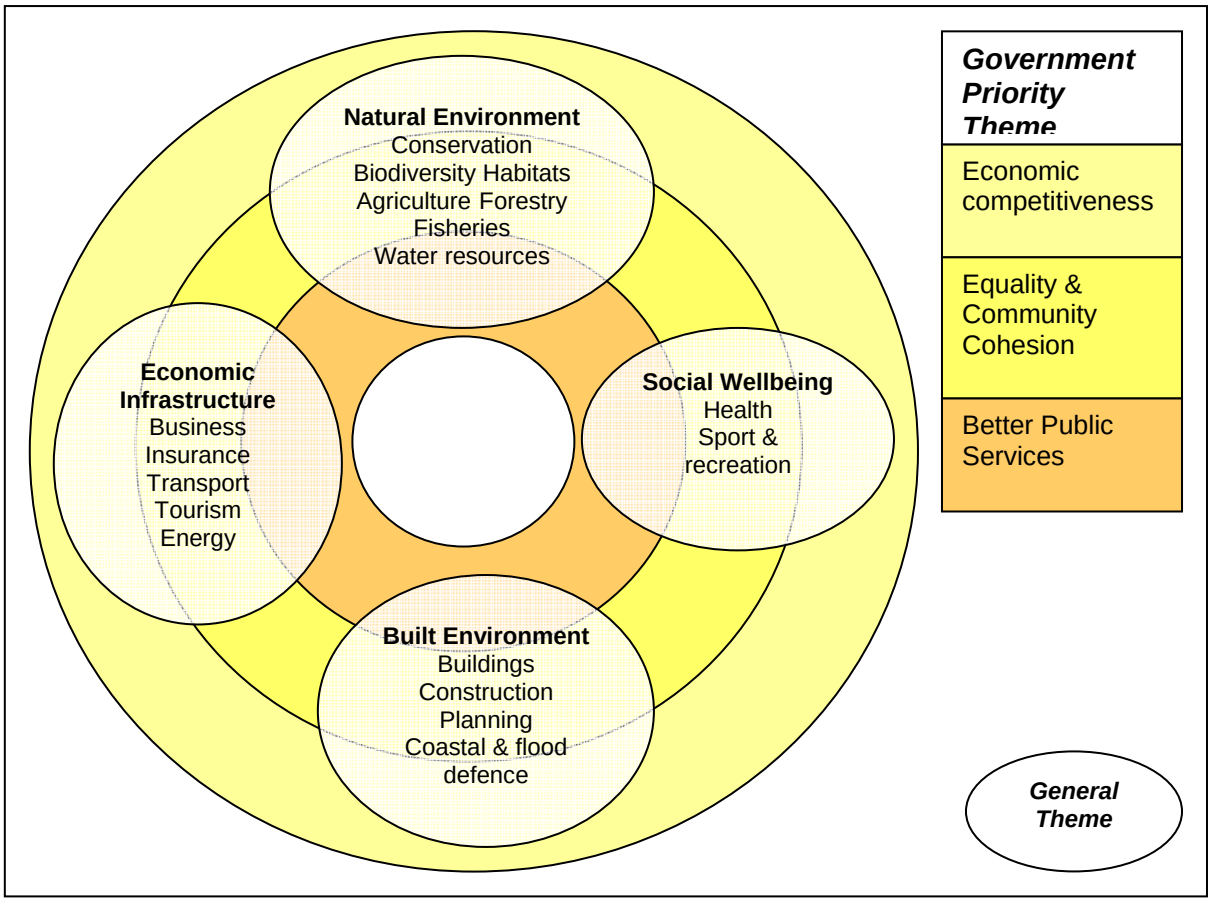
This study updates the scoping study, using the more recent UKCIP02 scenarios and drawing on the wealth of recently published research into climate change impacts. It examines the impacts across sectors and on the outcomes in relation to Government priority themes (Figure 1.1). The work builds on the Guidance for Public Bodies (EHS, 2005a) by identifying key risks and setting out an adaptation strategy for each impact, linked to public bodies. This study deals specifically with the potential impacts of a changing climate on Northern Ireland and does not aim to deal with the anticipated global impacts, though of course it is acknowledged that for many cases, the global situation will impact directly on Northern Ireland.

There are five main objectives of this study:

1. To provide an analysis, based on the themes of Economic Infrastructure, Built Environment, Natural Environment and Social Wellbeing, of climate change impacts upon Northern Ireland in the form of a sliding scale analysis, using the UKCIP02 scenarios and recent research in the field relevant to Northern Ireland.
2. To provide an analysis of the effect on public services, specifically on the key outcomes related to the Government's three priority themes of Economic Competitiveness, Equality and Community Cohesion and Better Public Services.
3. To produce a risk analysis of identified impacts with estimated likelihood of risk and resource implications.
4. To produce an adaptation strategy for each impact, identifying the public sector bodies responsible for delivery.
5. To produce a technical report of climate impacts for use by policy experts.

In addition, a non-technical summary report has been produced.

Figure 1.1 - Relationship between General Themes and Government Priority Themes



1.3 Report Structure

The report is structured in the following way:

- Section 2, Methodology, outlines the approach to the research.
- Section 3, Climate Change, examines recent climate change and weather-related events, presents scenarios for the coming century and discusses the key uncertainties in climate change impact assessment, including the issue of potential climate change shocks. Supporting maps are provided in Appendix A.
- Sections 4-16 provide impact and adaptation assessments for each sub-sector (or group of sub-sectors):
    - Conservation / Biodiversity / Habitats
    - Fisheries
    - Agriculture
    - Forestry
    - Water resources
    - Coastal & flood defence
    - Buildings / Construction / Planning
    - Business
    - Insurance
    - Transport
    - Energy
    - Tourism / Sport & recreation
    - Health

Each section follows the same format:

- Scope, which defines what the section covers.
- Background, which sets the context for the impact assessment.
- The issue now, which examines current weather-related impacts.
- How climate change may affect the future, which assess the threats and opportunities of climate change.
- The Climate Change Impacts table identifies impacts by climate variable.
- Actions already undertaken or underway and key gaps, which considers how current weather-related impacts are managed, how climate change is being planned for and identifies key gaps.
- Adaptation strategies, which sets out actions for adaptation and identifies responsible public bodies.
- The Impacts to Adaptation table provides the main summary. The matrix links impacts to public service area and identifies the effect on public services, risks and resource implications, adaptation strategies and responsible public sector bodies.

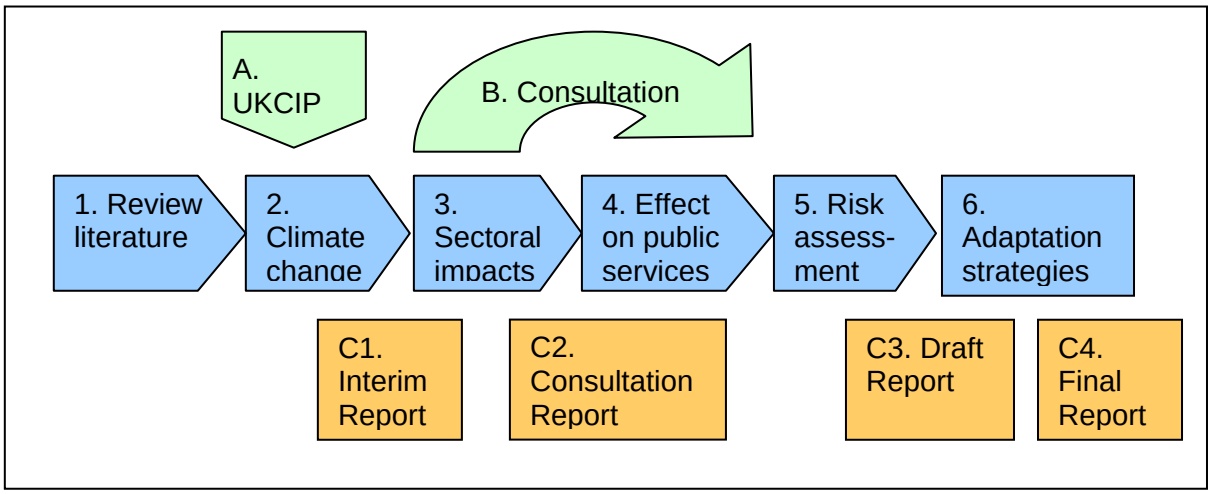
- Section 17, Integration across Sectors, provides a cross-sectoral analysis across the four sector-based themes of Economic Infrastructure, Built Environment, Natural Environment and Social Wellbeing. In addition, the section draws together the effect on public services, specifically on the key outcomes related to the Government's three priority themes of Economic Competitiveness, Equality and Community Cohesion and Better Public Services; findings in the context of Sustainable Development are also considered.
- Section 18, Conclusions and Recommendations, summarises the study findings and makes recommendations for building adaptive capacity (e.g. data collection, further research) and in delivering adaptive actions.
- Section 19, References, provides the full bibliographic details of references made in the report.
- Section 20, Appendices.

2 METHODOLOGY

2.1 Approach

Figure 2.1 sets out the approach used for this study; a detailed description of the methodology used and consideration of other approaches is given in Appendix A.

Figure 2.1 - Task Flow Chart



The study has drawn on a review of current climate change research, particularly focussing on the potential impacts on Northern Ireland (e.g. SNIFFER, 2002; EHS, 2004; EHS, 2005) and on specific sectors to identify current weather-related issues, the impacts of climate change and current or proposed responses.

Climate change scenarios for Northern Ireland have been taken from UKCIP02 (Hulme et al., 2002). An overview of the main changes in climate has been set against a review of recent climate and weather-related events to provide a context of potential change.

Ideally, the impacts of future scenarios of climate change should be considered in the context of a contemporary socio-economic setting; for example, using storylines under four different futures based on possible changes in social values and governance systems (OST, 1999, 2002) as impacts will be conditioned by socio-economic factors (which define the sensitivity of the receptor) and the same socio-economic factors will influence the approach to and success of adaptation (defining the adaptive capacity of the system).

However, whilst socio-economic scenarios have proved to be a useful tool in climate change impact assessment, there are currently no scenarios specific to Northern Ireland. The study has considered potential socio-economic development when assessing sensitivity and evaluating adaptive capacity but an early recommendation of this work is that the government of Northern Ireland build on the work being undertaken as part of BESEECH study and develop socio-economic scenarios specific to Northern Ireland.

2.2 Preliminary Identification of Impacts and Adaptation

The review of literature and climate change scenarios has been used to provide an initial view of impacts for each sub-sector. These have been described in terms of the:

- Source of impact (the change in a climate variable such as rainfall).

- Receptors that may be affected (such as buildings, people, economy).
- Pathways (the link between sources and receptors e.g. rivers).

Where possible, the potential impacts have been quantified, although in general there is very limited quantitative information available.

The impacts have been summarised in relation to the main changes in climate for each sub-sector. For each impact the relevant Public Service Area has been identified, along with a description of the effect on public service provision, to identify how climate change may affect the delivery of the Government's key priorities for the future, including in relation to vulnerable areas of:

- Infrastructure
- Energy provision
- Agri-food industry
- Housing
- Health
- Water resources

2.3 Consultation with Key Stakeholders

A consultation exercise with key stakeholders has been an essential element of the assessment of impacts and adaptation responses. Consultation has been undertaken through a telephone questionnaire survey and a workshop with key stakeholders.

The aim of the telephone survey was to improve understanding of impacts, their effect on public services, key risks, resource implications and responses and focussed on questions around five themes:

- Organisation Priorities and Planning.
- Today's Climate and Weather-Related Impacts.
- How Climate Change may affect organisations, objectives and priorities.
- Approaches to adaptation either being considered or that may employed.
- Constraints to adaptation.

The focus on public sector organisations (38 telephone interviews were conducted) imposes limitations on analysis of the responses given that the sample size is by definition small and, statistically, un-representative. The telephone consultation, nevertheless, provided valuable access to expert local knowledge across the main sectors and was felt to provide a good indication of the current thinking within the public sector in relation to climate change and its impacts in Northern Ireland.

The telephone consultation was followed by a workshop to explore the principal areas of risk and potential approaches to adaptation. This is reported in detail in Appendix C.

2.4 Risk Assessment

A qualitative approach has been used to asses the risks from a changing climate, based on a high level screening assessment. This provides a platform from which further detailed and quantitative risk assessments can be taken forward for specific sectors or in relation to specific climate-related questions.

The preliminary risk assessment brings together consideration of how the impacts may affect different receptors (who or what might be affected e.g. by increased flood risk, and

where) with an assessment of likelihood and level of threat / opportunity by sector. It identifies:

- Potential factors that might represent a present or future climate hazard as well as those that clearly do not.
- Potential receptors at risk and those not at significant risk.
- Potential climate risk management options to be addressed through adaptation.

The sector risk assessments were initially trialled through the consultation exercise to gain an understanding of climate related risks and sensitivity and then were then undertaken by sector authors based on their knowledge of the sector and available literature.

2.5 Adaptation Strategies

The study follows the UK Government's Adaptation Policy Framework (APF) and considers adaptation under two categories:

- Building adaptive capacity: through research, data collection, change to regulations and awareness raising.
- Delivering adaptation actions: through measures that accept impacts, share impacts, avoid negative impacts and exploit opportunities.

Adaptation strategies have been produced for each of the impacts identified, using outputs from the review of literature and climate change scenarios and the consultation with key stakeholders. Where possible these provide recommendations for practical measures that may be taken, policy advice and recommendations for further research as well as identifying where roles and responsibilities for implementation may lie within key public sector bodies. Cross-cutting adaptation measures have also been identified. Constraints to adaptation have also been identified, addressing:

- Lack of awareness.
- Uncertainty about further climate conditions.
- Lack of funding.
- Lack of human resources.
- Conflicts within or between organisations.

In identifying potential options for adaptation, the study has provided the basis for further appraisal of options by the relevant stakeholders within a broader context of consensus on a vision and strategy for adaptation within Northern Ireland. This will require active participation and engagement of stakeholders and experts in the review of sectoral and geographical policies, plans and issues to develop appropriate measures, targets and indicators that can then used to monitor progress in achievement.

2.6 How the Risk Assessments have been used

The impact and risk assessments for each sector (described in Chapters 4 to 16) have been summarised within the report in three steps identifying:

- Potential impacts of climate change to that sector (Table 2.1).
- Risks arising from those impacts (Figure 2.2).
- Adaptation responses in relation to the perceived risks of impact, the implications for resources and roles and responsibilities of the main public sector body accountable (Table 2.2).

A detailed description of the risk assessment methodology is presented in Appendix A.

Table 2.1 – Climate Change Impacts (By Sector)

Climate change	**Impact on receptor**
Wetter winters	Impact 1 (e.g. *increased flood risk*)
Drier summers	Impact 2 (e.g. *increased incidence of low river flows)*
Warmer winters	Impact 4
Hotter summers	Impact 5 (e.g. *increased incidence of heat related illness / mortality*)
Sea level rise	Impact 6

Figure 2.2 – Risk Assessment (By Sector)

Table 2.2 – Impacts and Adaptation Summary (By Sector)

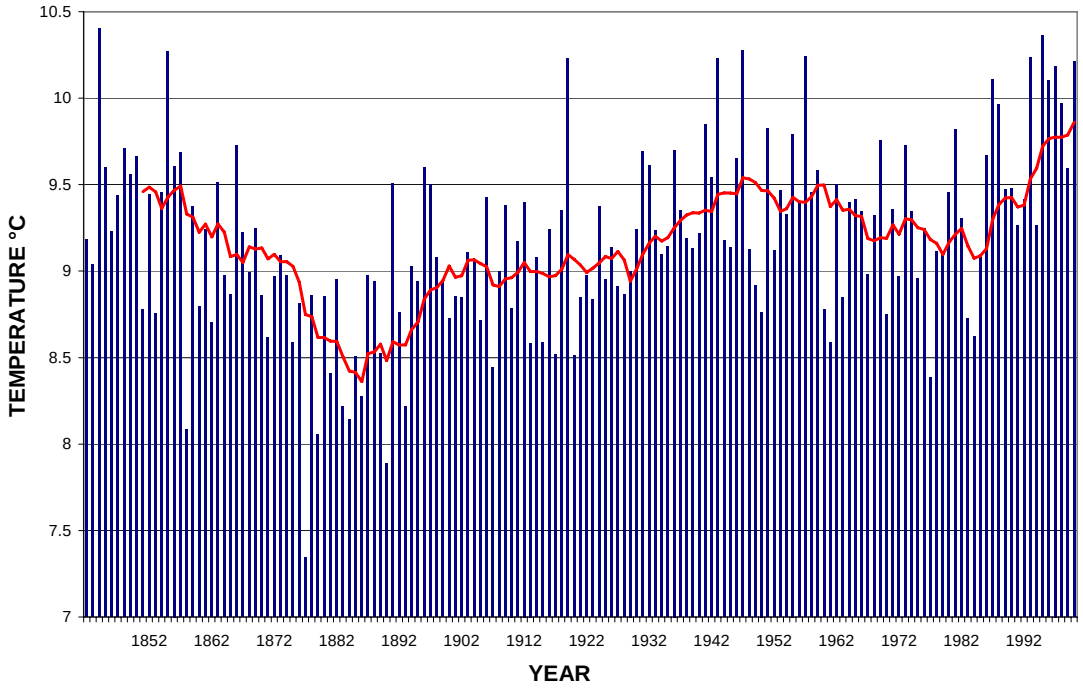
Impact on receptor	**Public Service Area**	**Effect on public services**	**Risk**	**Resource implications**	**Adaptation strategy**	**Responsible public sector body**
Impact 1						
Impact 2						
Impact 3						
…etc						

3 CLIMATE CHANGE

3.1 Recent Climate

The climate of Northern Ireland is relatively benign at present and is strongly influenced by its mid latitude position, on the ocean side of the British Isles (SNIFFER, 2002). This influence provides a relatively constant mean annual temperature, between 8.5°C and 9.5°C at low altitudes (on average between 1961 and 1990), although observations from the Armagh Observatory (made since 1841) show a steady rise in mean annual temperature from the early 1980s (Figure 3.1; SNIFFER, 2002; EHS, 2004).

Figure 3.1 - Mean Annual Temperature (Armagh Observatory)



Source: EHS (2004a); original data from Armagh Observatory.

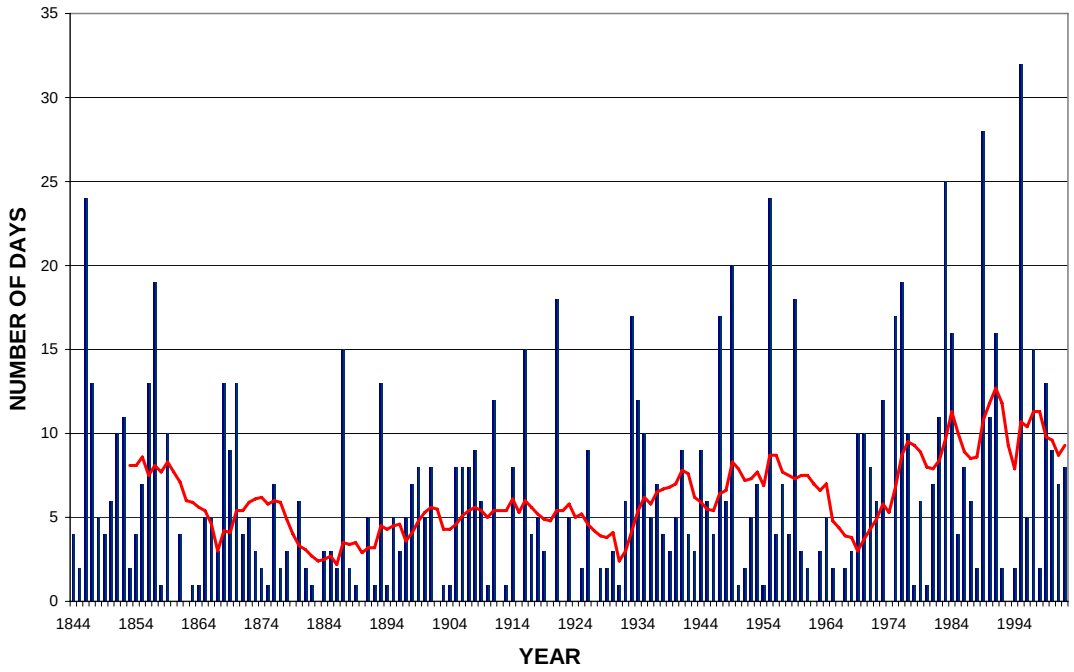
Seasonally temperatures vary with July being the warmest month (~10.5°C on average at the Armagh Observatory between 1961 and 1990) and January and February being the coldest (~7.0°C). The number of hot days (where the mean daily temperature is greater than 18°C) experienced at the Armagh Observatory in a year is highly variable, but has generally been high since the late 1980s (Figure 3.2; EHS, 2004). The number of cold days (mean daily temperature less than 0.5°C) is also variable, but has been very low since the late 1980s (Figure 3.3).

Precipitation is strongly related to topography, with upland areas receiving 1600mm or more per year, while the driest lowland areas receive 800mm or less (1961-1990 averages). Annual rainfall totals at Armagh Observatory (collected since 1930) are highly variable from year to year, but no long-term trend is obvious (Figure 3.4; EHS, 2004). Seasonal variation is not large, with the wettest months occurring between August and January (SNIFFER, 2002). There is no trend in the proportion of rainfall falling in winter (total rainfall in December, January and February as a percentage of annual rainfall; Figure 3.5); however, there is a slight decline in the proportion of summer rainfall (total rainfall in June, July and August as a percentage of annual rainfall; Figure 3.6). Heavy

rainfall events are infrequent due to the relatively low topography and limited severe summer convectional activity (SNIFFER, 2002).

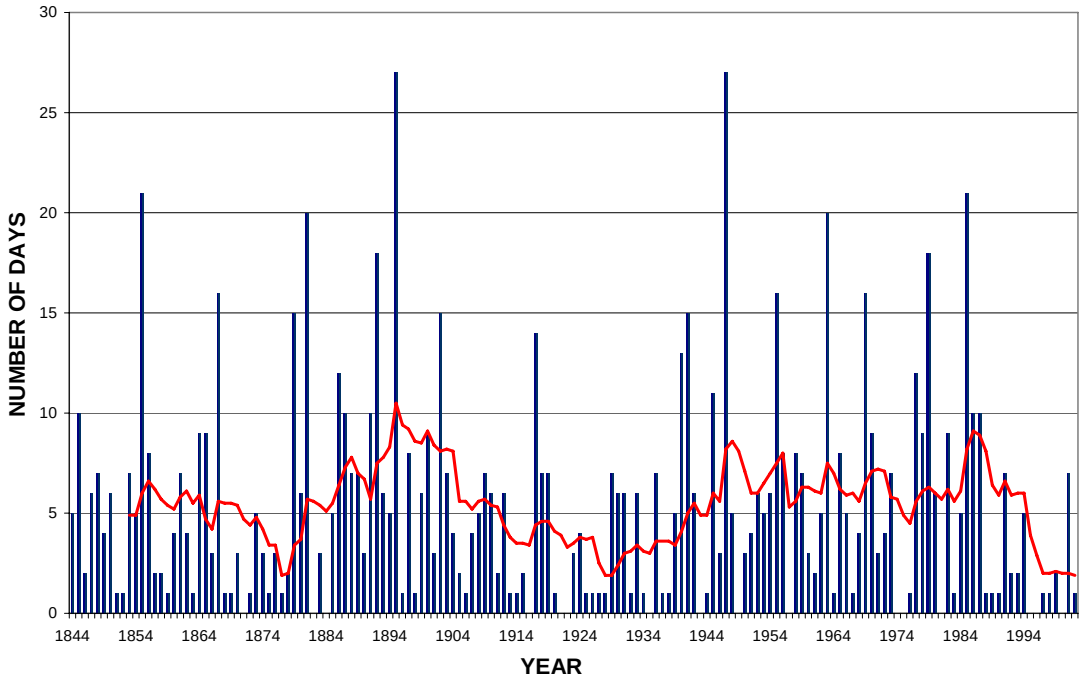
Mean annual potential evapotranspiration (PET) is highest in the south east and lower in north west and upland areas (SNIFFER, 2002). Precipitation exceeds PET for all months of the year in highland areas, with soil moisture deficits occurring for 3-4 months in lowland areas, particularly to the south of Lough Neagh and the south east coast (SNIFFER, 2002).

Figure 3.2 - Number of Hot Days (Armagh Observatory)



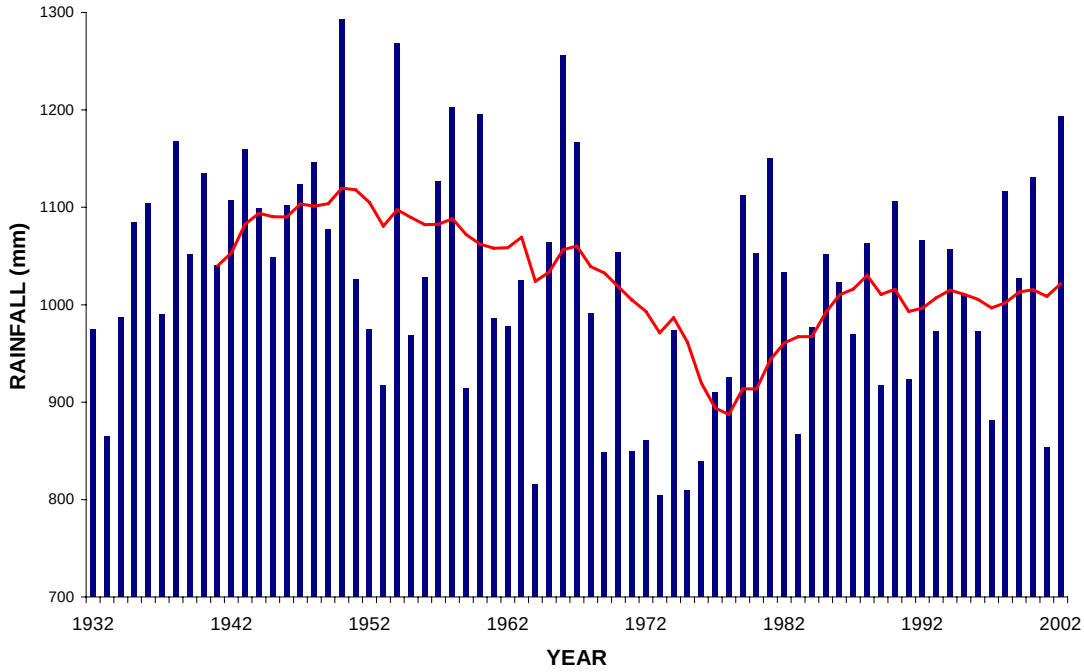
Source: EHS (2004a); original data from Armagh Observatory.

Figure 3.3 - Number of Cold Days (Armagh Observatory)



Source: EHS (2004a); original data from Armagh Observatory.

Figure 3.4 - Annual Rainfall (Armagh Observatory)



Source: EHS (2004a); original data from Armagh Observatory.

Figure 3.5 - Winter Rainfall (Armagh Observatory)

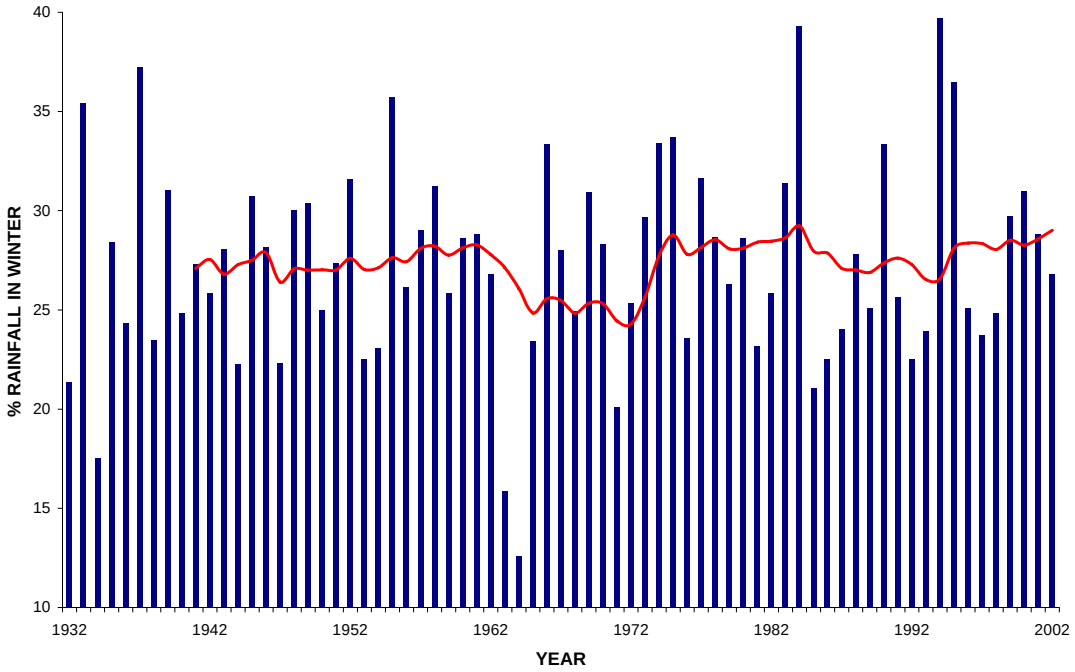
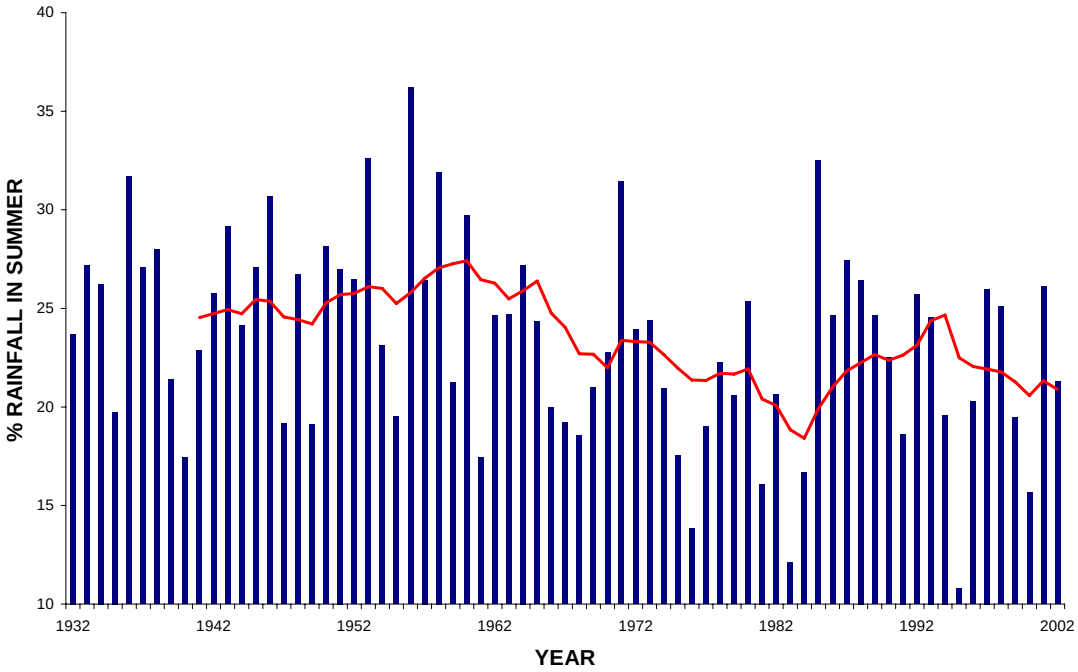
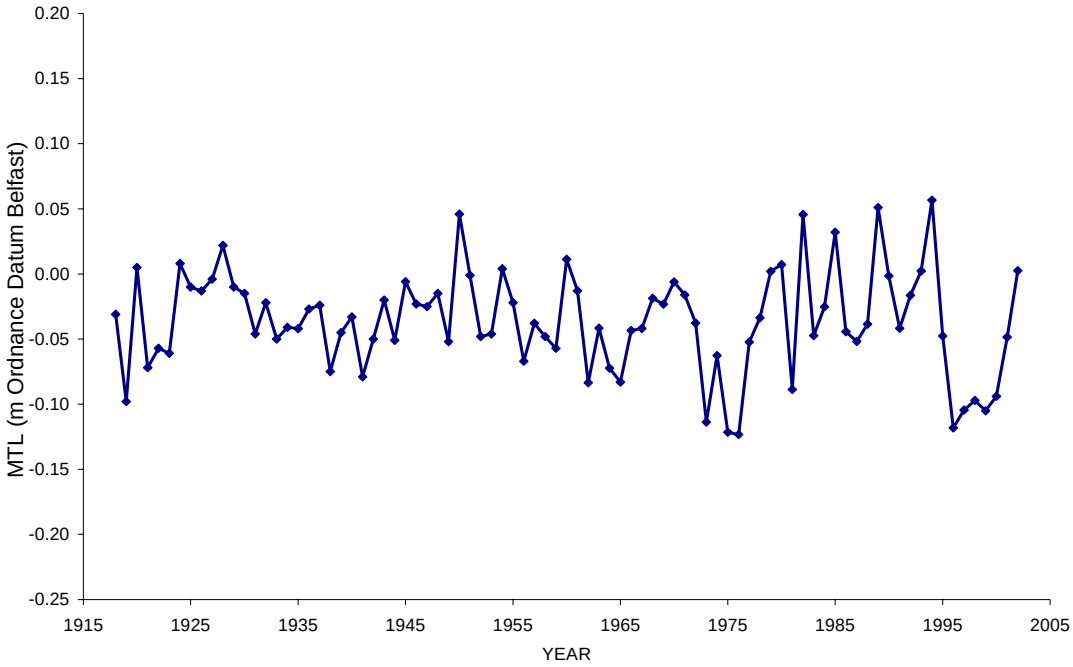


Figure 3.6 - Summer Rainfall (Armagh Observatory)



Source: EHS (2004a); original data from Armagh Observatory.

Figure 3.7 - Annual Mean Tidal Level (Belfast Harbour), 1918-2001



Source: EHS (2004a) from original data provided by Prof J. Orford (Orford et al., 2003).

Wind speeds are higher than those found in southern England, due to the position of Northern Ireland with respect to Atlantic depression tracks, although coastal areas are afforded some protection by the rest of Ireland and proximity to Scotland (SNIFFER, 2002). Annual mean wind speed ranges from less than 4.1 metres per second in sheltered inland sites to more than 6.7 metres per second on the North Antrim coast (SNIFFER, 2002).

Sea levels in Belfast Lough have been measured since 1918 and the long term series (adjusted to account for movement of the gauge and monitoring problems) indicates a slight fall (Figure 3.7; EHS, 2004). This is a similar trend to that experienced in other areas of northern England and Scotland that are still recovering from the last glaciation, when ice depressed the land surface. In these areas, including Northern Ireland, the post-glacial rebound (or isostatic uplift) is currently exceeding the global (eustatic) rise in sea levels, a consequence of the thermal expansion of water and melting of land-based glaciers. Further research on sea levels is discussed in Section 9.

3.2 Recent Weather Related Events

Northern Ireland has escaped some of the severe weather events that have affected other parts of the UK in recent times. For example, over the past 20 years southern England has experienced severe wind storms in 1987 and 1989, drought in 1995 and 2006, widespread floods during Easter 1998 and Autumn 2000 and a heatwave in summer 2003.

Nonetheless, Northern Ireland is not immune to such events; Table 3.1 provides a summary of the type of weather events which can be considered severe in a Northern Ireland context. While this is not an exhaustive list of events in the years 1996 - 2006, it provides an indication of the type of event and the subsequent impacts experienced.

These impacts may become more frequent and more intense under climate change (see below).

Table 3.1 - Severe Weather-Related Events in Northern Ireland, 1996 to 2006

Date	Event	Consequence
6th November 1996	Severe Gales	Fallen trees caused disruption to road and rail users – one motorist was injured after a tree fell on car. Ferry sailings to Great Britain were cancelled or delayed – injuries were caused to crew and passengers on one ferry that sailed. 4,000 homes were without electricity. Television services were also disrupted.
29th December 1998	Severe Gales	10,000 homes without electricity – 500 electricity poles broken, with water supplies hit due to electricity failures at power stations. Also bursts to mains caused by trees uprooting. Heavy rain caused further problems.
19th September 1999	Heavy localised flooding	Heavy rainfall caused the Three Mile Water to burst its banks close to Whiteabbey village. Extensive flooding in the village resulted, with the water needing a number of days to dissipate fully.
1st November 1999	Strong gales	Severe passenger delays due to ferry cancellations.
29th September 2000	Heavy rain and widespread flooding	Roads closed due to flooding – traffic disruption ensued. Railway lines closed by flooding. Heaviest rain was recorded at Ballypatrick Forest, with 60mm falling overnight.
21st June 2002	Heavy localised flooding	Exceptionally heavy rainfall fell as a result of a localised thunderstorm – the Met Office estimated it to have a return period of 1 in 300 years. Due to the combination of a high tide, low lying coastal areas in Carrickfergus and the village of Whiteabbey suffered severe flooding. Engineers explained that the local drainage system was not designed to cope with rainfall of this magnitude.
17th August 2004	Heavy localised flooding	The worst flooding in decades in Derry City, Co. Londonderry resulted in people being trapped in cars and extensive damage to property. Large parts of the city were under 2 foot of water for several hours.
25th November 2005	Widespread heavy snow	Severe delays to commuters as roads were blocked by large snowfalls
22nd September 2006	Strong gales	100,000 homes across Northern Ireland were left without power as the remnants of Hurricane Gordon brought strong gales. While the storm affected all parts of Northern Ireland, worst hit areas included Craigavon, Mid-Ulster and Newry. Roads were blocked by fallen trees in a number of locations.

3.3 Climate Change Scenarios

The original scoping study (SNIFFER, 2002) utilised the UKCIP98 climate change scenarios (Hulme and Jenkins, 1998). These have since been superseded by the UKCIP02 scenarios (Hulme et al., 2002) which are based on a more recent UK Met Office General Circulation Model (GCM), coupled to a Regional Climate Model (RCM). Although the same broad changes in climate were predicted, the UKCIP02 scenarios are 'drier' and suggest a decline in annual rainfall in Northern Ireland, with acute reductions in summer. The use of an RCM means that the UKCIP02 scenarios provide more spatial detail.

A summary of the major climate changes expected in Northern Ireland is provided in Table 3.2, with supporting maps for rainfall and temperature provided in Appendix B. All figures are derived from the UKCIP02 scenarios (Hulme et al., 2002) and are expressed relative to the 1961-1990 mean climate. Where a range is given this relates to the low emissions and high emissions scenarios, but also reflects grid-scale geographical variation within the province. Spring represents the average for March, April and May; summer the average for June, July and August; autumn the average for September, October and November; winter the average for December, January and February.

The UKCIP02 climate change scenarios are presented for 3 different future timeslices, representing the average climate over 30 year periods centred on the 2020s, 2050s and 2080s. The climate changes projected to the 2020s are similar across all scenarios. This is because we are already committed to some climate change as a result of past greenhouse gas emissions. Climate changes beyond the next few decades depend on future emissions, but even the low emissions scenario represents an acceleration of climate change when compared to changes that have occurred in the 20th century.

Table 3.2 - UKCIP02 Climate Change Scenarios for Northern Ireland

Climate variable		**2020s**	**2050s**	**2080s**
Temperature	Annual mean	+0.5 to +1.0°C	+0.5 to +2.0°C	+1.0 to +3.5°C
	Spring mean	+0.5 to +1.0°C	+0.5 to +2.0°C	+1.0 to +3.0°C
	Summer mean	+0.5 to +1.0°C	+1.0 to +2.5°C	+1.0 to +3.5°C
	Autumn mean	+0.5 to +1.0°C	+1.0 to +2.5°C	+1.5 to +4.0°C
	Winter mean	0 to +1.0°C	+0.5 to +1.5°C	+1.0 to +2.5°C
	Inter-annual variability[1]	Winter and particularly spring will become more reliably warm. Autumn and especially summer temperatures will vary more widely from year to year.		
	Diurnal range	Winter nights will warm more than winter days; summer days will warm more than summer nights, although summer evenings will be warmer. Overall will decline marginally.		
	Extremes	Extremely warm days will become more frequent; extremely warm days will become hotter. Heat waves will be more likely. The number of cold days will decline.		
	Sea surface	0 to +1.0°C	+0.5 to +1.5°C	+1.0 to +2.5°C
Precipitation[2]	Annual mean	WNV	Up to –10%	Up to –10%
	Spring mean	WNV	Up to +10%	Up to +10%
	Summer mean	Up to –20%	–10 to –30%	–20 to –50%

Climate variable		**2020s**	**2050s**	**2080s**
	Autumn mean	WNV	WNV	Up to –10%
	Winter mean	Up to +10%	Up to +15%	Up to +25%
	Snow	Average winter snowfall is likely to decline by between –40% and –100% (i.e. no snow on average) by the 2080s.		
	Inter-annual variability[1]	Summer will become more reliably dry. Precipitation in autumn, winter and particularly spring will become more variable.		
	Extremes	More intense rainfall days in winter and spring. Greater probability that an extreme rainfall event will occur on any given winter day. Evidence that intense summer storms may also increase (but limited by spatial resolution of model). Seasonally, there is an increased likelihood of very dry summers and very wet winters.		
Cloud cover		Cloud cover will reduce annually and in all seasons, particularly in summer.		
Relative humidity		Relative humidity will reduce annually and in all seasons, especially in summer.		
Soil moisture content		Soils will become drier overall, with soil moisture content declining by as much as 20% in some areas by the 2080s (high emissions). Soil moisture content will actually increase marginally in winter and spring, but this is offset by significant reductions in summer and autumn.		
Wind speed		Average wind speeds over land are likely to be similar in winter and spring and may decline in summer and autumn. The pattern of change for more extreme events is broadly similar over land; over sea more extreme wind speeds will be similar to those experienced at present, although in summer they will be lower. However, changes in wind speed are only predicted with low confidence.		
Sea level		Global mean sea level is expected to rise by between 9 and 69 cm by the 2080s (the range represents emissions and scientific uncertainty). Regional sea level variations may alter these values by +/-50%. Relative sea level can be calculated by subtracting isostatic uplift (and adding an allowance for sediment consolidation at the local level). Storm surge heights are not anticipated to increase much beyond the addition of mean relative sea level (unlike in other parts of the UK). However, changes in storm surge heights are only predicted with low – medium confidence.		

1 Based on model output for 2080s across the four UKCIP02 scenarios.
2 WNV = Within a measure of Natural Variability i.e. no trend detected.

A new set of climate change scenarios is due to be published by UKCIP in the near future, probably in 2008. These scenarios, currently termed UKCIP08, will provide users with a greater range of outputs. In addition, the scenarios will be presented as a probability density function, rather than a single number, with the probability representing some of the uncertainties inherent in climate modelling, downscaling and in relation to natural variability. However, the outputs will still be subject to uncertainty related to elements of the climate system poorly represented by climate models and uncertainties beyond the modelling process will not be captured. In particular this will still mean that separate emissions scenarios are required. Nonetheless, the new scenarios will represent a significant development and will be particularly useful for technical applications such as water resource planning.

In addition to the UKCIP02 scenarios, Northern Ireland is covered by scenarios published by the Irish Environmental Protection Agency (EPA). In 2003 scenarios were published based on the UK Met Office GCM and a statistical downscaling technique (Sweeney et al., 2003). In 2005, a further set of scenarios was published based on the first results of the new Met Éireann RCM (McGrath et al., 2005) . This RCM was driven by the Max Planck Institute GCM (ECHAM4) under an emissions scenario of moderately increasing GHG concentrations (SRES storyline B2 – see IPCC, 2000). This emissions scenario is equivalent to that used to produce the UKCIP02 medium-low scenario. Scenarios were produced for the 40 year period 2021-2060 (compared with a reference period of 1961-1990). Temperatures over Northern Ireland rise by between 1.25 and 1.50°C in January and by 1.50 to 1.75°C in July. Direct comparison between these results and the UKCIP02 scenarios are complicated by the averaging periods used. However, the EPA scenario suggests a higher rise in temperature than predicted under the UKCIP02 scenario medium-low emissions scenario. This is likely to be a consequence of the differences between the climate models, particularly the GCMs, and highlights the uncertainties inherent in climate modelling (see Section 3.4). For this study, the UKCIP02 scenarios will be primarily used as the outputs are more comprehensive. However, it is recommended that the outputs of EPA research are reviewed and used where possible to inform climate change impact assessment in Northern Ireland. This may include more detailed comparison of scenarios.

3.4 Climate Change Uncertainties

There are several uncertainties associated with future climate change scenarios. These need to be considered when assessing climate change impacts and risks, and when defining strategies and options for adaptation. Table 3.3 summarises the key uncertainties and how they are addressed within this study. A detailed review of uncertainties in relation to the UKCIP02 scenarios is provided in Chapter 7 of Hulme et al. (2002). Uncertainties will be identified and included within the impact assessment where appropriate to the nature of this study and where the information is easily available (see Table 3.3). Adaptation options will be robust to uncertainty and risks will be highlighted.

Table 3.3 - Key Climate Change Uncertainties

Uncertainty	Description	Approach in this study
Emissions	Results from uncertainty about future socio-economic development and consequences for emissions.	By considering the low-high emissions scenario range.
Climate sensitivity and climate modelling	The response of the climate to emissions varies between GCMs due to different representation of physical processes. Climate models do not perfectly represent the climate system, some aspects of which are particularly uncertain e.g. feedback mechanisms which may trigger rapid climate change.	This is the subject of much current research. However, in the absence of detailed results from other GCMs, and given the high-level nature of this study, the UKCIP02 scenarios are appropriate.
Downscaling global changes to the local level	The process of downscaling changes in global or large-scale climate to the regional or local level is complex and must also consider natural variability and change (e.g. isostatic uplift, which strongly influences mean sea level rise).	The UKCIP02 scenarios incorporate dynamic downscaling to a 50 km square grid. These changes in climate are considered here with respect to the baseline climatology of Northern Ireland (see SNIFFER, 2002; EHS, 2004). However, given the high-level nature of this study, uncertainty is not quantified. Rather, it will be discussed as part of the consultation and the recommendations will consider ways of dealing with uncertainty in detailed impact assessments and for adaptation.
Impact	Assessing the effects on climate change in impact models (e.g. hydrologic models) and in other evaluations (e.g. costing or consultation exercises) introduces further uncertainty.	Where impact model results are reviewed, there will be a discussion of uncertainty. Assessments made as part of this study (e.g. expert judgement, consultation) will also consider the uncertainty involved.

3.5 Rapid Climate Change resulting from feedbacks on the North Atlantic Drift

As noted in Table 3.3 above, there remains some uncertainty related to rapid climate change and to climate surprises or shocks. These largely relate to feedback mechanisms in the climate system, which are not yet fully understood. One example that has received much media attention is the possible shut down of the North Atlantic Drift and the resulting rapid cooling of north-west Europe and other areas such as the north-east seaboard of the USA. At present, ocean thermohaline circulation (THC) brings warm waters to the coastline of north-west Europe, helping to maintain significantly higher temperatures that would otherwise be the case (NERC, 2006), for example in comparison with continental areas at an equivalent latitude, such as Moscow.

An overview of the THC in the North Atlantic, and possible changes, is provided by Hulme et al. (2002) and summarised here. The THC is driven by variations in the density of sea water at different locations. In the North Atlantic, around Labrador and in the Greenland Sea, waters are cooled and subsequently sink to the ocean floor (a process called deepwater formation) before moving towards the equator. To balance this, and with support from surface winds, warm water is drawn from the Gulf of Mexico across the Atlantic to north-west Europe. Deepwater formation – and the resulting THC – depends on the density of surface waters in the North Atlantic. A large input of fresh water (from melting of the Greenland ice sheet, melting of sea ice, or increased precipitation in the north Atlantic) could reduce or halt the THC. This mechanism is believed to be responsible for the cooling of north-west Europe at the end of the last glacial period, when a large ice sheet over North America melted. Temperatures in north-west Europe may have fallen by 5°C within a few decades, and stayed relatively cool for more than 1000 years.

Observations suggest that the THC may be weakening, but further data is required for a more definitive conclusion to be reached. Improved monitoring of deepwater formation and development of a better understanding of high latitude processes are key areas of research under the Natural Environment Research Council's (NERC's) RAPID programme.

The THC is included in GCMs. Under all four UKCIP02 scenarios, it declines by about 25% by 2100, with the deepwater formation area near Labrador ceasing to operate (Hulme et al., 2002). Most other GCMs also show a weakening of the THC, but none demonstrate a total shut-down by 2100 (Hulme et al., 2002; NERC, 2006). Overall, global warming during the 21st century greatly exceeds cooling associated with this weakening, hence the UKCIP02 scenarios (which include the weakening) demonstrate significant warming to 2100. Nonetheless, given the potential consequences, this is an active area of current research. In addition to improved monitoring and understanding of the THC, the RAPID programme is seeking to: describe past events; test, and recommend improvements in, the representation of the THC in climate models; and, identify the climate consequences of rapid change, to include scenarios for use in risk assessment.

This study will not assess the impacts of rapid climate change, such as a shut-down of the THC and North Atlantic Drift, because this is considered unlikely in the 21st century, based on current findings. The RAPID programme, and other similar research, is likely to provide a better understanding of the probability and climate consequences of such events. At that stage, it may be appropriate to investigate rapid change scenarios, particularly to test resilience.

4 CONSERVATION, BIODIVERSITY AND HABITATS

4.1 Scope

This chapter of the report considers the potential impact of a changing climate on the species of Northern Ireland. The chapter provides an assessment of how climate change may affect the future of these species and habitats, with specific reference to the impact of wetter winters, increasing temperatures, drier summers and sea level rise. The chapter also details actions which are already underway, and provides an overview of potential adaptation strategies for meeting climate change. For further details on associated topics see the chapters on Fisheries, Agriculture and Forestry.

4.2 Background

Biodiversity in Northern Ireland is represented by about 20,000 known species found in terrestrial, freshwater and marine habitats (EHS, 2002). A number of UK priority habitats listed in the Biodiversity Plan are present in Northern Ireland including blanket bog such as on the Antrim Plateau or in the Sperrins; seagrass beds in sea loughs such as Strangford; upland heath in the Ring of Gullion and elsewhere; tidal rapids found in locations in Strangford Lough and at Larne Lough and Lough Foyle; species rich hedgerows found throughout Northern Ireland and maerl beds located in Strangford Lough and off the coast of Antrim. Furthermore, a number of priority species listed in the Biodiversity Strategy, such as, for example the Irish hare, and red squirrel are found in Northern Ireland.

4.3 The Issue Now

The changes predicted to take place under various climate change scenarios are expected to exacerbate other known impacts of human activity such as habitat fragmentation, agricultural change, invasion of alien species and eutrophication (SNIFFER 2002).

The consultation exercise undertaken as part of this study indicated that the present day climate is already impacting on habitats and species. For example, flooding can cause increased pollution and wash out of salmon spawning beds. Table 4.1 provides some examples of current weather conditions and the problems being caused with which organisations must deal and which have been detailed by participants in the consultation exercise.

Table 4.1 - Summary of responses from consultation

Weather/climate	Examples of how current climate affects organisation
Wetter Winters	Flooding leading to pollution Wash out of salmon beds Impact on fish migration Reduces no. of field days for habitat monitoring / study Impact on habitats / species such as moth pupae which become vulnerable to fungal infections (Rothamsted Insect Survey (Conrad, K. F. et al. 2002)
Drier Summers	Impact on wetlands. Areas prone to fire. Eutrophication Drought impacts on fry / hatcheries Impact on fish migration Damage to habitats and organisms, particularly those

Weather/climate	Examples of how current climate affects organisation
	with low dispersal ability
Warmer Winters	Colder weather may bring positive as well as negative impacts – for example native organisms should be able to withstand severe frosts, but harmful invasive aliens may be curtailed, though some species may be impacted by a lack of frost hampering regeneration. Delayed development of some species Impacts on fish productivity
Hotter Summers	Not all habitats would be sustainable in long hot summers Drought will impact trees with shallow root fans by damaging roots and increasing vulnerability to fungal infections, and damage Arctic alpine plant and animal communities on mountain tops
Increased Storminess	Impact on trees / plants. Long term decline in mature trees likely with impacts on forest ecosysytems, particularly of the saproxylic (dead wood) component of biodiversity, currently the most threatened in Europe Inhibit development of fish industry

4.4 How Climate Change May Affect The Future

Climate change has the potential to change the composition and geographic range of plant communities. In response to concerns over climate change, the MONARCH models were established. These models were designed to model impacts of bioclimatic change on a number of critical species, habitats and geomorphological features in terrestrial, freshwater, coastal and marine environments (Harrison et al., 2001; Berry et al., 2005).

The SPECIES model, developed in MONARCH 1 and taken further under MONARCH 2, was used to simulate changes in the potential climate space of species at a 5-kilometre square resolution and provide a guide to future species distribution at the Britain and Ireland scale.
Species specific modelling, reported under the first MONARCH modelling process (Harrison et al., 2001), has indicated that the following species would be likely to change their range under the various scenarios (Table 4.1).

Table 4.2 - Species lost from or gained by Ireland based on the MONARCH 1 model (Harrison et al. 2001)

Species lost	Scenario	Species Gained	Scenario
Flat sedge	2050 High	Common storksbill	2020 Low
Carex bigelowii	2050 High	Reed warbler	2020 High
Wood cranesbill	2050 High	Nuthatch	2020 Low
Trailing azalea	2050 High	Turtle dove	2050 High
		Yellow wagtail	2050 High

In the second MONARCH model it was, however, reported that Ireland as a whole would become less suitable for all the species modelled, apart from white beak sedge (Rhynchospora alba) and bracken (Pteridium aquilinum) (Berry et al., 2005).

Summary predictions for temperature and sea level as a result of global warming in general indicate that the impact in Ireland will be less severe than that likely to be experienced in Britain (Harrison et al., 2001). Impacts are outlined here on a habitat basis.

4.4.1 Woodlands

In Northern Ireland the following woodland habitats are present:

- Wet woodland (e.g. Rea's Wood, Antrim Loughshore)
- Oakwood (widespread but particularly in the Sperrins and Co. Fermanagh)
- Mixed ashwoods (main woodland type in Northern Ireland – particularly in Co. Antrim)
- Hedgerows (widespread, with different species in different areas)
- Parkland (e.g. Castle Crom and Castle Coole, Fermanagh and Belvoir Park and Lagan Valley in Belfast).

The climate change scenarios indicate that summer precipitation could decrease from 20 to 50% by 2080 (Hulme et al., 2002). This is likely to cause reduced cloud and relative humidity in all seasons, particularly in summer and an overall decline in soil moisture (Hulme et al., 2002). This in turn is likely to require increased water demand (EHS, 2005c). Drier summers predicted under such scenarios are reported to cause a threat to native woodland in Northern Ireland and an increased fire risk (EHS, 2005c). Damage to shallow rooting mature trees such as beech will promote the incidence of fungal disease and increase mortality. The age profile of semi-natural woodland will change drastically with bias towards younger trees and a decline in dead wood fauna.

4.4.2 Wetlands

In Northern Ireland the following wetland habitats are present;

- Reedbeds
- Blanket Bog (as on Antrim Plateau or in the Sperrins)
- Coastal and Floodplain grazing marsh (as at Quoile Pondage or at Lough Foyle)
- Fens (examples at Upper Lough Erne)
- Lowland Raised Bog (a number of examples occur in inter drumlin hollows and around the Lough Neagh basin)

In general habitats such as these may be modified or lost as a result of increasing temperatures. There may, therefore, be a shift in the composition of ecological communities towards those more commonly found in drier areas (West and Gawith, 2005). This is envisaged to be the norm by 2050. For example, it is predicted that there will be a potential reduction in the area of peat bog and an increase in the area of wet heath vegetation (Berry et al., 2005). Whilst MONARCH 2 only showed a limited response when this was modelled it is thought that this reflected that most of the selected species chosen were not at the edge of their range at the selected case study site (Berry et al., 2005).

More specific comments on the following wetland habitats are as follows.

4.4.2.1 Reedbeds

Climate change could potentially result in changes in species composition and diversity of reedbeds and their associated invertebrate populations (EHS, 2005c) although no information is available on how this might occur.

4.4.2.2 Blanket bog and lowland raised bog

In the context of climate change the role of blanket bogs as a carbon store is now considered significant. In Northern Ireland, it was reported by Harrison et al. (2001) that increased winter rainfall could lead to higher levels of winter ponding and flooding (Harrison et al. 2001) which may benefit raised bogs. It is predicted that conditions for blanket bog growth will therefore be improved due to increased winter rainfall, which together with milder winters, will result in extended growth periods. However, although suitable climatic conditions will persist for the maintenance and restoration of blanket bog in Northern Ireland, the species composition of the plant communities may well change from peat bog to wet heath (EHS, 2005d).

The SPECIES 2 model predicts higher summer temperatures could cause the loss of species such as the rare orchid Listera cordata through seasonal drying out of the peat. Despite seasonal drying out of the peatland not being picked up as a potential impact by the model (Berry et al., 2005), no suitable climate space was predicted in the model for the species, in the Cuilcagh area, to be present under the 2050s scenario. Flightless Carabidae are vulnerable to local extinction through drought and may suffer wider extinction through time (Anderson & Bealey 2003).

On the whole however modelling has predicted that the Cuilcagh / Pettigo peatland site, will experience little change by the 2050s despite some of the area becoming warmer (Berry et al., 2005). However, it may be that the reduced number of variables used in the bioclimate dataset, masked the full extent of the possible changes, as when this area was modelled previously under the UKCIP98 scenarios, the area showed increased sensitivity to a changing climate.

4.4.2.3 Coastal and Floodplain grazing marsh

With sea levels predicted to rise between 9-69cm by 2080 (Hulme et al., 2002) it is anticipated that inter-tidal habitats, coastal grazing marsh, salt marshes and mudflats will become threatened or lost (West and Gawith, 2005; Foresight, 2004 in West and Gawith, 2005). Sea level changes will have an impact on littoral communities which are adapted to certain amounts of desiccation and immersion and to certain tidal regimes, however, the impact has not yet been defined (EHS 2005d). The Marine Biodiversity and Climate Change Project and West and Gawith, 2005 also show that the impacts on the near shore marine environment are still being investigated. Sea level changes may require a program of managed retreat to conserve coastal habitats.

Climatic change may also affect Ireland's over-wintering waterbirds in a variety of ways either through the direct effect of changes in climatic conditions that could affect waterbird distribution or by the indirect effect of rising sea levels on the availability and nature of their coastal habitat (Harrison et al., 2001).

The managed realignment of sea defences may result in more extensive intertidal flats at the expense of marshes (Harrison et al., 2001). Loss of salt and freshwater marshes as a result of coastal squeeze is most likely to negatively impact on waterbirds, especially

those species that do not feed on the intertidal flats (Harrison et al., 2001). Rising sea levels might also change the shape of estuaries (Harrison et al., 2001). However it is also possible that those habitats which are lost could be offset by those which are newly created.

4.4.2.4 Fens

Climate change may result in changes in the species composition and diversity of fens and associated invertebrate populations (EHS, 2005c) although no information is available on how this might occur.

4.4.3 Marine and Coastal Habitats

In Northern Ireland the following marine habitats are present (some examples of locations are given in brackets);

- Sabellaria alveolata reefs (Glassdrumman)
- Maerl beds (Strangford Lough)
- Littoral and sublittoral chalk (Antrim Coast / Rathlin Island)
- Mud in deep water (off east coast between NI and Isle of Man)
- Sabellaria spinulosa reefs (most notably at Magilligan)
- Sublittoral sands and gravels (Garron Point)
- Coastal sand dune (Bann Estuary; Murlough Bay)
- Sheltered muddy gravels
- Saline lagoon (Lough Foyle)
- Maritime cliff and slope (north of Larne)
- Tidal rapids (Strangford Lough)

Information on the impact of climate change is not available for all these habitats but where it is available the impacts are described below. Increased summer temperatures, may lead to an increased level of desiccation in the intertidal area, restricting the distribution of the intertidal species. This is likely to impact on Sabellaria alveolata reefs, sheltered muddy gravel and saline lagoons.

An increase in extreme storm events could affect sheltered muddy gravels, maerl beds and tidal rapids, by increasing the level of wave energy in the water column, thereby preventing the settlement of fine organic and inorganic materials. Increased storminess is also likely to impact on saline lagoons by increasing the level of wave energy at or around the sills at the mouth of the lagoons (EHS, 2005c and 2005d).

The results from the recently completed MarClim study are reported to indicate that climate change is already happening in a significant way (Laffoley et al., 2005). The MarClim study was devised in order to rescue, assemble and collate historical data on the intertidal environment collected in the 1950s, 1960s and 1970s and to use this to understand better the impact of climatically driven changes.

The study reports that changes are now having a profound impact on seashore indicator species. This confirms that the impacts of climate change are not only restricted to changing distributions of warm and cold water plankton species. The study reports that even seashore indicator species are beyond previous scales of variation seen over the last 60 years.

4.4.3.1 Sabellaria alveolata reefs

S. alveolata reefs are at the northern end of their range in Britain and Northern Ireland and at present are affected by extremely cold winters. It is anticipated though that winters will be more reliably warm in Northern Ireland and while the impacts in Northern Ireland of temperature change on Sabellaria spp. are not well studied it is unlikely that experience from elsewhere (Crisp 1964, Gubbay 1988, in EHS, 2005c) which suggests that die back is likely, will occur in Northern Ireland.

4.4.3.2 Maerl beds

Milder winters may be beneficial to maerl since the incidence of loss due to severe winter frost or ice events will decrease and growth periods will be extended. Warming by a couple of degrees could encourage the flourishing of the cold sensitive Lithothamnion coralloides in more northerly areas, whereas L. glaciale may retreat (Birkett et al. 1998, Hiscock et al.,. 2001, in EHS 2005d).

4.4.3.3 Coastal sand dune

It is thought that temporary ponding of water through increased levels of precipitation in areas such as dune slacks could become important for breeding amphibians and may increase their numbers and persistence (Harrison et al., 2001).

4.4.3.4 Saline lagoon

Sea level rise may present opportunities for creation of new lagoonal habitat where seawater inundates freshwater areas, including sites that were once coastal lagoons.
One study estimated that about 120 ha of coastal lagoons in England (10% of the existing resource in England) would be lost over the subsequent 20 years, mainly as a consequence of sea level rise (Smith and Laffoley, 1992, in EHS, 2005c). No information is available on how much habitat could be lost in Northern Ireland.

4.4.4 Heathlands

In Northern Ireland the following heathland habitats are present (some examples of locations are given in brackets);

- Upland Heathland (scarp slopes of western Fermanagh)
- Lowland heathland (Rathlin Island)
- Montane Heath (Mourne Mountains)

Heathland development may benefit from the predicted increase in rainfall, especially in winter, in northern regions of the UK, which together with milder winters, will result in extended growth periods. However although conditions may remain suitable for heath communities, species composition of the plant communities may well change (EHS, 2005d). For example, wet heaths should not lose the dominant Erica tetralix but changing water availability in Ireland could lead to the drying of heathland and to E. tetralix being outcompeted (Harrison et al., 2001).

Warmer conditions are likely to impact on heath communities through both loss and gain of species to Northern Ireland. In the MONARCH report species and habitats at their southern limits in Britain and Ireland were reported to be more likely to lose suitable

climate space e.g. montane heaths were identified as being potentially impacted (Harrison et al., 2001). Although montane heaths may benefit from increased rainfall, and milder winters, there are still uncertainties in relation to the impacts of a changing climate e.g. any climatic change will be exacerbated on the mountain summits and particularly on habitats currently at the edge of their natural range – therefore the impacts will be site specific and not uniform across Northern Ireland. The future position therefore is still unclear but it is worth noting that one of the dominant heathland species, heather, does have a relatively wide tolerance of temperature and rainfall, providing the overall climate remains oceanic (EHS, 2005d).

4.4.5 Grasslands

Climate change could potentially result in changes in the species composition and diversity of the following communities (example locations in brackets)

- Purple Moor Grass and rush pasture communities (Co. Fermanagh)
- Calcareous grassland and associated invertebrate communities (mainly Co. Fermanagh)
- Lowland acid grassland and associated invertebrate populations (small scattered locations across NI)
- Lowland meadow and associated invertebrate populations (small scattered locations across NI)

With drier summers resulting from climate change it is possible that nutrient input from airborne dust will increase. Higher summer temperatures may result in drier summer conditions, while milder, wetter winters may result in extended growth periods. There is a need to assess the impact of atmospheric nutrient deposition and climate change for each type of grassland habitat.

4.4.6 Limestone pavements

Rainfall is vital for karst geomorphology, soil moisture and the behaviour of seasonal lakes (turloughs) such as those found in Northern Ireland. Increased annual effective rainfall means that the karst areas of the Cuilcagh are predicted to see an increase in dissolution of 2-5% (Harrison et al., 2001). It was shown that an increase of less than 10% is, however, unlikely to produce a visible effect in dissolution rates. This, together with the more recent predictions showing an overall decrease in rainfall by 10% (Hulme et al., 2002), point either towards maintaining the status quo or to a negative impact on these habitats.

4.4.7 Lakes

In Northern Ireland the following lake habitats are present (example locations in brackets);

- Marl lakes (Tullybrick and Kiltubbrid Loughs Co. Armagh)
- Mesotrophic lakes (Lough Melvin and Upper Lough Macnean Co. Fermanagh)
- Eutrophic standing waters (Lower Lough Erne Co. Fermanagh)

It is unclear how the Northern Ireland lake habitats will respond to hotter summers and milder winters resulting in drier summers and extended growing periods. However, one effect is increased risk of eutrophication (West and Gawith, 2005) and an associated decrease in water quality. This has well established negative impacts on lake diversity and can cause a fundamental shift from well oxygenated water with good macrophyte and

macroinvertebrate communities providing food and habitat for a diverse fish community towards a deoxygenated algal dominated soup where only small zooplanktonivorous fish can survive (Moss, 1988).

4.4.8 Birds

Responses of birds to climate change in the UK have been well documented. Under MONARCH 2 two models were used to predict the effects of climate change and sea level rise on the distribution and numbers of over-wintering waterbirds in Britain and Ireland. Responses included phenological changes such as changes in breeding success and advancing egg-laying dates, or migration patterns changing in time and space (RSPB, 2004). Modelling has shown that wintering waterbirds have started to re-distribute themselves as a result of climate change, tending to winter more to the north and east of Britain and Ireland as winters have become milder (Berry et al., 2005). Changes in weather patterns over the past three decades were also shown to have resulted in a broad scale redistribution of waders over-wintering in Britain from western coastal estuaries to those on the east coast (Berry et al., 2005).

Climate change has already been identified as a significant factor contributing to the worst seabird breeding season on record in 2004 (RSPB, 2004). For example, kittiwakes had a poor breeding season which the report attributes to be due to a lack of sandeels, their staple food. While there is still speculation about why the fish are declining, it is thought that environmental factors, such as climate change, are a greater threat to sandeel numbers than industrial fishing (RSPB, 2004).

Wintering migrants have also been affected. The cumulative population of wintering ducks, geese, swans and wading birds has dropped to its lowest level since the winter of 1994. Some winter visitors that were once common in Northern Ireland, like the Bewick's swan that comes here from breeding grounds in Siberia, are now quite rare (RSPB, 2004). Modelling of the estuaries in England which are protected by hard defences showed that sea-level rise was simulated to have little impact on waterbird numbers, with defences likely to be maintained (Berry et al., 2005).

4.4.9 New / invader species

New invader species, not previously seen in Northern Ireland could gain habitat space (West and Gawith, 2005; EHS, 2005c). Dispersal modelling work has reported that new invader species or “recruitment species” had potential to spread; for example, the invasion of species such as Betula pubescens downy birch and Pteridium aquilinum bracken (Berry et al., 2005). An analysis of the SPECIES model results by region showed that Ireland has the greatest potential for receiving species within the British Isles as a consequence of climate change (Harrison et al. 2001). This was, however, at least in part, thought to be an artifact of the modelling process in that a number of the modelled species already occurred in Ireland (Berry et al., 2005).

A shift in the dominance of species such as B. pubescens and P. aquilinum could have far reaching impacts on bog community composition (Berry et al., 2005). If conditions such as nutrient and mineral concentrations in the soil are suitable, both species have the potential to colonise. With the spread of these species, additional species of invertebrates and fungi, not yet occurring in Northern Ireland blanket bogs, could also be possible. The colonisation of such species would, therefore, represent an entirely new functional group if they should prove capable of invading the bog community (Berry et al., 2005).

Stokes et al. (draft MS) conclude that the spread of invasive aliens, both plants and animals, is likely to accelerate rapidly in response to climate change, and to the increasing commercial use of live native plants from across the globe, for sale in Ireland and elsewhere. There is already a sizeable component of invasive aliens within invertebrate communities in Ireland (Anderson 2005).

4.4.10 Conclusions

By and large we do not yet really know how the expected changes in climate will affect the species composition in Northern Ireland.

In general modelled responses to the impacts of climate change were reported to be highly variable (Harrison et al., 2001). Plants, insects and bird species were all modelled under the MONARCH programme and while some species / habitats showed potential for decline others were more likely to expand their habitat range.

Summary predictions for temperature and sea level as a result of global warming in general indicate that the impact in Ireland will be less than that likely to be experienced in Britain (Harrison et al., 2001). However, the second more recent MONARCH model reported that Ireland as a whole would become less suitable for all the species modelled, apart from white beak sedge (Rhynchospora alba) and bracken (Pteridium aquilinum) (Berry et al., 2005). In summary the impacts of climate change on habitats found in Northern Ireland are reported as follows:

- Wetland habitats such as peat bogs could be at risk of drying out although modelling has predicted that the Cuilcagh / Pettigo peatlands, in Ireland, will experience little change by the 2050s (Berry et al., 2005). However, the reduced number of variables used in the bioclimate dataset, may have masked the full extent of the changes.
- On the coast the MarClim research confirms that the impacts of climate change on seashore indicator species are beyond previous scales of variation seen over the last 60 years.
- As a result of increasing rainfall heathlands may develop faster, in northern regions of the UK, this combined with milder winters, is likely to result in extended growth periods. However, whilst conditions may remain suitable for heath communities species composition of the plant communities may well change (EHS, 2005d).
- In lakes another affect of increases in summer temperatures, is increased risk of eutrophication (West and Gawith, 2005) and an associated decrease in water quality.
- Lastly in bird populations responses to climate change included phenological changes such as changes in breeding success and advancing egg-laying dates, or migration patterns changing in time and space (RSPB, 2004).

One drawback of the MONARCH model is that climate space changes are based solely on a mean change in bioclimate. In reality, climate changes are more likely to be expressed by changes in the scale and frequency of extreme events such as drought, flooding and wind speed; it will be these that are likely to be most significant in changing community composition (Berry et al., 2005).

While climate change may exacerbate habitat loss, such as the erosion problems on blanket bog, it should not be forgotten, that most often it is the impacts of human activities,

such as overgrazing, that initiate problems and subsequently render areas more vulnerable to the effects of climate change (Berry et al., 2005).

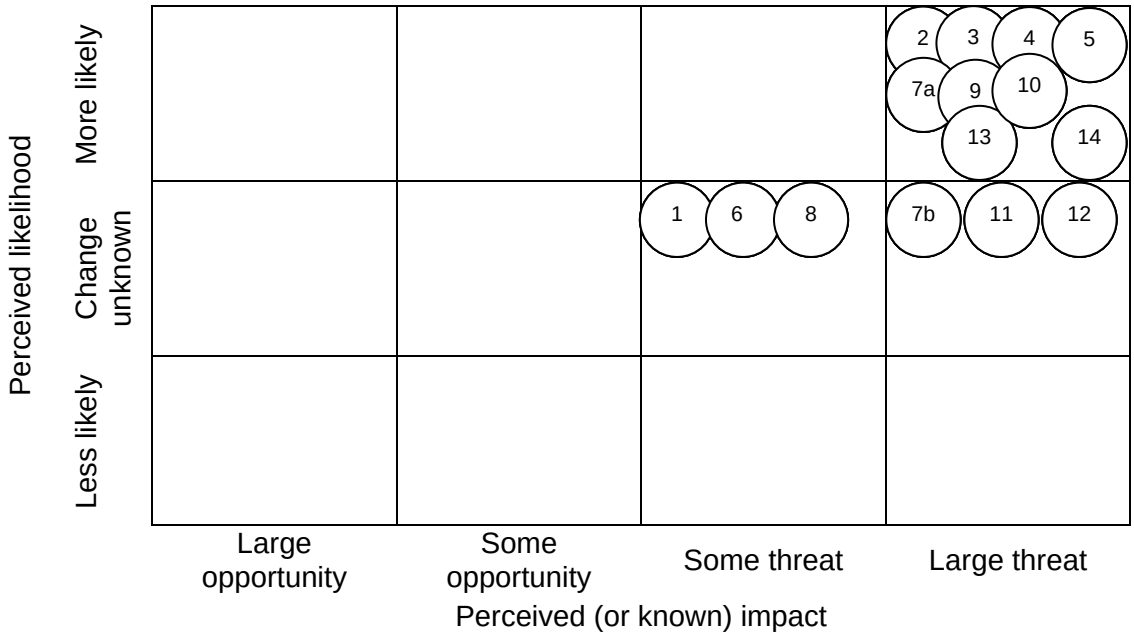
Impacts on conservation, biodiversity and habitats are summarised in Table 4.2.

Table 4.3 - Climate Change Impacts: Conservation, Biodiversity and Habitats

Climate change	Impact on receptor
Wetter winters	Increased rainfall and frequency of flooding causing changes to ecosystems in particular in river and estuarine ecosystems
Drier summers	Decreased water inputs to blanket bogs, raised bogs, mires, wet grasslands and fens
	Lower flows and changes in water quality of rivers and streams
	Increased eutrophication of water bodies, watercourses and coastal waters
	Increased fire risk to heathlands, grasslands and 'dry' woodlands
	Changes in insect biomass affecting many animal species particularly flightless and other species with low dispersal ability
Warmer winters	Distribution and species composition of habitats will change
	Increase in species at northern edge of range and decrease in species at southern edge of range
	Increase in range of some invasive and exotic terrestrial, freshwater and marine animal and plant species which threaten native ecosystems
	Longer breeding season for some species but greater likelihood that frosts (when they do occur) could negatively impact on plants, insects and birds
	Unknown impacts on hibernating species including moths which are already impacted by fungal infection in over-wintering pupae
Hotter summers	Distribution and species composition of habitats will change
	Increase in species at northern edge of range and decrease in species at southern edge of range with probable widespread extinctions in Arctic-alpine communities
	Extension in range of some invasive and exotic terrestrial, freshwater and marine animal and plant species which threaten native ecosystems
	Changed migration patterns affecting birds, insects etc
Sea level rise	Inter-tidal habitats, salt marshes and mudflats threatened through flooding and erosion.
	Loss of coastal grazing marsh and lagoonal habitats.
	Estuarine and river ecology threatened by tidal flooding.
Other	***North Atlantic Oscillation:*** Warmer sea temperatures causing changes to the phytoplankton communities resulting in a decline in sand eel populations which adversely affect a wide range of seabirds (e.g. auks, puffins, kittiwakes, terns)

Impacts from SNIFFER (2002).

Figure 4.1 - Risk Assessment: Conservation, Biodiversity and Habitats



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 4.4).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

4.5 Actions Undertaken or Underway and Key Gaps

The biodiversity is building up a strong technical position in developing its understanding of the implications of a changing climate and initiatives such as MONARCH and BRANCH at a national level will help in developing area / habitat specific risk assessments and the development of adaptation strategies. However, Northern Ireland based research will nevertheless be required. The strong technical position emphasises the current gap between science and practice, particularly in terms of the apparent lack of co-ordination of policy development and strategic planning between the various responsible bodies to address climate change risks and adaptation. An assessment of the potential impacts across sectors and involving a variety of stakeholder interests will also need to be developed – this may lead to closer integration of strategic planning policies and objectives.

4.6 Adaptation Strategies

Phone questionnaires were carried out across a range of government and conservation bodies to establish likely adaptation strategies. Of the 11 bodies interviewed just around half were delaying decisions in order to wait and see what happens whilst the remainder were trying to work out adaptation strategies.

Currently within Northern Ireland there is some awareness of adaptation strategies within their sectors already operating in England and Scotland. Current ideas on adaptation strategies raised through the telephone interviews ranged from the following;

- Monitoring and subsequent action

- Responding to specific incidents
- Trying to use existing impacts as a lever to raise awareness
- Requirement for new legislation
- Change attitude of senior management

In general, it is likely that measures from Great Britain will be adapted to suit the climate changes felt in Northern Ireland. These could include the following:

- Increasing connectivity of wetlands
- Reducing nutrient inputs
- Better management of headwater wetlands and river flow
- Protection of salt marshes and creation of new salt marshes by 'planned retreat'.
- Monitoring of key habitats, including fens, raised bogs, old growth woodland and acid grassland and fauna and flora sensitive to potential impacts.
- Monitor and limit the introduction of alien species, particularly those associated with plant nurseries and garden centres, ports and shipping.
- Increased awareness of Environmentally Sensitive Areas.
- Managing the wider countryside for biodiversity and not just relying on nature reserves.
- Increasing connectivity between ecosystems and habitats through changes in land management practices and creation of 'wildlife corridors'

Training and support will be necessary for all of the above measures. In Northern Ireland raised bogs and soft, supra-littoral coastal sediments are considered to be particularly at risk from climate change impacts (SNIFFER 2002). Therefore adaptation strategies should ensure these habitats are protected where possible. In all cases the situation should be under constant review to ensure that all strategies are updated to reflect improved scientific understanding of climate change.

4.7 Conclusions and Recommendations

Biodiversity in Northern Ireland includes approximately 20,000 different species found across a wide range of different habitats. These habitats are of varying importance and include a number of UK priority habitats including blanket bog, seagrass beds, upland heath, tidal rapids, species rich hedgerows and maerl beds. There are also populations (some quite significant) of priority species, including Red Squirrel and Irish Hare.

A changing climate could have significant impacts on the conservation value of many of the species and habitats presently found in Northern Ireland. The impacts of a changing climate also need to be considered in combination with current impacts of human activity on biodiversity such as habitat fragmentation, agricultural change, invasion of alien species and eutrophication and which are already having major impacts on the species and habitats.

The impact of a changing climate will not be felt equally across all habitats and species (with the particular impact of human activity often being critical). Impacts from a changing climate may not all be negative and indeed it may provide opportunities for species / habitats – particularly those that are at the northern limit of their range to establish their presence more effectively.

Modelling by the MONARCH project indicates there may continue to be a suitable climate for the main habitats within Northern Ireland. However, there is a need for more strategic monitoring if the Northern Ireland authorities are to pick up any significant changes in

species / habitat composition which may require adjustment or change to management practices.

Changes to coastal habitats should be expected with rising sea levels, realignment and coastal squeeze. At this stage, however, the extent to which there may be a balance in habitat loss and gain is unclear. Potential impacts on biodiversity, for example to winter fowl and related habitats, may also impact across sectors; in this case, on tourism.

Although there is a significant amount of climate related research in this sector, there appears to be a lack of carry through in terms of policy development and strategic planning among the various responsible bodies to address climate change risks and adaptation.

Whilst the biodiversity sector would appear to be in a strong position technically in terms of understanding the implications of a changing climate, there are a number of recommendations that need to be undertaken in the short term to help plan for medium to longer term responses. These include:

- A review of existing / intended legislation to assess whether it will provide sufficient protection for existing habitats in light of likely climate change and to identify whether new / amended legislation will be required.
- A review of monitoring systems and approaches to assess whether existing systems and techniques employed are sufficiently robust to take into account a changing climate and identify new procedures / techniques where appropriate.
- Education and awareness: to provide greater and more focused education of landowners and other interested parties including the general public on the human impact on species / habitat may help reduce the impact of human activity which has been shown to be critical to the scale of the likely impact of a changing climate.

All of the above recommendations should be implemented with a specific Northern Ireland focus in order to make these relevant to the local situation, though it is acknowledged that these could be based on reviews or measures that have been carried out in Great Britain, Republic of Ireland or further a field.

Table 4.4 - Impacts and Adaptation Summary: Conservation, Biodiversity and Habitats

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
1	Increased rainfall and frequency of flooding causing changes to riverine ecosystems	Conservation Greenspace management; Emergency Planning; Water Supply; Watercourse management	Implications for health of designated sites	Major unknown risk	*Factor climate change into biodiversity and habitat action plans.* *Develop policies for creating and restoring ecosystems* *Share information between governments and their agencies, NGOs, communities, and research institutions on potential and observed climate change impacts and extreme events*	DARD Rivers Agency EHS Local councils FCB Loughs Agency DCAL Inland Fisheries NITB DRD Water Service
2	Decreased water inputs to blanket bogs, raised bogs, mires, wet grasslands and fens	Conservation Greenspace management; Water Supply; Watercourse management	Implications for health of designated sites/ species Impact on tourism and aesthetic value	Major threat	*Factor climate change into biodiversity and habitat action plans.* *Develop policies for creating and restoring ecosystems* *Explore how Environmental Stewardship can make a greater contribution.* Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas	EHS NITB Local Councils DARD Rivers Agency DRD Water Service
3	Lower flows and changes in water quality of rivers and streams	Conservation Greenspace management; Watercourse management Water Supply	Implications for health of designated sites	Major threat	*Factor climate change into biodiversity and habitat action plans.*	DARD Rivers Agency EHS DRD Water Service
4	Increased eutrophication of water bodies, watercourses and coastal waters	Conservation Greenspace management; Water Supply; Watercourse management	Public health	Major threat	*Ensure that the development of measures under the Catchment Sensitive Farming Programme and Nitrate Action Plan also support climate change goals.* *Improve natural resource planning and management to focus on ecosystem functionality across the landscape and seascape* *Ensure compliance with existing regulations on the use of land, water and marine resources*	DARD Rivers Agency EHS DRD Water Service

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
5	Increased fire risk to heathlands, grasslands and 'dry' woodlands	Conservation Greenspace management; Water Supply; Emergency Planning	Property damage	Major threat	*Factor climate change into biodiversity and habitat action plans.* *Adopt policies that lessen pressures on resources, remove adverse incentives for agriculture, forests, water and fisheries* *Share information between governments and their agencies, NGOs, communities, and research institutions on potential and observed climate change impacts and extreme events*	EHS Forest Service Local Councils DARD
6	Changes in insect biomass affecting many animal species	Conservation Greenspace management;		Major unknown risk	Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas Implement ex-situ conservation and translocation strategies if appropriate	EHS DARD
7a	Distribution and species composition of habitats will change	Conservation Greenspace management;	Implications for health of designated sites/ species	Major threat	Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas Implement ex-situ conservation and translocation strategies if appropriate	EHS DARD
7b			Impact on tourism and aesthetic value	Major unknown threat		NITB
8	Increase in species at northern edge of range and decrease in species at southern edge of range	Conservation Greenspace management;		Major unknown risk	Implement ex-situ conservation and translocation strategies if appropriate Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas	EHS DARD

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
9	Increase in range of some invasive and exotic terrestrial, freshwater and marine animal and plant species which threaten native ecosystems	Conservation Greenspace management;		Major threat	Implement ex-situ conservation and translocation strategies if appropriate Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas	EHS DARD Loughs Agency FCB DCAL Inland Fisheries
10	Longer breeding season for some species but greater likelihood that frosts (when they do occur) could negatively impact on plants, insects and birds	Conservation Greenspace management;		Minor unknown risk	Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas Implement ex-situ conservation and translocation strategies if appropriate	DARD EHS
11	Unknown impacts on hibernating species – vulnerable Lepidoptera are already known to be declining	Conservation Greenspace management;		Major unknown risk	*Develop awareness campaigns to highlight the value that ecosystem services provide as buffers against climate variability and secure public acceptance for climate change adaptation*	EHS
12	Changed migration patterns affecting birds, insects etc	Conservation Greenspace management;	Loss of amenity/ tourism	Major unknown risk	Enlarge conservation areas where appropriate Create and restore buffering zones and habitat mosaics around conservation areas Implement ex-situ conservation and translocation strategies if appropriate	EHS DARD NITB
13	Sea level rise causing damage to intertidal habitat, salt marshes and mudflats, loss of coastal grazing marsh and risk to ecology.	Conservation Greenspace management;	Loss of amenity/ tourism	Major threat	*Improve natural resource planning and management to focus on ecosystem functionality across the landscape and seascape* *Adopt policies that lessen pressures on resources, remove adverse incentives for agriculture, forests, water and fisheries* *Develop policies for creating and restoring ecosystems* *Ensure compliance with existing regulations on the use of land, water and marine resources*	EHS DARD Rivers Agency DARD Local Councils NITB

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
14	Warmer sea temperatures causing changes to the phytoplankton communities resulting in a decline in sand eel populations which adversely affect a wide range of seabirds (e.g. auks, puffins, kittiwakes, terns)	Conservation Greenspace management;	Loss of amenity/ tourism	Major threat	*Improve natural resource planning and management to focus on ecosystem functionality across the landscape and seascape* *Adopt policies that lessen pressures on resources, remove adverse incentives for agriculture, forests, water and fisheries* *Develop policies for creating and restoring ecosystems* *Ensure compliance with existing regulations on the use of land, water and marine resources*	EHS DARD NITB

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

5 FISHERIES

5.1 Scope

This chapter details how climate change may affect the future of fisheries in and around Northern Ireland and considers specifically the potential impact of rising sea surface temperatures, sea level rise, increased temperatures and drier summers and increased flooding. For further details on associated topics see the chapter on Conservation, Biodiversity and Habitats.

5.2 Background

Responsibility for fisheries within Northern Ireland and in its coastal waters falls under the remit of a number of different organisations. Among these organisations are the following:

- Department for Culture, Arts and Leisure (Inland Fisheries)
- Fisheries Conservancy Board (FCB)
- Loughs Agency (cross border)
- Department of Agriculture and Rural Development
- Agri-Food and Biosciences Institute (AFBNI)

The indigenous fish fauna of the UK can be divided into two groups, those that can tolerate both salt and fresh water (euryhaline species), such as salmon, trout and shad, and those which only live in fresh water (stenohaline), such as pike, perch, roach etc (Maitland, 2004). Andromodous species such as salmon, sea trout (brown trout are generally recognised as the freshwater form of sea trout) and shad, use rivers for reproductive and nursery phases, while they require the marine environment for adult development and rapid growth (Mills 1991 in Hendry and Cragg-Hine 2003; Maitland and Hatton-Ellis, 2003). While stenohaline fish such as Pollan, the only whitefish species found in Ireland, spend their entire lifecycle in freshwaters.

Commercial fishing is an important activity within Northern Ireland. The three main landing ports are Ardglass, Kilkeel and Portavogie and the main processing centres are Kilkeel, Ardglass, Portavogie and Annalong. Approximately 1,300 people are employed in processes and marketing, with the 39 companies involved having an annual turnover of around £70 million (Atkins, 2004). Aquaculture is a growing industry and almost thirty sites are licensed for the cultivation of species including mussels, oysters and clams.

5.3 The Issue Now

Hot dry summers, combined with human activities such as abstraction, agriculture, river regulation etc., cause low flows in rivers and lakes (Hendry and Cragg-Hine, 2003). Low flows in turn can cause a host of direct physical and chemical problems, such as those outlined below, the combination of which often results in fish kills (Hendry and Cragg-Hine, 2003):

- Elevated fresh water, estuarine and marine temperatures.
- Lowered levels of dissolved oxygen.
- A reduction in wetted perimeter.
- Loss of spawning and juvenile rearing habitat.
- Increased intra-specific and inter-specific competition for habitat.
- Insufficient flows to draw adult fish back into their rivers or to allow fish passage over riverine obstacles such as weirs etc.

- Increased winter spates leading to increasing possibility of redd wash out and increased mortalities with salmon and trout fry emergence.
- Lowered water quality/increased risk of eutrophication.
- Higher sea temperatures may lead to greater success in European flat oyster spawning

High summer temperatures in Lough Neagh have a negative effect on the growth of its pollan population (EHS 2005b). High temperatures, combined with calm weather, sometimes cause deoxygenation of the bottom layers of the Lough. This reduces the quality of the deeper cooler summer refuge waters making living conditions difficult for the fish.

Flash floods bring during winter and spring may create difficulties for salmonids by washing away salmon eggs and alevins and eroding spawning beds (Crisp, 1995, in Hendry and Cragg-Hine, 2003).

5.4 How Climate Change May Affect the Future

Climate change in Northern Ireland is likely to manifest itself in a number of ways in relation to its fisheries and of all the major climate changes expected, the following are most likely to impact in Northern Ireland:

- Sea surface temperatures could rise between 1-2.5°C by 2080 (Hulme et al., 2002).
- Sea level itself is expected to be between 9-69cm by 2080 (Hulme et al., 2002).
- Precipitation is likely to be more variable, most likely causing summers to be drier and autumn, winter and spring periods to be wetter and more unpredictable (Hulme et al., 2002).

The combination of these factors will impact on the freshwater and saline environment and therefore on fish at various points during their life cycle. For each climatic change mentioned above, the likely impacts on the fish of Northern Ireland and the UK are addressed in the text below. Freshwater and saltwaters are separated out to allow the impacts to be shown for each.

5.4.1 Freshwater fisheries

5.4.1.1 Increased temperatures and drier summers

Higher summer temperatures are likely to exacerbate the current water quality problems highlighted in Section 5.3. Long term studies on marine survival of wild salmon in the R. Bush in Co. Antrim have indicated possible climate change driven mechanisms associated with decreased survival of salmon at sea. Decreases in cohort survival at sea from the late 1990s on correlate well with timing of smolt migrations, which have been occurring earlier than previously recorded, possibly as a result of higher winter average temperatures in fresh water. The differential between river and sea temperatures experienced by the early migrating smolts has been greater than usual as a result (Crozier and Kennedy, 2003), perhaps contributing to subsequently poor survival at sea.

Furthermore, increased winter temperatures could conceivably interfere with pollan spawning behaviour if climate change processes cause winter temperatures to rise further posing more problems for pollan survival (Harrod et al., 2001 in EHS, 2005b)

Low flows can also impact on fish communities, both directly and indirectly. An example of the latter would be where low flows cause negative impacts on macroinvertebrate populations, such as a reduced abundance through loss or a reduction of species preferring high flows. This will result in a decrease in food for fish, with detrimental effects for fisheries businesses (EA, 2004).

Salmonids (salmon and trout) may be impacted together with species of coarse fish. The upstream migration of salmon and trout primarily occurs when rivers are in spate, typically triggered by increases in flow (Hendry and Cragg-Hine 2003); low flows are likely to interfere with migration patterns. Solomon and Bambrook (2004) indicated that low river discharge associated with hot, dry summers delayed and in some instances prevented freshwater entry by returning adult salmon in South west England. Shifts in long term climatic conditions may impact on juvenile salmonid life stages. Swansberg et al., (2004) suggested that increases in air and water temperature were associated with smaller Atlantic salmon parr, which in turn may have relevance to subsequent survival rates. Cunjak et al., (1993) indicated that juvenile salmonids experiencing thermal stress tend to seek out cooler habitats and reduce feeding rates. As trout have a lower thermal tolerance than salmon it is also likely that they will be more seriously impacted if hotter summers become more frequent (Davidson Hazlewood and Cove, in press, in EA, 2005).

This being said, in a recent application of the Atlantic salmon growth model (Elliott and Hurley, 1997, in EA, 2005) to the currently predicted temperature profiles (Hulme et al., 2002) indicated under the 'low-emissions' climate change scenario, it was found that the growth of salmon in freshwater could generally improve over the next 100 years. Under the 'high emissions' scenario, however, where temperatures are predicted to exceed optimum levels for salmon by the latter half of the century, growth is likely to fall below current levels resulting in lower abundance and survival (EA, 2005). Effects are most severe in more southerly rivers in England, but even in more northerly rivers, perhaps more typical of Northern Ireland, size at age could fall well below that of recent years by the end of the century (EA, 2005).

5.4.1.2 Increased flooding

With the likelihood of more intense rainfall days in winter and spring it is predicted that there will be greater probability of an extreme rainfall event on any given winter day (Hulme et al., 2002). This could increase the current difficulties experienced by salmonids, through the wash out of redds or by displacement of alevins from streambed substratum (Elwood and Waters, 1969). Equally, despite adult shad appearing to favour spawning at relatively high discharge levels, if floods occur at the wrong time migration, and therefore spawning, appears to drop off. The general conclusion is that high flows are, therefore, likely to be detrimental to populations of allis shad. It is thought that high flows not only make it difficult for them to access spawning grounds, but also lowers recruitment after spawning, probably due to eggs and fry being swept downstream into the sea (Maitland and Hatton-Ellis, 2003).

5.4.2 Marine Fisheries

5.4.2.1 Sea level change

Estimates show that global mean sea level is expected to be between 9 and 69 cm by the 2080s (Hulme et al., 2002). This is resulting in part due to melting of the polar ice pack. Such melting is changing the temperature regime of the northern Atlantic which as a result may change the extent of thermally attractive habitat for salmon that prefer a water temperature of between 6 and 9°C.

5.4.2.2 Rising sea surface temperatures

Marine survival rates and the phase of the salmon, trout and shad life cycle that occurs in the sea is already causing concern due to recent declines in post smolt marine survival rates (Hendry and Cragg-Hine, 2003). The relationship between such declines and changes in their marine habitat are not, at present, clearly understood, but, as indicated above, current estimates on climate change indicate temperatures are likely to increase by 1 to 2.5°C.

One reason put forward as causing trout and salmon decline is this increasing sea surface temperature resulting in reduced areas of suitable habitat, through loss of the required cooler water areas, and therefore increased levels of intra-specific competition (Friedland and Reddin, 1993, in Hendry and Cragg-Hine, 2003) with other warmer water species.

Recent research tried to correlate temperature with post smolt growth patterns in order to indicate likely growth and potential survival during the marine life stage. The study found that sea surface temperature was poorly associated with post smolt growth patterns (EA, 2005). Rather than showing temperature to be unimportant, however, it is thought that the temperature variables in this study poorly represented the true influence on the salmonid biology (EA, 2005).

The effects of global warming on salmon in the sea cannot, therefore, yet be confirmed or ruled out.

One potential benefit for Northern Ireland is that some shellfish cultures may be better able to spawn allowing them to colonise new waters (West and Gawith, 2005) and creating the potential for alternative commercial opportunities. It may also have benefits for some native species such as the European flat oyster.

5.4.2.3 The North Atlantic Oscillation Index.

The North Atlantic Oscillation Index (NAOI) has been found to provide a generalised measure of climate variation for the northern hemisphere for more that the last one hundred years. Recent work from the River Foyle using a 126 year data set has shown that when the NAOI in winter is below 0.15 (i.e. negative) it can be used as a tool for predicting the size of returning adult Atlantic salmon populations. This may be attributed to the NAOI indicating changing thermal habitat optima available to the salmon (Boylan and Adams 2006).

Climate change models predict the NAOI is likely to increase with time, it is thought that one consequence of this is the likely reduction in the population size of returning salmon (Boylan and Adams 2006).

5.4.3 Conclusions

Physico-chemical conditions in the aquatic environment are predicted to become more adverse on a more frequent basis and this will impact on marine and freshwater fisheries. This is likely to cause species, such as salmon and trout, to be negatively impacted both in their juvenile and adult phases through the exacerbation of current climatic conditions.

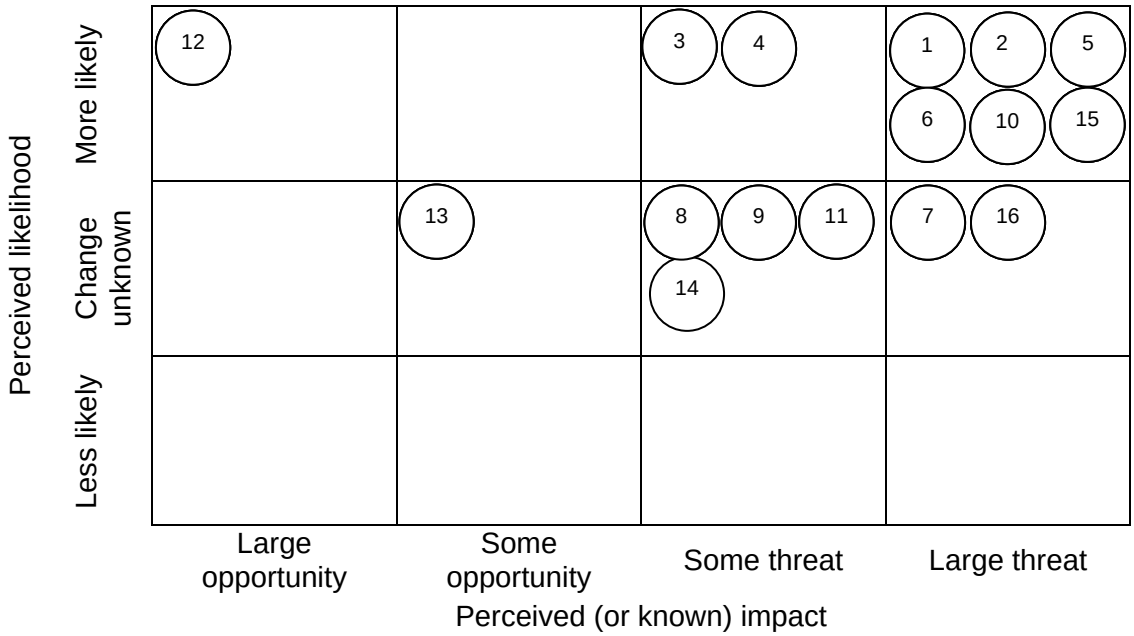
Marine species such as haddock and cod are also likely to be impacted and are likely to change in their distribution, this could have adverse consequences for the fishing industry.

The impacts of climate change on fisheries is summarised in Table 5.1.

Table 5.1 - Climate Change Impacts: Fisheries

Climate change	**Impact on receptor**
Wetter winters	Increased frequency flooding could lead to decreased fish egg survival and washing away of juvenile salmonids.
Drier summers	Lower flows, lower water quality and increased temperatures could lead to fish kills.
	Reduced stream flow could have negative impact on salmonid migration triggers.
	Loss of fly life and shifts in abundance/ecology of macroinvertebrates resulting from low flows could lead to less available fish food
Hotter summers	Increased temperatures in rivers lead to poor freshwater quality leading to fish kills.
	Increased temperatures can become lethal for some fish such as salmonids.
	Change in distribution of marine fisheries. Increased likelihood of spawning and settlement of cultivated non-native species such as the Pacific oyster, and the northward shift of north-south biogeographic species boundaries such as haddock and cod.
	Growth rates of salmonids could improve or decline depending on rate of temperature increases.
	Physiological processes such as gametogenesis (the development and maturation of sex cells through meiosis) other than growth may be affected by temperature change.
Sea level rise	The melting of the polar ice pack has cooled the northern Atlantic, reducing the extent of thermally attractive habitat for Salmonids.
Other (*stated)*	***Warmer waters (marine and freshwater):***
	Intertidal cultivated species may experience thermal stress as a result of temperature changes
	Benefits to aquaculture include higher growth rates and new species.
	Geographical differences in growth rates of salmon and trout could become more marked in the next few decades as temperatures rise.
	Inland fish possibly affected if land allowed to flood.
	Angling affected by disturbance of breeding season of fish.
	North Atlantic Oscillation:
	Sea level rise leading to a decline in sand eel populations in the Northern Atlantic and Irish sea

Figure 5.1 - Risk Assessment: Fisheries



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 5.2).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

5.5 Actions Undertaken or Underway and Key Gaps

There are also a number of bodies which do not have a formal role in fisheries, but whose activities can have a direct impact on this sector and these bodies include Rivers Agency and Environment & Heritage Service. Interwoven among the responsibilities of the above organisations is a network of voluntary organisations such as angling clubs, bodies such as the North Atlantic Salmon Fund, interested individuals including landowners and other organisations including commercial operations such as the Lough Neagh Fisherman's Co-operative.

Each of these bodies has an interest in the continued success of the fishery sector in Northern Ireland. However, while each of the above bodies has an interest in the continued success of fisheries, their various remits ensures that they follow paths which while in some areas are complimentary, in other areas are contradictory – for example hard engineering works carried out by Rivers Agency for drainage purposes may not always be in keeping with the aims of Environment and Heritage Service, Loughs Agency or Fisheries Conservancy Board.

A range of research is currently undertaken to determine the stock status and long term abundance trends of particular important fish species such as the long term stock-recruitment study of Atlantic salmon on the River Bush (conducted by DCAL/AFBI). At present, however there are limited individual research projects specifically focused on the likely impacts of climate change on particular species such as Atlantic Salmon (like that carried out by Loughs Agency). There is no overall research programme cutting across all the interested parties, nor is there an overarching strategy in place to assess the likely

impact of climate change on the particular Northern Ireland fisheries sector. Key gaps for this sector therefore are:

- Need for overview of research to ensure this is targeted and relevant
- Need for an overarching strategy to ensure that all the various interested parties in fisheries in Northern Ireland are made aware of and understand the likely implications (including opportunities) of a changing climate.

5.6 Adaptation Strategies

Species of economic importance within Northern Ireland include salmonids such as the Atlantic salmon, brown trout and sea trout and sea fisheries species such as mollusc and crustacean shellfish such as mussels, prawns, scallops clams and oysters. There are also a number of species significant in terms of biodiversity such as Pollan. Adaptation strategies should therefore aim to protect these key species.

5.6.1.1 Freshwater fisheries

- For species such as Pollan climate change per se may be beyond local control, once introduced species such as roach and zebra mussels are present they are practically impossible to control (as can be seen with the situation with Zebra Mussels in Lough Erne). However, the dominating effects of alien species on native aquatic biodiversity, and even some impacts of climate change, may be minimised if enrichment is abated and the lakes move towards their original trophic state.
- Ensure conservation limits for Atlantic salmon and other species of conservation concern are maintained in order to maintain stock levels.

5.6.1.2 Marine fisheries

- Need to research new target species to prevent overfishing these new stocks.
- May be necessary to replace or modify fishing gear in order to exploit different suites of species.
- May need to diversify further the range of fish stocks exploited by the industry in order to minimise risk of overfishing any single species.
- Fishing port facilities and river management programmes will also need to be considered.

5.7 Conclusions and Recommendations

Within Northern Ireland, fisheries, both freshwater and marine, are an important economic and social activity. Within the freshwater sector, angling provides a recreational activity for many people from all sections of society and there is also important economic activity through activities such as tackle and bait dealers, licence payments, accommodation providers, boat hire and a number of freshwater fisheries operating on the ‘catch and pay’ principle. There are also larger scale commercial operations, most notably the eel fishing on Lough Neagh and associated processing plant at Toome and several fish farms.

Within the marine environment, there are three main ports, with approximately 1,300 people employed in processing and marketing and a market value in 2004 of c.£70 million.

It is likely that climate change will impact on both the freshwater and saline environments and therefore on fish at various points in their life cycle. Although salmon fisheries may be impacted by low flows under a changing climate, recent modelling suggests that climate change may also provide benefits through more preferential changes in water temperature. Increased risk of flooding and flood intensity may also impact on key habitats and life stages.

The principal gaps appear in relation to marine fisheries, where there is a need to ensure that strategic planning allows for recognition of potential changes in, and requirements of, key species and changes to conservation targets linked with changes in marine fishery strategies. There are a number of potential impacts across sectors, between biodiversity, conservation, fisheries and tourism that will require closer integration of strategic planning and policies.

It should be noted that recommendations made for other sectors will have implications for the fisheries sector, but there are sector specific recommendations for fisheries as follows:

- Further research: both into the impacts on specific species and on fisheries in general, focusing particularly on the Northern Ireland context and concentrating (at least in the short term) on more valuable species for both biodiversity and economic reasons.
- Research should also be undertaken into the potential for exploitation of new target species in the marine environment and how any impacts on these species may be affected by a changing climate. This research will need to address broader issues involved in the exploitation of new species, such as consumer tastes.
- A review of the physical facilities available for fishing e.g. ports or river structures (including management programmes) should be made in light of the potential impacts on these facilities from a changing climate.

Table 5.2 - Impacts and Adaptation Summary: Fisheries

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risks	Resource implications	Adaptation strategy^	Responsible public sector body
1	Increased frequency flooding could lead to decreased fish egg survival and washing away of juvenile salmonids.	Conservation;	Implication for the health of designated species.	Major threat	Staff time and costs.	*Factor climate change into biodiversity and habitat action plans.* Include adaptation to climate change in the management objectives and strategies of conservation areas Create and restore buffering zones and habitat mosaics around conservation areas Ensure conservation limits for Atlantic salmon and other species of conservation concern are maintained in order to maintain stock levels.	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
2	Lower flows leads to lower water quality and can lead to fish kills.	Conservation; Water Supply	Negative effect on Water quality	Major threat	Staff time and costs.	Where possible improve water quality of rivers	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
3	Reduced stream flow could have negative impact on salmonid migration triggers.	Conservation; Water Supply	Implication for the health of designated species.	Minor threat	Staff time and costs.	Ensure conservation limits for Atlantic salmon and other species of conservation concern are maintained in order to maintain stock levels.	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risks	Resource implications	Adaptation strategy^	Responsible public sector body
4	Loss of fly life and alteration of / to macroinvertebrate ecology resulting from low flows may lead to less available fish food	Conservation; Water Supply	Implication for the health of designated species.	Minor threat	Staff time and costs.	Where possible improve water quality of rivers Ensure conservation limits for Atlantic salmon and other species of conservation concern are maintained in order to maintain stock levels.	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
5 / 6	Increased temperatures in rivers lead to poor freshwater quality leading to fish kills.	Conservation; Water Supply	Negative effect on Water quality	Major threat	Staff time and costs.	Manage abstraction regimes to try and prevent increases in water temperature.	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
7	Change in distribution of marine fisheries. Increased likelihood of spawning and settlement of cultivated non-native species such as the Pacific oyster, and the northward shift of north-south biogeographic species boundaries such as haddock and cod.	Conservation;	Impact on fishery industry	Major unknown risk	Staff time and costs.	*Need to research new target species to prevent overfishing these new stocks.* May be necessary to replace or modify fishing gear in order to exploit different suites of species. May need to diversify further the range of fish stocks exploited by the industry in order to minimise risk of overfishing any single species. *Fishing port facilities and river management programmes will also need to be considered.*	Loughs Agency DARD EHS Natural Heritage
8	Growth rates of salmonids could improve or decline depending on rate of temperature increases.	Conservation;	Could impact positively or negatively on fly fishing. Implications for health of salmonid populations	Minor unknown risk	Staff time and costs.	*Monitoring of salmonid population in relation to temperature change.*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risks	Resource implications	Adaptation strategy^	Responsible public sector body
9	Physiological processes such as gametogenesis (the development and maturation of sex cells through meiosis) other than growth may be affected by temperature change.	Conservation;	Implications for health of salmonid populations	Minor unknown risk	Staff time and costs.	*Monitoring of salmonid population in relation to temperature change.*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
10	The melting of the polar ice pack has cooled the northern Atlantic, reducing the extent of thermally attractive habitat for Salmonids.	Conservation;	Implications for health of salmonid populations	Major threat	Staff time and costs.	*Monitoring of salmonid population in relation to temperature change.*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
11	Intertidal cultivated species may experience thermal stress as a result of temperature changes	Conservation;	Impact on shell fishery industry	Minor unknown risk	Staff time and costs.	*May need to research new species to prevent overfishing existing stocks*.	Loughs Agency DARDNI EHS Natural Heritage DARD
12	Benefits to aquaculture include higher growth rates and new species.	Agriculture	Impact on fishery industry	Major opportunity	Staff time and costs.	May be necessary to replace or modify fishing gear in order to exploit different species.	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries DARDNI EHS Natural Heritage DARD

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risks	Resource implications	Adaptation strategy^	Responsible public sector body
13	Geographical differences in growth rates of salmon and trout could become more marked in the next few decades as temperatures rise.	Conservation;	Could impact positively or negatively on fly fishing. Implications for health of salmonid populations	Minor unknown risk	Staff time and costs.	*Monitoring of salmonid population in relation to temperature change.*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
14	Inland fish possibly affected if land allowed to flood.	Conservation;	Reduced angling potential	Minor unknown threat	Staff time and costs.	*Raise awareness*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage
15	Angling affected by disturbance of breeding season of fish.	Conservation;	Reduced angling potential	Major threat	Staff time and costs.	*Raise awareness*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL Inland Fisheries EHS Natural Heritage DARD
16	Sea level rise leading to a decline in sand eel populations in the Northern Atlantic and Irish sea	Conservation;	Implication for the health of sea bird species – tourism could be affected.	Major unknown threat	Staff time and costs.	*Monitoring of sand eel population in relation to sea level change.*	Loughs Agency Fisheries Conservancy Board (FCB) DCAL EHS Natural Heritage DARD

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

6 AGRICULTURE

6.1 Scope

This chapter of the report considers the potential impacts on Agriculture in Northern Ireland. The chapter provides an assessment of how climate change may affect the future of Agriculture and details some of the likely impacts facing Crops, Intensive Grass Production, Livestock and Farm Management from a changing climate as well as provides an assessment of likely adaptation strategies. For further details on associated topics see Fisheries, Forestry, Water Resources and Business.

6.2 Background

Within Northern Ireland, agriculture (and agri-food business) is of major importance, both in a social and an economic context. 7% of the workforce is employed directly in agriculture, with another sizeable proportion employed in sectors such as food processing which are dependent upon agriculture. The total value of this economic activity is in excess of £3.0 billion (DARD – Northern Ireland: An Overview, August 2004) and as such is a major mainstay of the local economy. Consequently the potential impacts of climate change on agriculture in Northern Ireland have major implications for the whole of the local economy.

It should be noted that agriculture within Northern Ireland is not in a 'steady state' in that it has experienced a process of continual change over the last 150 years i.e. since famine times. This process of change is illustrated by details of Crop areas and Livestock Numbers in Northern Ireland, taken from agricultural census data 1854 – 2004 (quoted in the Northern Ireland Agricultural Census 2004). The data shows how Northern Ireland has changed from a mixed farming economy to one dependant upon grazing livestock:

Table 6.1 - Crop Areas and Livestock Numbers, 1854-2004

	1854	**1904**	**1954**	**2004**
Crop Areas ('000 ha)				
Cereals	264	154	113	38
Potatoes	93	71	53	6
Flax	36	14	4	0
Hay and Pasture	651	804	717	838
Livestock ('000 head)				
Cattle	706	811	942	1678
Sheep	215	360	930	2225
Horses	n.a.	117	30	9
Pigs	247	219	820	424
Poultry	1718	4551	11386	20509

While the changes detailed above are due to many factors (for example the decline in horse numbers is likely to be due to increased mechanisation), it shows that there is an ability within agriculture to adapt to changing circumstances over time and that the agricultural industry is likely to be able to adapt to any potential threats, as well as take advantage of any potential opportunities presented by a changing climate over a similar time frame.

6.3 The Issue Now

While Northern Ireland tends not to get the extreme weather events experienced elsewhere, there is enough variability in weather conditions to still cause difficulties for agriculture on occasion. In recent years, agriculture has been impacted by periods of both wet and dry weather. For example in winter 2002 – 2003, farmers had significant difficulty in harvesting potato and other root crops due to water logging in fields (Climate, Weather and Irish Agriculture, AGMET 2004). On the other hand a lack of rainfall over the summer months (June, July and August) of 2006 caused difficulties in growing grass for silage, though mild autumnal weather extended the traditional silage cutting season into October (BBC Northern Ireland News Website).

There are various procedures for dealing with adverse weather conditions at present. The Department of Agriculture and Rural Development (DARD) issues management notes each month and these detail procedures for dealing with weather conditions at that particular time.

While there are no specific compensation measures within Northern Ireland for compensating farmers for severe weather events, there are mechanisms in place by which compensation may be paid on an ad hoc basis. An important source of compensation is through the Government paying state aid to farmers, after the government has made a case to and obtained agreement with the European Union. This process is very complex in that the EU needs to be convinced that the state is not giving illegal state aid and a case needs to be made that shows that production has fallen across Northern Ireland in relation to previous years and this has to be correlated with weather data. It is also the case that not all sectors of agriculture will receive aid as there may be sectors which were not impacted by the weather, depending upon when the severe weather occurred. It should be noted that this methodology is only used on occasion in Northern Ireland as weather events tend not to be severe enough to reduce production sufficiently. Payments are in the process of being made for weather disruption in 2002 and these are the first payments since the mid 1980's (telephone conversation between Atkins and DARD).

Financial relief can also be provided to farmers after severe weather by the issuing of normal grants earlier than would be usual – this though would not be seen as compensation and again is provided on an ad hoc basis, with cases having to be made after any severe weather. This method is likely to end under the Single Farm Payment scheme.

From consultation with representatives of the farming community and elsewhere, there are a number of issues that the agricultural sector is facing at present which are felt to be at least as important to this sector as climate change, if not more so. These other issues include:

- Single Farm Payment and other CAP reform
- Nitrates Directive and other EU Legislation / Policy
- Problems with beef exports
- Environmental schemes
- Planning Issues e.g. issues surrounding new draft PPS 14 'Sustainable Development in the Countryside'
- Animal health issues
- Abandonment of upland areas
- Rural development

6.4 How Climate Change May Affect The Future

Contained within the National Farmers Union document 'UK Agriculture and Climate Change' (NFU, 2005) is the following table which it is considered worth including here as it gives an overall 'flavour' of potential impacts on agriculture in the United Kingdom from a changing climate. It should be noted though that these impacts may be experienced in some parts of the UK only e.g. south-east England and not necessarily Northern Ireland.

Table 6.2 - UK Agriculture and Climate Change

Climate Changes (based on UKCIP 02)	**Possible impacts on agriculture in the UK (based on UKCIP02)**
Carbon Dioxide levels: • Increase in CO_2 levels	• Potential stimulated photosynthesis and yields (e.g. potatoes, wheat and forage) • Change the quality or composition of crops and grasslands (e.g. grapevines)
Temperature • Temp. increase of 1-2^{o}C in winter and 1.5-3^{o}C in summer by the 2050's (this effect is regionally variable & is based on high emissions scenario) • Increases in the number of 'hot' ($\geq$20^{o}C) and 'very hot' ($\geq$ 27^{o}C) days • Marked decline in the number of frosts • Growing season will lengthen	• Increased / change in range of native / alien pest & disease problems (e.g. potato blight, Fusarium) • Reduced vernalisation (cold winter weather required for flowering) • Leave animals in fields for longer/housing period decreased • House design changes; cooling and ventilation system installation, increasing costs to minimise heat stress, increased need for shade • Increased grazing opportunities in winter especially on freer draining soils • Damaged crops (e.g. wheat, salad crops) at extreme temperatures • Heat benefits some crops (onions, legumes, carrots and sweetcorn) • Changes in crops grown (diversification into sunflowers, navy beans, lupins, borage, apricots, walnuts, peaches, grapevines & evening primrose, most notably in SE), less frost damage • Change in crop range within UK (e.g. maize production move north • Lengthening of growing season leading to a greater availability of UK grown produce throughout year (e.g. soft fruit).
Precipitation • Decrease in summer rainfall	• Drop in some crop yields • Increased irrigation needs and changes in methods (e.g. potatoes)

Climate Changes (based on UKCIP 02)	**Possible impacts on agriculture in the UK (based on UKCIP02)**
• Increase in winter rainfall (regionally variable)	• Decrease in summer soil moisture • Changed poaching / water logging risk in some areas • Late harvest problematic (e.g. increased drying costs & working on wet ground) • Increased housing needed for livestock • Increase in drainage systems • Increase in wet weather related animal health problems / pest & disease problems
Weather extremes • Increased frequency of extreme events such as droughts & high temperatures, torrential rains & very strong winds	• Crop damage / total crop loss (e.g. lodging of wheat, unharvestable fields) • Damage to agricultural buildings / changes in building specifications • Changing cropping practices • Increased soil erosion • Lack of grazing in drought events • Increased heat stress in livestock • Increase in housing needed for livestock
Sea level rise • Increase in sea level	• Loss of coastal, estuary and floodplain agricultural land • Erosion of land and salinisation of ground water
Multiple Changes	• Increase in cost and range of insurance • Increasing diversification • New skills training / differing agricultural workload • Change in agricultural markets, demand and competition

From NFU (2005).

The various climate change scenarios provide a number of threats, as well as opportunities to agriculture in Northern Ireland, with those involved in agriculture being forced to adapt their practices in order to accommodate any new risks, as well as take advantage of the new opportunities. There will be a financial cost implication in meeting these changed circumstances.

As discussed, the various potential impacts detailed in the table above apply to the United Kingdom as a whole and may not necessarily apply to Northern Ireland. In the case of Northern Ireland, it is anticipated that for the main agricultural areas, impacts are likely to be as detailed below. It should be borne in mind though that the following are generalisations of the main agricultural activities in Northern Ireland. The precise impacts of climate at present and in the future on these activities are difficult to quantify accurately as agriculture is (and will continue to be) influenced by many factors such as management, market forces, subsidy payments and agricultural policy (Climate Change

Indicators for Ireland, Environmental Protection Agency 2002). Other complex environmental factors will also play a part in influencing future agricultural activities and therefore add to the difficulties of predicting future responses to climate change.

6.4.1 Crops

It is likely that crops such as barley and maize will continue to be viable to grow and yields may increase. Forage maize may become a valuable alternative to silage and grain maize will begin to displace other cereals. This may be enhanced by an increase in the production area as temperatures rise and conditions may allow the introduction of new warm weather varieties (it was suggested in the BBC Northern Ireland Website on 18/10/06 that this may already be happening in Northern Ireland). The cereal harvest could occur up to a month earlier than at present.

Potatoes could become uneconomic to grow without irrigation in the late summer months and crop yields may decline. Increased rainfall in late autumn / early winters may cause problems for harvesting.

Increased rainfall levels, or decreases in frost occurrence / severity could encourage pests and disease for all crops. However, it is not possible with currently available data to assess the change in prevalence of blight and other fungal pathogens. It is anticipated that chemical intervention will increase with climate change (Climate, Weather and Irish Agriculture, AGMET 2004).

While artificial irrigation systems are not generally associated with agriculture in Ireland (particularly in the north), it may become necessary for farmers to introduce these – particularly for crops such as potato during the summer months. Some systems have been introduced and it is thought that this may have been initiated after the 1995 drought (Climate Change Indicators for Ireland, Environmental Protection Agency 2002). Introduction of irrigation systems would therefore be a capital cost implication for agricultural businesses.

There is a potential that in future ‘exotic’ crops such as soybean may be suitable for growing, though of course the value of growing such crops will be dependant on other factors such as economic conditions, grant schemes etc, both in Northern Ireland and elsewhere.

It is also worth noting that the impacts on yield and yield quality varies between crops, cultivars and even plants. There is likely to be a need to develop new cultivars to cope with climate change. However, predictions of effects on individual crops are hampered by uncertain scenarios of climate change and the lack of experiments on the interactions of extreme temperatures, CO2 enrichment and water stress, (DEFRA Climate Change & Agriculture in the United Kingdom) as well as the impact of the multitude of various other influences and their interaction on agricultural production. It should be borne in mind that over the last few decades many crops have increased their yields due to improved management. If this rate of improvement continues in the future, the effects of these gradual improvements are likely to outweigh the effects of climate change (DEFRA Climate Change & Agriculture in the United Kingdom).

6.4.2 Intensive Grass Production

While within the United Kingdom as a whole, grassland accounts for more than 70% of the farmed land, the percentage is much higher in Northern Ireland. Within Northern Ireland, the production of hay and silage from grass is the main supply of winter fodder for

livestock. The variables likely to have the most direct effect on grass are CO2 concentration, temperature and rainfall (DEFRA Climate Change & Agriculture in the United Kingdom).

It has been shown in some areas that an increase in temperature can cause a decrease in soil moisture and a decline in the grass yield. Therefore if temperatures rise, with no change in rainfall patterns, then yields will fall in Northern Ireland. This situation would be exacerbated by a decrease in summer rainfall. Conversely if rainfall and temperature increase, yields could be maintained or increased. It is also possible that some areas which are not ideal for intensive grassland (e.g. upland areas), may become more suitable under a changing climate.

Yields may also increase due to a direct fertilising effect of increased atmospheric CO2 coupled with increasing temperatures, though precise interaction with water supply and other environmental variables are unknown at present (Climate Change Indicators for Ireland, Environmental Protection Agency 2002). It should also be borne in mind that while increased CO2 may enhance primary production it may also lead to changes in leaf / sheaf ratio, reduced nitrogen and increased fibre content and therefore have an overall reduction in dietary quality (DEFRA Climate Change and Agriculture in United Kingdom). A further complicating factor is the fact that most grass swards contain a mix of species which will have differential responses to changes in temperature moisture and CO2 concentration.

It is possible that changes in climate could lead to some areas of the United Kingdom being invaded by weed species not native to those areas. This may have implications for Northern Ireland.

6.4.3 Livestock

The growth, reproduction, behaviour and health of farm livestock are influenced both by the environment in which they live and by their genetic makeup. Climatic variations and change have direct effects on livestock appetite and health (DEFRA Climate Change and Agriculture in United Kingdom). For example while factors such as the climatic change impact on grass production will have an indirect influence on livestock, an example of a potential direct effect may be that turnout dates of cattle become earlier.

Other direct effects could include aspects such as increased mean temperatures leading to increased heat stress on animals in the field, housing or during transportation. Conversely decreased winter temperatures could reduce the risk of cold to animals – particularly young animals.

Reduced rainfall levels may also put pressure on drinking water for livestock – farmers may also face increased competition for water supply as domestic consumption continues to grow in more highly urbanised regions.

Increased rainfall levels may change grazing regimes as grazing in wet conditions can damage soil structure and impact grass growth. A requirement to house livestock for longer due to poor ground conditions would raise important questions relating to slurry storage and spreading.

Livestock may also suffer increased incidences of pests and disease e.g. tick borne disease due to milder winters, with less frost and increased temperatures. Many of the effects of climatic variability on animal health are indirect. Changes in temperature, humidity and wind may reduce immunity and the efficacy of vaccination.

A further indirect impact of raised temperatures on housed animals is due to the possibility of increased rates of production of ammonia and other gases by microbes in slurry (Climate Change and Agriculture in United Kingdom).

6.4.4 Farm Management

When considering climate change and its impact on agriculture it is important to note that the impact of climate change on farming cannot be determined in isolation – soils, climate, markets, technology, capital and policy all influence the type and location of farming (Climate Change and Agriculture in United Kingdom). It should also be noted that as with many other sectors, farming in Northern Ireland is increasingly exposed to world markets and therefore the impact of climate change on a global scale and the impacts this has on global production can have an impact on local competitiveness.

Changing patterns of diet – perhaps enhanced by climate change as warmer weather may increase demand for 'lighter' foods such as salad crops at the expense of 'heavier' cooked vegetables will also help to change agriculture in Northern Ireland as demand for particular products changes.

New technology may allow the main adverse impacts of climate change to be mitigated, while allowing the positive benefits to be exploited to a greater degree. The extent to which this may be possible is unclear at present, but has clear implications for farm competitiveness. Similarly the future cost of farming equipment and its design may change due to changing needs of farmers, but due to the return period required for capital expenditure, there are further clear implications for farming costs.

6.4.5 Overview

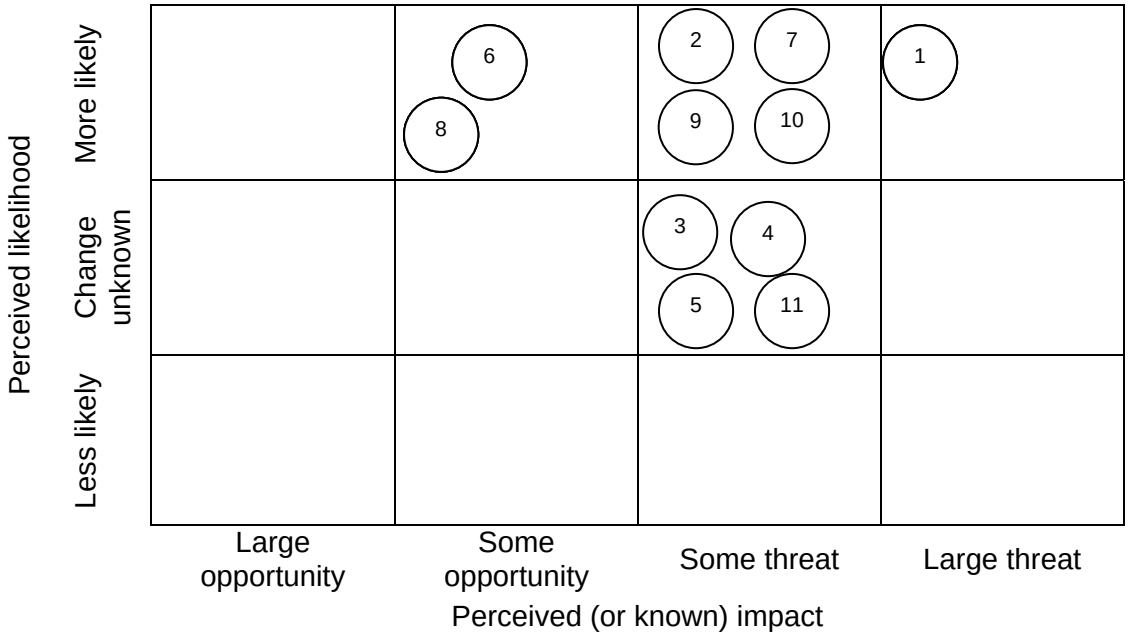
The impacts of specific changes in climate on agriculture are summarised in Table 6.3.

Table 6.3 - Climate Change Impacts: Agriculture

Climate change	Impact on receptor
Wetter winters	Potential drop in some crop yields. Greater difficulties in accessing fields (water logging) – problematic harvesting and ground preparation Increase in wet weather animal health problems Pest & disease problems Impact on drainage systems
Drier summers	Potential impacts on crop yields Increased need for irrigation and change in farming methodology e.g. for potatoes. Potential for new crops or crop varieties to be introduced. Increased need for greater water supply – cost implication.
Warmer winters	Increased change in range of native / alien pest & disease problems e.g. potato blight. Chemical intervention may increase. Reduced vernalisation Animals can be left in fields for longer / housing period decreased. Increased grazing on freer draining soils

Climate change	Impact on receptor
	Reduction in frost damage Lengthening of growing season
Hotter summers	Potential need for greater ventilation / cooling systems in animal housing. Increased need for shade Heat may benefit some crops, though may damage others
Sea level rise	Loss of coastal, estuary and floodplain agricultural land – major implications for polder areas at Lough Foyle. Erosion of land and salinisation of ground water.
Reduced soil moisture	Possible increase in crop stress, with implications for yield e.g. grass yield. Further implications in NI of providing winter fodder due to reduced silage crop.
Change in Storminess	Increased crop damage Increased soil erosion Damage to agricultural buildings / changes in building specifications
Other	Potential implications for farm management – though note there are many other factors such as grant schemes, government policies, consumer patterns etc.

Figure 6.1 - Risk Assessment: Agriculture



The numbers in the above matrix relate to generalisations of the identified potential climate impacts on agriculture as detailed in Table 6.3. These generalisations are as follows:

1 = Wetter Winters – Field drainage issues
2 = Wetter Winters – Physical damage to crops
3 = Wetter Winters – Disease to crops

4 = Wetter Winters - Disease to animals
5 = Dry Summers – Physical damage to crops
6 = Dry Summers – Introduction of new crops
7 = Dry Summers – Need for irrigation
8 = Warm Winters – Increased length of growing season
9 = Hotter Summers – Need to keep livestock cool
10 = Sea Level Rise – Loss of coastal areas
11 = Change in Storminess – Damage to agricultural Buildings

Please note that the impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are considered to be of the same significance.

6.5 Actions Undertaken or Underway and Key Gaps

Due to the nature of agriculture, with the sector being made up of numerous individual privately owned businesses, it is difficult for the sector to meet challenges to it in a coherent and cost effective manner. Often new technologies, procedures and even new ideas can be difficult to introduce into businesses which are often small, family concerns. Within agriculture in Northern Ireland today, there is a growing part time aspect, with a demographically aging workforce in many areas. As with any sector in which the workforce contains a strong element of a demographically aging profile, it is perhaps not unreasonable to suggest that many members of this community will be sceptical of the concept of climate change (borne out through verbal conversation with the farming community representatives). This may make moves to introduce new adaptation strategies difficult. Having said that it is also clear that there are many farmers within Northern Ireland who are aware of climate change and who would be proactive in their approach to dealing with its challenges. This realisation of climate change and the need for adaptation to it is borne out by remarks by Joe McDonald of the Ulster Farmers Union quoted in the BBC Northern Ireland Website (18/10/06) when he said “some predictions seem to suggest wetter and windier weather and dryer summers – that changes things in farming. In the West of the province they get more rainfall, so farmers are not looking forward to even wetter winters”. Mr McDonald went on to explain that maize (which is normally grown in areas such as mainland Europe with higher sunshine levels) was being grown more widely in Northern Ireland. Mr McDonald explained further the issue of farm diversification due to climate change and that “we will see more areas of land dedicated to this type of thing (new diverse crops) in the years to come”. Overall, it is likely that the farming communities attitudes to climate change accurately reflect the attitudes of the general public from which they come – therefore strategies to change the public perception of climate change are likely to bear fruit with the farming community.

The agricultural sector is also heavily regulated at present – indeed there is a sense among the sector that it is over regulated and that the industry has had to endure a period of change and challenges that have driven many businesses to fail. Many of these regulations have been derived from and driven by national or European legislation and policies. These though are effective methods for driving new strategies across a sector that is as diverse in members as agriculture. It is likely that any future strategies would need an element of ‘carrot and stick’ in order to gain widespread acceptance across the sector. It is likely that government (through DARD, EHS and other similar bodies) would be required to provide guidance and incentives for preparing for climate change.

6.6 Adaptation Strategies

There are a number of adoption strategies that can be undertaken specifically by the agricultural sector in order to prepare for a changing climate. It is likely that while these should be suited directly to the climate scenario for Northern Ireland, they will be based on strategies and measures adopted / to be adopted in Great Britain and elsewhere in Ireland. These could include the following:

- Research into new crop varieties that will be able to cope with the particular anticipated climate of Northern Ireland. These new varieties will need to be economically viable. Research may be available from other countries (CLA Climate Change Working Group - Climate Change and the Rural Economy) and use should be made of this.
- Shifting crops or livestock to areas with the best conditions for efficient production – this may involve greater use of upland areas, or areas that have been previously considered and designated in Northern Ireland as 'less favourable'.
- Changes to farming practice and timings that will optimise rates of production. This would apply to both crops and livestock.
- Introduction of existing crops that have been previously unviable in Northern Ireland.
- Adoption of new technologies, or systems that have not been used on a large scale in Northern Ireland to date e.g. more widespread irrigation may become necessary.
- Increased and improved monitoring surveillance of arable and livestock pests to ensure that pests not native to Northern Ireland are not introduced or able to gain a foothold.
- Education for the members of the agricultural sector on the impacts of climate change and the opportunities that this may provide.

For all of the above, it is vital that the necessary training and support mechanisms are put in place in order to aid the agricultural sector. Given that climate change is anticipated to be a gradual phenomenon, over the coming decades, there is likely to be time and scope for appropriate mechanisms to be put in place. The farming community has demonstrated in the past that it is flexible and willing to change, though the rate at which future adaptation to climate change needs to take place and the manner of the change is still open to debate due to the uncertainties remaining in our understanding of climate change. Therefore there is a need for adaptation strategies to be constantly reviewed and updated in light of any increased understanding of climate change.

6.7 Conclusions and Recommendations

Within Northern Ireland, agriculture is of major importance in both an economic and a social context. Due to the number of people employed in this sector and the value of their activity, the potential impacts of climate change on agriculture have major implications for both the local economy and the social fabric of Northern Ireland.

Agriculture is not in a 'steady state' and it has been shown that agriculture has the ability to change to changing needs and circumstances. This ability to change means that the agricultural industry is likely to be able to adapt to any potential threats, as well as take advantage of, any potential opportunities presented by a changing climate.

When considering the potential impacts of a changing climate on agriculture it needs to be borne in mind that the impact of climate change can not be determined in isolation. Issues

such as soils, markets, technology, capital and policy all influence the type and location of farming. Agriculture also increasingly operates on a global scale and therefore the impacts of climate change at this level can impact on agricultural competitiveness at the local level. There are therefore a number of issues in relation to a changing climate and its impact that need to be addressed before agriculture in Northern Ireland can meet the challenges ahead in a proactive and efficient manner. It is recommended therefore that in the short term, the following issues are analysed in order to produce cost effective and efficient policies that can help address the challenges:

- Sector specific research: to undertake a detailed review of climate change research for the Northern Ireland agriculture sector, changes in agricultural policy and practices, and a sector-specific risk assessment to identify areas where local agriculture may benefit from a changing climate, as well as methods that may be introduced to mitigate the worst aspects.
- Education and awareness: as well as delivering the results of the research, education could be used to drive new techniques and methodologies. As with research, the education needs to be relevant to the local, Northern Ireland, scenario. While this education could be based on that given elsewhere, there needs to be a local 'twist'. This will help ensure that it is relevant and understood by the local community – it is also likely to be better received if people can immediately see the local relevance. A review therefore of what education would be appropriate should be taken in the first instance and resources should be made available for this. It may be that in the short term, education to help reduce the potential scale of climate change (e.g. in energy efficiency) which would benefit the farmer immediately as well as provide long term benefits may be appropriate. In the more long term, educational needs could evolve as the impacts of a changing climate become clearer.

In the medium to longer term, the outcome from these recommendations will help ensure that potential changes in farming practices remain sustainable in the face of a changing climate. Inevitably, there will need to be a degree of flexibility in response to provide the necessary changes in priorities if future models show that climate change is progressing at a greater or lesser rate or that the impacts will be of a greater severity.

Table 6.4 - Impacts and Adaptation Summary: Agriculture

Ref.	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Potential drop in some crop yields.	Food supply Business support	Food security Higher food bills in public hospitals / prisons / armed forces / public body staff canteens. Impact on import / export of food levels – balance of payments.	Minor Threat	Research required Research into yields	Change in menus? *Change in procurement policies*	Cuts right across all public bodies involved in food supply; DARD; Treasury.
2	Greater difficulties in accessing fields (water logging) – problematic harvesting and ground preparation	None	N/A - Impact on individual farmers	Major Threat	N/A	N/A	N/A
3	Increase in wet weather animal health problems	Business support Veterinary services	Potential need for grant aid	Minor Unknown	Research required. Greater chemical intervention required.	*Review of animal health reporting procedures in light of potential increase.* Potential increase in need for housing animals during wet weather.	DARD Veterinary Service
4	Pest & disease problems	None	N/A - Impact on individual farmers	Minor Threat Unknown	Research required		DARD Veterinary Service
5	Impact on drainage systems	Watercourse management	Potential capital expenditure for bodies responsible for features associated with watercourses e.g. bridges	Major Threat	Greater maintenance required. Potential impact on 'hard engineering' features such as bridges etc from higher flows.	*Review of procedures for engineering design, inspections etc.*	DARD Rivers Agency DRD Roads Service Waterways Ireland
6	Increased need for irrigation and change in farming methodology e.g. for potatoes.	Water Supply	Potential need for grant aid.	Minor Threat	Increased demand on water	Reduction in leakage. Identification of and	DRD Water Service EHS DARD Rivers

Ref.	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
					resources	bringing online new sources of water.	Agency
7	Potential for new crops or crop varieties to be introduced.	Business support	Potential need for grant aid to develop new markets	Minor Opportunity	Research required into what crops could be economically viable	*Investigation of new markets for new crops.* Marketing of these new crops.	DARD
8	Increased need for greater water supply – cost implication	Water supply Business support	Increased cost implication for water consumers. Increased pressure on features of water supply – lakes etc.	Minor Threat	Increased demand on water resources	Reduction in leakage. Identification of and bringing online new sources of water.	DRD Water Service EHS DARD Rivers Agency
9	Increased change in range of native / alien pest & disease problems e.g. potato blight. Chemical intervention may increase.	Business support	Potential need for grant aid	Minor Threat Unknown	Research required	*Education in correct application of chemicals etc.*	DARD
10	Reduced vernalisation	None	N/A - Impact on individual farmers	Minor Threat	N/A	N/A	N/A
11	Animals can be left in fields for longer / housing period decreased	None	N/A - Impact on individual farmers	Minor Opportunity	N/A	N/A	N/A
12	Increased grazing on freer draining soils	None	N/A - Impact on individual farmers	Minor Opportunity	N/A	N/A	N/A
13	Reduction in frost damage	None	N/A - Impact on individual farmers	Minor Opportunity	N/A	N/A	N/A
14	Lengthening of growing season	None	N/A - Impact on individual farmers	Minor Opportunity	N/A	N/A	N/A
15	Potential need for greater ventilation / cooling systems in animal housing.	Business support	Potential need for grant aid	Minor Threat	Research into building design	N/A	DARD
16	Increased need for shade	Business support	N/A - Impact on individual farmers	Minor Threat	N/A	Increased planting of trees in hedgerows, side of buildings etc.	N/A
17	Heat may benefit some crops, though may damage others	Food supply	Food security Higher food bills in public hospitals / prisons / armed forces / public body staff canteens. Impact on import /	Minor Unknown	Research required Research into yields	Change in menus? *Change in procurement policies*	Cuts right across all public bodies involved in food supply; DARD; Treasury.

Ref.	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
			export of food levels – balance of payments.				
18	Loss of coastal, estuary and floodplain agricultural land – major implications for polder areas at Lough Foyle.	Land management	Impact on councils and other bodies who maintain 'hard engineering' at coast. Loss of / damage to facilities such as railway lines, roads etc.	Minor Threat	Greater requirement for maintenance crews.	*Review of need for engineered structures at coast. Research into concept of 'managed retreat' and its applicability to NI.*	Land owning public bodies e.g. Councils, DRD
19	Erosion of land and salinisation of ground water.	Water supply Land management	Impact on councils and other bodies who maintain 'hard engineering' at coast. Loss of / damage to facilities such as railway lines, roads etc.	Minor Threat	Greater requirement for maintenance crews.		Land owning public bodies e.g. Councils, DRD
20	Possible increase in crop stress, with implications for yield e.g. grass yield. Further implications in NI of providing winter fodder due to reduced silage crop.	Food supply Animal Food supply Business support	Food security Higher food bills in public hospitals / prisons / armed forces / public body staff canteens. Impact on import / export of food levels – balance of payments.	Minor Threat	Research required Research into yields	Change in menus? *Change in procurement policies*	Cuts right across all public bodies involved in food supply; DARD; Treasury.
21	Increased crop damage	Food supply	Food security Higher food bills in public hospitals / prisons / armed forces / public body staff canteens. Impact on import / export of food levels – balance of payments.	Minor Threat	Research required Research into yields	Change in menus? *Change in procurement policies*	Cuts right across all public bodies involved in food supply; DARD; Treasury.
22	Increased soil erosion	Land management	Impact on councils and other bodies who maintain 'hard engineering'. Damage to facilities such as railway lines,	Minor Threat	Greater requirement for maintenance crews.	*Review of need for engineered structures at coast. Research into concept of 'managed retreat'*	Land owning public bodies e.g. Councils, DRD

Ref.	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
			roads, buildings etc. Greater cleaning of public buildings may be required due to increase in wind borne dust.			*and its applicability to NI.*	
23	Damage to agricultural buildings / changes in building specifications	Building control	Impact on individual farmers only	Minor Threat	Research into building requirements	*Review of building regulations*	Local Councils
24	Potential implications for farm management – though note there are many other factors such as grant schemes, government policies, consumer patterns etc.	Agricultural policy Business support	Impact on individual farmers only	Minor Threat	N/A	N/A	DARD

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

7 FORESTRY

7.1 Scope

In relation to the impact of climate change on forestry within Northern Ireland, this chapter provides an assessment of the current situation, as well as the likely future impacts and focuses primarily on impacts on commercial production forestry, as well as the impacts on semi-natural woodland ecosystems. Adaptation strategies for meeting the impacts of climate change are also suggested in the chapter. For further details on associated topics see the chapters on Conservation, Biodiversity and Habitats and Agriculture.

7.2 Background

Forestry is a devolved matter, and the Forest Service, an Agency within the Department of Agriculture and Rural Development, has responsibility in Northern Ireland. An extensive consultation on forestry in Northern Ireland has recently been concluded, with the publication of Northern Ireland Forestry: a strategy for sustainability and growth' in March 2006. The strategy identified two overarching priorities – how more forests can be created and on the sustainable management of existing forests, of which DARD owns three quarters. It also confirmed existing responsibilities for the forestry sector.

Land cover in Northern Ireland was dominated by woodland in the past, but land clearance reduced woodland cover to 1.4% (19,000 ha) immediately after the First World War. Although woodland cover is still low (86 000 ha; 6% land cover), forestry makes a small but significant contribution to the rural economy. For example, about 1000 people are employed by the forestry and primary timber processing industry and it has been estimated that the Forestry Programme provides benefits of about £18 million from value added in timber processing alone.

Commercially productive woodland is dominated by Sitka spruce, contributing to a total area of production forest of 57 000 ha. Other important species are lodgepole pine and Scots pine. There are an estimated 13,000 ha of ancient and semi-natural woodland, including 2 000 ha on designated sites (ASSI). The link between tree growth and climate has been recognised for many centuries. It therefore follows that climate change will, equally, have an effect on tree growth The climate of Northern Ireland is, currently highly amenable to production forestry and mean productivity of conifer species in Northern Ireland (14 m3 ha-1 yr-1) is greater than that for Great Britain (11.6 m3 ha-1 yr-1).

7.3 The Issue Now

Woodland cover in Northern Ireland is very low (6%) and well below the UK average (12.5%). Woodland creation is therefore a priority, with the Forestry Service aiming to double this figure over the coming 50 years. However, the current rate of woodland expansion of 500 ha yr-1 is insufficient to meet this target. The second priority outlined in the recently published strategy for sustainability and growth is the sustainable management of existing woodlands, with timber production a continuing priority but with other objectives of woodlands such as recreation and public access given higher visibility.

The natural environment is a significant determinant of the species that are planted, their commercial management and productivity, and the make-up of native woodland. Climate is therefore prominent in any forestry-related decision-making process. Of particular concern in this respect are resilience to wind damage (under current climatic conditions), the extent of waterlogging in winter, water deficits in the east of Northern Ireland in summer, and damage caused by late spring frosts. The extent of winter waterlogging is

doubly important, affecting both species suitability on individual sites and limiting access of machinery for management and harvesting. All these areas have direct relevance to climate change and mean that the forestry sector should be a receptive audience for communicating the requirement for adaptation strategies to mitigate the impacts of climate change.

There is a good understanding of species suitability under current climatic conditions, with the two principal commercially planted species, Sitka spruce and lodgepole pine both well suited to the climate of Northern Ireland. Provenance selection of Sitka spruce minimises the risk of late spring frost damage. Guidance for the planting of new native woodland encourages the planting of locally sourced seed, although this is not always possible and seed material from the Republic of Ireland and GB is acceptable as an alternative.

As in the rest of the UK, the forestry sector is challenged by the poor state of the timber market, largely as a result of the availability of cheap, imported timber. However, the profile of woodfuel and bioenergy has risen in recent years, in part as a result of the establishment of a thriving wood-pellet plant at Balcas that is supplying two power stations in England, using co-products from wood processing. Woodfuel has the potential to add value to sawmill co-products which may eventually improve the market for the timber grower. The potential contribution of short rotation coppice willow is currently a focus of activity, following publication of the report of the Biomass Task Force, and Government's response to it. Given the commitments of both the devolved administration and UK Government to climate change mitigation through the increased use of renewable energy, this is likely to remain a priority.

7.4 How Climate Change May Affect the Future

7.4.1 Impacts on woodland ecosystems

There is concern over the future of a number of habitats in the UK, particularly montane and some wetland habitats (Harrison et al., 2001). All habitats will be liable to change, although trees are likely to be the most resilient vegetation form; they are long-lived and have had to endure extreme climatic events in the past – for example, 1806 was a far more serious drought than that of 1976, while we did not lose large tracts of woodland during the mini ice-age of the 17th century. Climate, and climate change will not have the same effect on all species; the corollary is that climate change will affect competition between species and the composition of woodland communities including associated fauna. It is clear from the natural distribution of species native to Northern Ireland, that the majority are either in the middle, or towards the colder/wetter extent of their climatic range; it is therefore unlikely that, even if the High Emissions scenario is realised, that current native tree species will be lost. This may not be the case for plant species that make up the ground vegetation of woodland ecosystems; indeed it is likely that woodland vegetation communities will change, even if the overstorey tree species are largely unaffected by climate change. Changes to the current woodland National Vegetation Classification (NVC) system will therefore warrant consideration. The management objective of ancient and semi-natural woodland is often to maintain vegetation community structures as represented in the NVC (Rodwell, 1991). This may increasingly become an unrealistic objective and may warrant reconsideration in time.

Invasive species such as Rhododendron, Himalayan balsam and Japanese knotweed are already having an impact on native vegetation. Climate change is likely to exacerbate these problems and, also, to provide a suitable habitat for a new range of species. The issue of 'invasive species' should not be restricted to plants, as climate change is likely to present opportunities for a new range of tree diseases and forest insect pests. Although

firm predictions cannot be made as to which diseases and insect pests may benefit from climate change, expert judgement can provide some insight based on their current distribution and associated climatic conditions (see Broadmeadow and Ray, 2005). Populations of grey squirrels and deer currently affect natural regeneration in both native and plantation woodlands. Milder winters together with increased forage availability in spring are likely to benefit populations of both, increasing the pressures on regeneration if appropriate control measures are not implemented.

The effect of milder winter and spring temperatures is already apparent on the date of budburst, with the flushing of oak in southern England already some two weeks earlier than when recording of this data-set began in the 1950s. Although there are no specific indicators relating to trees included in the Climate Change Indicators for Northern Ireland (EHS, 2004), the length of the thermal growing season is. Changes in phenology (the timing of natural events) can affect the functioning of natural ecosystems. Although the implications are uncertain, examples such as the potential loss of synchrony between emergence of the winter moth and budburst of oak indicate the serious possible consequences of climate change.

7.4.2 Impacts on commercial production forestry

During the course of the 21st century, it is unlikely that climate change will have a direct, negative effect on commercial timber production. Even under the 2080 high emissions scenario, rainfall is sufficient across the majority of Northern Ireland to maintain, at least, current levels of productivity. Longer growing seasons (Hulme et al., 2002) together with rising levels of carbon dioxide in the atmosphere will lead to an enhancement of growth rates. However, water availability may limit the growth of Sitka spruce on some of the drier sites on which it is currently planted. In the longer term, climate change is likely to have a significant impact on the performance and survival of species that are currently planted, and changes in species or provenance choice are likely to be necessary. Milder winters and springs will advance flushing, potentially increasing the risk of frost damage; this would need to be taken into account in provenance selection.

Predictions of increased water deficits in summer are likely to initially impact on establishment, requiring changes in practice, including the timing of establishment. The issue may be further complicated by milder winters reducing the dormant period for roots, during which time they should be lifted. This may require a further movement to containerised stock in nurseries.

Heavier winter rainfall, falling in more intense events may affect the ability of the forest infrastructure to cope. There are current concerns that forest roads will require high specifications and that drainage systems, particularly culverts, may need upgrading. If as predicted, increased winter rainfall increases the extent and frequency of winter waterlogging, this will affect access for routine management activities if soil structure is not to be compromised. Waterlogging has two further impacts, reducing the stability of trees, thus increasing the risk of windthrow, and leading to the death of fine roots and increasing susceptibility to drought the following summer. Although predictions are for mean windspeeds to fall, particularly on the east coast, changes to the wind climate are the least robust of the predictions. Furthermore, more deep depressions may cross the UK in winter, and a general increase in the severity of extreme climatic events is also thought likely. The potential for wind damage may therefore increase, counter to the expectations that result from the prediction of lower mean windspeeds. Ongoing forest management to accommodate wind risk will continue to be important, and should include awareness of the implications of climate change. Snowfall is predicted to become a rare

event, and damage to crops would therefore be expected to decline. However, the snow that does fall may become 'wetter', having a larger impact on the value of the crop.

Predictions of an increased severity and frequency of summer drought raises the possibility of more forest fires, which would be of concern, not least, because of the increasingly close relationships between centres of population and woodland.

Forest fires remain an area of concern on account of their potentially serious consequences and are currently accommodated by Forest Service fire management plans. Summer droughts will also have implications for water availability, with predictions for potential evapotranspiration to increase significantly compounding the reduction in summer rainfall. The higher water use of trees compared to other vegetation types may need to be taken into account in catchment management and forest design plans where water availability is an issue.

A major area of uncertainty, and potentially the most significant threat, is the impact of climate change on the activity of, and damage caused by, insect pests and diseases. Although firm predictions cannot be made because of the complexity of the interactions involved in biological systems, some assertions can be made on the basis of expert judgement and an analysis of current outbreaks and associated epidemiology (see Broadmeadow et al., 2005). Of particular concern to the forestry sector in Northern Ireland is the potential for climate change to benefit the green spruce aphid (see Evans et al., 2002). This topic is further complicated by uncertainty in how introduced pests might impact on commercial plantations. There is concern that in the absence of natural predators or resistance, impacts could be serious. Continuing vigilance and monitoring is therefore seen as important.

7.4.3 Analysis of current knowledge of likely climate change impacts

The literature on climate change impacts on the forestry sector in the UK is relatively good, but with relatively little information specific to Northern Ireland. The area of greatest uncertainty (outside of the climate change predictions) is how the composition of semi-natural woodlands may change in the long-term, in response to changes in competition between species. There is also uncertainty in the adaptive capacity of populations to cope with the magnitude of climate change that is predicted.

A second area of uncertainty, linked to the published climate change scenarios is how woodlands will respond to the extreme climatic events that are predicted – it is the droughts and storms that are likely to determine the response of woodlands to climate change, rather than changes to the mean climate. Although information is available on the impacts of individual droughts, the impact of a number of consecutive drought years is more difficult to predict. The literature on storms is good, and those factors that affect wind risk are well understood and implemented in existing management plans.

7.4.4 Summary

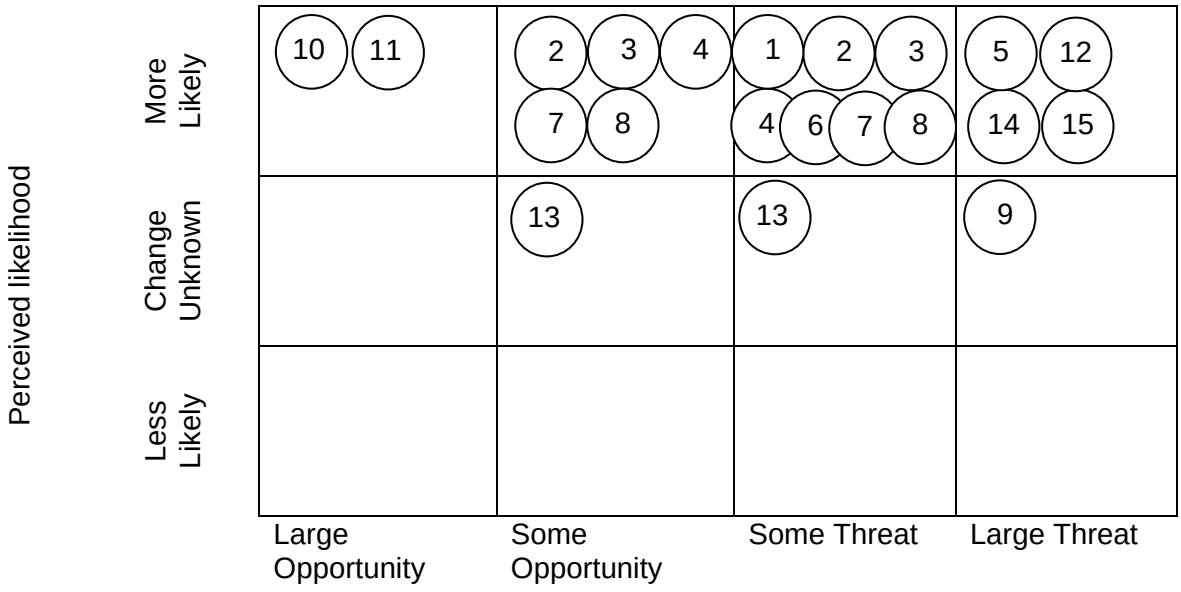
The impacts of climate change on forestry are summarised in Table 7.1. These impacts are related to the direct effects of climate change on forestry and do not look to the wider implications for the sector, particularly the opportunities that are identified in the Risk Matrix (Figure 7.1) and the summary of adaptation strategies (Table 7.2).

Table 7.1 - Climate Change Impacts: Forestry

Climate change	Impact	
	Woodland ecosystem function and quality	**Commercial woodland management and timber production**
Wetter winters	Enhanced water-logging leading to reduced stability and fine root death, potentially limiting rooting depth and making some species more vulnerable to summer drought	Enhanced water-logging leading to reduced stability and fine root death; inability of forest infrastructure (forest roads and culverts) to cope
Drier summers	Oxidation of peat; change in competition between species; loss of habitat through frost/heathland fires	Timber 'crack'; trees weakened and more susceptible to disease; productivity could fall on some sites and some species that are currently planted could prove unsuitable for commercial timber production on some sites; high water use of trees compared to other vegetation may raise land use issues; loss of productive woodland through forest fires
Warmer winters	Invasive species could become more of a problem; the climate may become suitable for a new range of invasive species (including higher plants, pathogens, insect and mammal pests)	Reduced cold-related mortality of insect pest, deer and squirrel populations; longer growing season; less winter cold damage, although reduced hardening could reverse this benefit; increased potential for spring frost damage as a result of earlier flushing; potential for range of new species
Hotter summers	Higher water temperature presenting threat to fish populations – possible driver for expansion of riparian woodland	Increased insect pest activity
Sea level rise	Loss of habitat (although very little woodland at risk of saline incursion)	Risk of saline incursion and loss of woodland (although very little woodland at risk of saline incursion)
Reduced soil moisture	Oxidation of peatlands	Changes in species suitability

Climate change	**Impact**	
	Woodland ecosystem function and quality	**Commercial woodland management and timber production**
Change in Storminess	Loss of mature woodland habitat; benefits associated with opening canopy enhancing regeneration	Increased risk of windthrow and wind snap
Reduced snowfall		Less snow damage, although the remaining snow may be 'wetter' and cause more damage
Other (*stated)*	***Higher CO_2 levels:*** Predictions of denser canopies, reducing light levels on forest floor and ground vegetation community structure; expectation that ephemeral/ weed species may benefit at expense of slower growing species	***Higher CO_2 levels:*** Increased productivity

Figure 7.1 - Risk Assessment: Forestry



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 7.3).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

7.5 Actions Undertaken or Underway and Key Gaps

Telephone questionnaires and interviews indicate that no adaptive actions have been taken to minimise the impacts of climate change and, at an operational level, awareness of the issues of climate change is limited. However, at a strategic level, there is clear realisation that adaptive measures will be a necessity and that information is needed to guide the development of adaptation strategies.

Forestry in Northern Ireland is subject to the UK Forestry Standard, which provides high level guidance, underpinned by a series of Guidelines and practice guidance published by the Forestry Commission and Forest Service. All Forest Service woodlands have also been certified under the UK Woodland Assurance Standard. As the Guidelines are revised, advice on the implications of climate change is being incorporated. Adherence to published best practice will ensure that woodlands in Northern Ireland are resilient to climate change. Links have been maintained with the forestry research community across the UK and opportunities also exist for integration with climate change research projects focussed on the Republic of Ireland. Information therefore exists, but there is a requirement to link the information available from a range of sources (including the MONARCH programme) and a range of SNIFFER-funded projects into a climate change adaptation strategy for the forestry sector in Northern Ireland.

Climate change mitigation provides opportunities for the forestry sector. Carbon sequestration provides an additional driver for the stated policy of woodland expansion, while the woodfuel market is likely to expand, potentially providing additional funding for the management of existing woodland and the planting of short rotation energy crops. The woodfuel/wood-pellet industry has made significant progress in recent years, and the Balcas wood pellet plant is the largest producer in the UK.

7.6 Adaptation Strategies

When contemplating climate change adaptation strategies for the forestry sector, it is necessary to take a long-term approach. Decisions made now may only bear fruit towards the end of the century, while the consequences of not implementing adaptation strategies will also only become evident then. Any change in planting material or practice must also be appropriate to both the current and future climate. For example, it is known that planting ‘provenances’ from a hotter, drier climate is likely to provide better growth and enhance the ability to cope with the reduced level of summer rainfall that has been predicted. However, these more southerly provenances are, typically, more prone to frost damage and could either suffer significant mortality or loss of form as a result of repeated frosting before the effects of climate change are fully realised. There are also genetic conservation issues associated with planting non-native provenances when creating new native woodland. To draw comparison with another sector, increasing the level of protection provided by flood defences accommodates both predicted climate change and also provides increased protection against extreme events under the current climate. These ‘win-win’ or ‘no-regret’ adaptive actions are more difficult in the forestry sector on account of the requirement to be appropriate to current and future climates.

There will be changes in species suitability, both for semi-natural and plantation woodlands. The simple approach of not planting a species, already at the drier end of its climatic range is an easy adaptation strategy. Of greater security in the long term, is a strategy of planting mixed species stands, as all species are unlikely to be affected to the same extent. The development of the ESC decision support system, for aiding species selection under climate change scenarios (Broadmeadow and Ray, 2005), to Northern Ireland would help in the implementation of this strategy. If the severity and frequency of

summer drought does become an issue for forestry in Northern Ireland, its effect will initially be evident on establishment. Changes in the timing of lifting from nurseries and planting may warrant consideration while, conversion to continuous cover systems of management may prove beneficial for establishment.

Forest fires and storms both have the potential to cause significant damage and their frequency is expected to increase as a result of climate change. Standby fire plans constitute part of good practice and have recently been reviewed to accommodate recent changes in the incidence of forest fires. Climate change predictions could also be incorporated. A similar process exists for storm damage, particularly relating to road closures.

It is hoped that native populations of semi-natural woodland have enough adaptive capacity to accommodate the level of climate change predicted. This capacity is greater in larger areas of woodland, while more permeable landscapes also enhance the ability of natural ecosystems to adapt to climate change. Landscape level planning therefore has a role to play in climate change adaptation. The role of woodland in the wider landscape is also important, having the potential to help adapt to the impacts of climate change. Woodland cover can reduce erosion of vulnerable soils, both as a result of drier soils in summer and heavier winter rainfall, helping to reduce siltation. Floodplain woodland can attenuate downstream flood flows and reduce bankside erosion, while riparian woodland has the potential to reduce water temperature in summer, which may become increasingly important in protecting fish populations as climate change progresses. Trees in the urban environment have a cooling effect and provide shade, which is likely to be seen as increasingly important.

Woodland also has a role to play in mitigation – providing a renewable form of energy in the form of woodfuel, a low energy material as wood and wood products and in new and existing woodland sequestering carbon from the atmosphere. Woodland, particularly in the UK where land area relative to population restricts its potential, can only make a small contribution, but this contribution could be significant. However, this mitigation role should not compromise the wider objectives of sustainable forest management and should consider implications for biodiversity and conservation.

Adaptive strategies that are available to the sector covers the full range of options, as outlined in Tables 7.2 and 7.3. These strategies range from ‘do nothing’, as will be the case for some natural woodland ecosystems which may be left for natural selection processes to take their course and for new plant assemblages to develop, to developing adaptive actions that might include ‘climate-proofing’ species selection for Woodland Grant Scheme applications and planting new woodland with the specific objective of combating soil erosion and watercourse siltation. However, the majority of adaptation strategies fall into the ‘building adaptive capacity’ and ‘delay’ categories, with research and monitoring in the former, strengthening the knowledge base of the requirement for and likely success of the latter category. It is also noteworthy that the objective of a number of the adaptive actions is to build adaptive capacity for natural systems to adapt to climate change through evolution and migration.

7.6.1 Constraints to adaptation

The Forest Service have identified a range of constraints to implementing effective adaptation strategies, over and above the problems associated with developing strategies for the forestry sector that may be appropriate to both current and future climates. There is a perceived lack of awareness of climate change in the sector, particularly the rate and magnitude of change that is predicted. In part, this is because much of the research on

which adaptation strategies is based is UK wide or restricted to GB, and there is little information specific to Northern Ireland.

In practical terms, funding and human resources in the sector are extremely limited, largely due to the depressed state of the timber market for more than a decade. Operational decisions are therefore likely to be focussed on optimising management under current climatic conditions, rather than thinking of the future. Specifically, the diversification strategies identified in section 7.6 are likely to represent an additional cost over and above the current silviculture dominated by Sitka spruce. Moreover, there may be reticence in moving away from established practice into less well documented territory if climate change predictions indicate that such a move is necessary.

The recently published strategy for sustainability and growth identifies the two priorities for the sector as being woodland creation and sustainable management of existing woodlands. Although both are relevant to the climate change debate and indeed, woodland creation could be seen as a mitigation response although that is not the principal driver, immediate actions are not focussed on climate change adaptation. In time, genetic conservation policy, which encourages the planting of local provenance of native species, could prove to be a constraint to changing planting stock as an adaptive strategy. This is an area of active debate, not just in the UK, but across Europe.

The most significant constraint to implementing adaptation strategies at present is a perceived lack of urgency. This could be viewed as a 'delay' or 'wait and see' strategy, and in many respects is an appropriate approach for the sector. Implementing adaptive actions prematurely would be a retrograde step, potentially compromising woodlands. However, there are a number of no-regret or low-regret measures that could be implemented now, primarily those identified as building adaptive capacity in Table 7.2. The adaptive actions identified are also low or no-regret, but more costly or difficult to implement. As our understanding of climate change and the response of woodlands to it improves, the requirement to implement the adaptive actions will become far more apparent.

Table 7.2 - Summary of Potential Adaptation Strategies

Adaptation strategy	**Climate change impact**
Do nothing	
Accept that NVC species assemblages will change/ redefine NVC woodland types	Effect of climate change on competition between and suitability of individual species
Not act prematurely; trees and woodlands are resilient to climatic extremes; established woodlands are unlikely to be affected in the near to medium term	Perceived requirement to do 'something' would compromise the woodland if the wrong strategy was implemented
Building adaptive capacity	
Monitor frequency of severe spring frost and winter cold damage	Rising temperatures advancing budburst in spring and reducing the level of hardening in winter
Build climate change scenarios into wind management models	Changing frequency and severity of windstorms; increase in leaf area in response to rising CO_2 levels; increased winter water-logging.
Build climate change scenarios into fire risk models, adjusting 'trigger points' as necessary	Lower summer rainfall and higher temperatures increasing fire risk

Adaptation strategy	**Climate change impact**
Increased vigilance over pest and disease outbreaks, particularly the potential introduction of new species; continuing research into resistant genotypes and management of outbreaks	Milder winters, increased warmth and an increased prevalence of drought stressed trees favouring insect pests and diseases of forest trees
Awareness raising of climate change issues to woodland owners and managers, forestry contractors and agents and responsible for species selection of street trees, amenity planning and landscaping schemes	All aspects of climate change on the forestry sector
Map soils at risk from landslip	Increased frequency of winter waterlogging and intensity of rainfall events increase landslip risk
Improve representation of climate change in decision support systems for species selection	All aspects of climate change on species suitability
Delay	
Adjust rotation length as impact of climate change on growth rates becomes apparent	Direct effects of rising CO_2 levels on productivity, coupled with climate induced changes in growth rates
Adjust lifting windows and establishment strategies as impact on winter hardening becomes apparent	Milder winters delaying and reducing hardening off, coupled with a potential move to autumn planting to limit the impact of early summer drought on establishment
Introduce better adapted species/ provenances if the impacts of climate change on existing woodland become serious	All aspects of climate change (including uncertainty), together with uncertainty over responses
Adaptive actions	
Plant new floodplain woodland to alleviate flooding	Increased frequency and severity of winter flooding
Plant new or manage riparian woodland to provide shade and maintain lower water temperatures	Rising water temperature approaching lethal limit for some salmonid populations
'Climate-proofing' species selection for WGS applications, and new planning/restocking of FS estate.	All aspects of climate change on species suitability
Plant species mixtures to provide insurance against the uncertainty associated with climate change and responses to it	All aspects of climate change on species suitability
Plant provenance mixtures to widen the genetic base and enhance the adaptive capacity of new native woodland	Direct effects of changes in temperature and rainfall on the growth and survival of individual populations
Enlarge areas of semi-natural woodland and make landscape more 'permeable' to species migration – create habitat networks through a pro-active planning process; encourage natural adaptive processes	Impact of all aspects of climate change on natural ranges and climatic suitability of individual populations
Consider the water use of trees in forest design, catchment management and soil management plans	Reduced availability of water in summer

Table 7.3 - Impacts and Adaptation Summary: Forestry

Ref	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource implications	Adaptation strategy	Responsible public sector body
1	Hotter, drier summers will increase the water use of woodlands potentially restricting their planting in areas with limited water availability	Conservation; water supply	Potential restriction of water supply	Minor threat	Staff time and associated costs	*Consider the water use of trees in forest design plans and catchment management plans*	FS, EHS
12	Increased frequency of forest fires: in isolation, predicted climate change will increase the fire risk; however, the species make-up and age structure influences the fire risk making the overall effect on fire risk less certain	Emergency planning	Loss of life; loss of habitat	Major threat	Research; Staff time; insurance	*Incorporate climate change predictions in standby fire plan*	FS, Fire Service
11	Higher potential productivity resulting from increased warmth and higher CO2 levels: will vary with timeframe, with benefits may be offset by increasing incidence of summer droughts in time	Business support	Improved economic performance	Major opportunity	Staff time	*Adjust yield models/management plans/ production forecasts to accommodate changing growth rates*	FS, DETI
2	Hotter, drier summers (plus demographic change) will increase pressure on rural leisure resources: represents both a threat to natural forest ecosystems and plantation forest productivity and an opportunity for woodland expansion and non-timber revenues	Leisure	Pressure on existing leisure resources	Minor threat; minor opportunity	Staff time and associated costs; loss of production	*Ensure forestry sector plans for increased demand*	FS

Ref	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource implications	Adaptation strategy	Responsible public sector body
3	Heavier winter rainfall will enhance soil erosion: represents both a threat to woodlands (particularly if landslips become more common) and an opportunity for woodland expansion to counter the problem of soil erosion associated with other land covers	Watercourse management and conservation	Negative effect on water quality; siltation of water bodies	Minor opportunity; minor threat	Staff time; possible WGS requirement	*Consider the beneficial role of woodland in catchment management plans and management plans for sites of high conservation value*	FS, EHS
4	Heavier winter rainfall will enhance flooding: represents both a small threat to existing woodlands, but also a larger opportunity for the expansion of floodplain woodland to help alleviate fluvial flooding	Planning and watercourse management	Enhanced flooding and bankside erosion	Minor opportunity; minor threat	Staff time; possible WGS requirement	*Consider the beneficial role of woodland in catchment management plans and river management plans.*	FS, EHS
5	More frequent storms will lead to enhanced windthrow and windsnap: this may be exacerbated by more frequent winter waterlogging and increased leaf area in response to rising CO_2 levels	Transport planning; building control	Fallen trees cause damage to buildings and affect transport infrastructure	Major threat	Research investment; staff time	*Include climate change predictions in wind hazard maps; ensure that planning guidance relating to trees and buildings is appropriate*	FS, DoE PS
6	Milder winters may lead to an increase in deer and squirrel populations: large interactions with other land uses and management initiatives	Conservation	Loss of habitat quality	Minor threat	Staff time and associated costs	*Include the likely effects of climate change in control strategies.*	FS
14	Milder winters, increased numbers of drought stressed trees and global trade may increase the impact of insect pests and diseases	Business support; conservation	Loss of production; habitat degradation	Major threat	Research; monitoring; remediation costs	*Accommodate climate change predictions in Pest Risk Analyses; diversify plantation forests*	FS

Ref	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource implications	Adaptation strategy	Responsible public sector body
13	Less winter cold and snow damage: both 'opportunities' could be turned into 'threats' by other climatic/ physiological interactions. Although the expectation is for significantly less snow, the snow that does fall may be 'wetter', causing more damage; in the same way, predictions of milder winters may mean that trees do not harden off completely making them more vulnerable to occasional periods of extreme cold	Business support	Loss of production; poor timber quality	Minor unknown risk; minor unknown opportunity	Research costs	*Monitoring of frost and winter cold damage; adjust provenance choice if necessary; adjust timing of lifting and establishment if necessary*	FS
7	Changing climatic conditions will alter site suitability of tree species that are currently planted: much is known about the changes to the suitability of individual species, some of which will benefit and some lose out; the direction of the response will also depend on the timeframe considered	Greenspace management	Tree decline/death or requirement for irrigation	Minor threat; minor opportunity	Research; staff time; irrigation	Ensure that greenspace is planted with species that can accommodate predicted climate change	DoE PS, FS
15	Extended summer droughts leading to widespread tree mortality: could be exacerbated by 14, but mitigated by 11	Greenspace management	Tree decline/death or requirement for irrigation	Major threat	Research; staff time; irrigation	Ensure that greenspace is planted with species that can accommodate predicted climate change	DoE PS, FS
8	Hotter summers may have negative impacts on fish populations: riparian woodland provides shade and climate change may therefore be a driver for its expansion	Conservation and watercourse management	Negative impacts on fish populations	Minor threat; minor opportunity	Staff time; possible WGS requirement	*Consider the benefits of riparian woodland in river management plans.*	DARD, DOENI, FS

Ref	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource implications	Adaptation strategy	Responsible public sector body
9	A changing climate will affect the distribution of native species	Conservation	Potential loss of habitats of high conservation value	Major unknown risk	Change in land use; possible WGS requirement	The capacity for evolution and migration is maximised by enlarging areas of native woodland and by creating a more 'permeable' landscape through landscape-level planning	FS, DARD, EHS
10	Drive for GHG emissions reductions will promote sustainable use of wood as both an energy source and as a renewable, low energy material	Business support Conservation	Economic benefit for sector; habitat improvement possible	Major opportunity	Staff time for advice; capital grant-aid	*Ensure sustainable market development and adherence to conservation and environmental guidelines*	DARD, FS, DOENI, DETINI

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

8 WATER RESOURCES

8.1 Scope

This chapter provides an update to the findings of the 2002 SNIFFER report, describing new climate change scenarios, research and methodological tools published in the past 4 years – including in particular the findings based on the UKCIP02 scenarios. As with the other chapters of this report, the chapter details actions which are already underway and provides an overview of potential adaptation strategies for climate change. For further details on associated topics see the chapters on Fisheries and Coastal & Flood Defence.

8.2 Background

The Water Service is an Executive Agency within the Department for Regional Development. Water Service provides water and sewerage services to over 730,000 domestic, agricultural, commercial and business customers throughout Northern Ireland with an annual budget before capital charges of £302 million and fixed assets valued at £4.9 billion. Water Service is set to become a Government Company (GoCo) in 2007. Allied to this is a major investment programme to upgrade Water Service infrastructure over the coming years.

At present over 99% of households in Northern Ireland have a public water supply and each day Water Service supplies some 630 million litres of drinking water to the public. Water Service maintains and operates a water infrastructure consisting of 48 impounding reservoirs, 47 major water treatment works and 25,000 kilometres of water mains.

Approximately 83% of households are served by the public sewerage system. Water Service collects, treats and disposes of around 134 million cubic metres of wastewater each year. In addition, there is provision of a de-sludging service for over 59,000 private septic tanks. The sewerage infrastructure maintained and operated by Water Service consists of 13,000 kilometres of sewers and 918 wastewater treatment works.

The responsibilities of the Water Service, Water Council, Water Appeals Commission and EHS Management Unit are summarised in Table 8.1.

Table 8.1 - Key Responsibilities for Organisations in the Water Resources Sector

Organisation	Responsibility
DRD Water Service	• Supply and distribute water which, when supplied for domestic or food production purposes is wholesome at the time of supply. • Provide and maintain sewers for draining domestic sewage, surface water and trade effluent • Make provision for effectually dealing with the contents of its sewers
Water Council	• Provides advice to DRD Water Service on the exercising of its functions
Water Appeals Commission	• Considers appeals against decisions taken by DRD Water Service on a specified range of functions
EHS Water Management Unit	• Protection of the aquatic environment, through water quality monitoring, discharge control, abstraction control and management of pollution

8.3 The Issue Now

The water resources sector is affected by current weather in a number of ways. Wet weather leads to flooding problems and at wastewater treatment works can lead to storm discharges, where sewage that has only been subject to initial screening is discharged into the environment. Flooding can be a problem when it follows dry weather as sediment is washed into gullies and pipes. In cold weather metal pipes can rupture due to ground heave. Hot weather leads to additional demands on the system and has contributed to hydrant abuse, a big problem in Belfast. Stormy conditions have little impact, but Major Incident Plans include provision and preparedness of standby generators in the event of power disruption.

In addition to the weather, a number of other issues are of importance to the sector at present. These include privatisation of the Water Service and its implications, the Nitrates Directive and impact on agriculture and the Water Framework Directive.

8.4 How Climate Change May Affect the Future

The impacts of climate change on water resources were comprehensively reviewed in SNIFFER (2002). The impacts are summarised in Table 8.3 at the end of this section. This study updates that work describing new climate change scenarios, research and methodological tools published in the past 4 years.

The UKCIP02 scenarios suggest an overall (annual) decline in rainfall for Northern Ireland, a marked change from the UKCIP98 scenarios. This means a reduction in a resource which will be increasingly demanded in a warmer climate (and more affluent world). Summer rainfall will decline by up to 20% by the 2020s and by up to 50% by the 2080s. As there is little evidence for large winter groundwater storage to support summer river flows, river levels are likely to fall. Runoff may decline by at least 20% in the months of July, August and September by the 2020s – see Table 9.2 (Arnell, 2003). Table 8.2 illustrates how a commonly used indicator of low flow, Q95 (the flow exceeded 95% of the time), will change for three rivers in Northern Ireland by the 2020s under different scenarios of climate change (UKCIP02 low, medium and high and two scenarios that represent the range of climate model uncertainty). The reduction in summer river flows, combined with water quality problems, will have implications for water abstraction, aquatic ecology and recreational uses.

Table 8.2 - Percentage change in Q95 by the 2020s, compared to 1961-1990

Gauging Station	'Cool-wet'	Low	Medium	High	'Warm-dry'
Fairy Water at Dudgeon Bridge	-2	-12	-13	-14	-17
Six Mile Water at Antrim	-4	-17	-19	-21	-24
Claudy at Glenone Bridge	-3	-15	-17	-18	-21

From Arnell, 2003.

The demand for water may also alter under climate change. The CCDeW (Climate Change and the Demand for Water) project (Downing et al., 2003) used a variety of models to estimate future demand under a framework of climate change and water demand scenarios, the latter derived from reference socio-economic scenarios. The models and scenarios were developed for Environment Agency regions of England and Wales and therefore the results are not directly applicable to Northern Ireland. The total impact in England and Wales for 2024/2025 was calculated as 1.4 to 2.0% depending on the scenario. Regionally, this varied from 1.3% in the North West to 3.9% in the Anglian region where spray irrigation was important (under Beta reference scenario and medium-

high emissions). Agricultural demand showed the biggest increases (of around 20%), industrial and commercial demand increased by approximately 2.5%, while domestic demand showed more modest increases of about 1.5%. Overall, the impact of climate change was less than the change in demand related to socio-economic factors. However, extreme events would present more significant challenges, beyond the mean climate changes modelled in CCDeW. These will be partly captured by applying the results of CCDeW to forecast dry-year demand as recommended by the authors (Downing et al., 2003).

In response to the potentially significant impact of climate change on supplies, UK Water Industry Research (UKWIR) has commissioned a number of research studies to facilitate assessment of climate change in water resource planning. Arnell (2003) presented three options for the assessment of the UKCIP02 scenarios:

1. Use a locally-calibrated and validated catchment or aquifer model and apply UKCIP02 scenarios.
2. Use a locally-calibrated and validated catchment or aquifer model and apply regional average changes in monthly mean climate (provided).
3. Perturb naturalised monthly runoff or annual groundwater recharge by runoff and recharge factors (provided).

Arnell's methodology was adopted for the 2004 periodic assessment of water company plans in England and Wales, and provided a conceptual framework for work which followed. Recognition of the high level of uncertainty, combined with developments in climate change and hydrological sciences and the continued adoption of a risk-based water resource planning framework, has resulted in the development of a new methodological toolkit (UKWIR, 2005). This considers the full range of uncertainties from General Circulation Models to catchment models and presents a practical methodology which can be adapted to the particular purpose of assessment.

The House of Commons Environment, Food and Rural Affairs Committee report on Climate Change, Water Security and Flooding (HoC, 2004) recognised the impact of climate change on both supply and demand. It recommended that:

• Water companies, the Government and environmental regulator raise awareness about the value of water and the potential for water scarcity in the absence of careful management.

- Society moves towards more rational use of water, with the Government evaluating alternative pricing mechanisms, whilst considering how best to protect those vulnerable to water poverty.
- The Office of the Deputy Prime Minister and Defra develop specific proposals to increase household water efficiency.
- Planning authorities should require water availability to be taken into consideration; building regulations should require greater water efficiency and Government should facilitate the manufacture of more efficient domestic appliances.
- Water companies reduce leakage.
- Reservoirs are not seen as an alternative to demand management measures, but that, where needed, environmental and economic consequences are properly addressed.

Table 8.3 - Climate Change Impacts: Water Resources

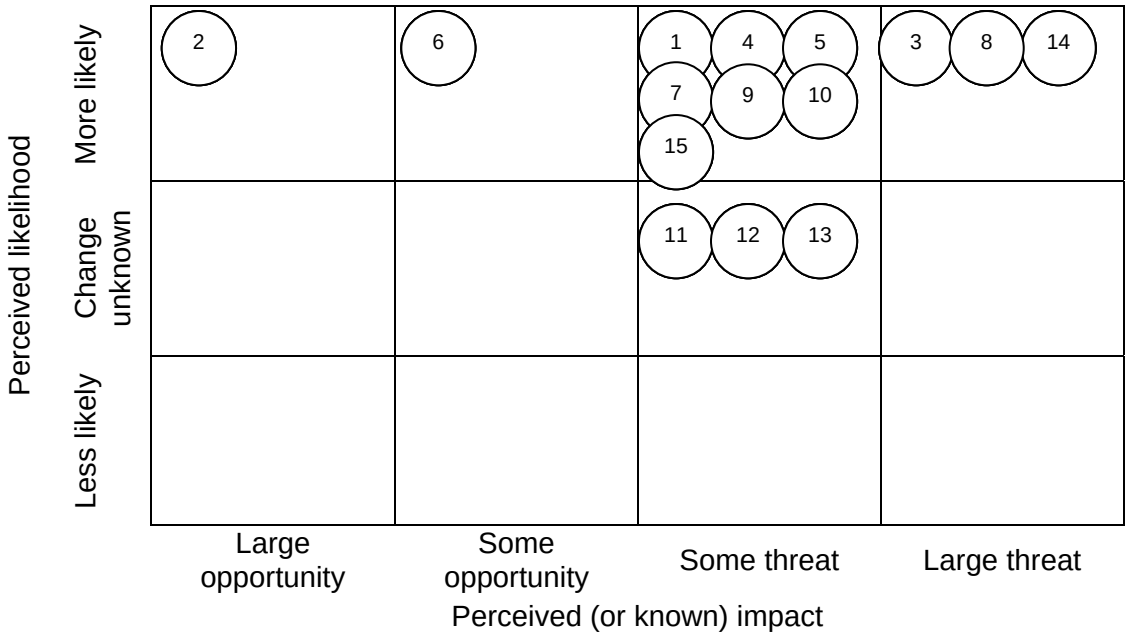
Climate change	Impact on receptor
Wetter winters	Greater runoff, erosion of soil and leaching of agrochemical and agricultural wastes, leading to water quality problems with implications for aquatic life, abstractions and river users. Potential damage to river channels from more intense rainfall, leading to aquatic damage. Increased rainfall provides opportunity for winter storage, benefiting the Water Service and farmers and increased groundwater recharge.
Drier summers	Lower flows leading to problems for users relating to abstraction, ability to dilute effluent, aquatic ecology and recreation. Increases in evapotranspiration and development of soil moisture deficits resulting in reduced run-off and groundwater recharge. Increase demand for water, potentially affecting the ability of abstractors to meet requirements. Reduction in volume of sewer base flow may result in blockages. Reduced flushing of estuaries and lakes and increased residence time of pollutants may lead to deterioration of water quality with implications for shell fisheries, lake ecology and abstractors.
Warmer winters	Increase in pests and change in life cycle of aquatic and land-based organisms.
Hotter summers	Increase in river and lake temperatures, reduction in dissolved oxygen concentrations and effects on aquatic life. Problems with reservoir water quality associated with changes in temperature, solar radiation and wind speed such as increased potential of algal blooms. Increase demand for water and water-intensive products and activities, potentially affecting the ability of abstractors to meet requirements but providing opportunities for manufacturers.
Sea level rise	May lead to saline intrusion of freshwater aquifers, affecting abstractions, though this will be more of a problem for private abstractions rather than the public water provider.

Climate change	Impact on receptor
Changes in soil moisture	Higher soil moisture deficits in summer and autumn will delay winter recharge. Lower summer groundwater tables may increase risk of pollution infiltration, affecting abstractions and groundwater-fed ecology. Increased soil wetness in winter may enhance leaching and threaten groundwater, affecting abstractions and groundwater-fed ecology.
Change in Storminess	Summer storms, following extended dry periods, may reduce water quality, affecting aquatic life. Increase in intense storm events may morphologically alter watercourses and redistribute sediment. Storms may lead to more Combined Sewer Overflows and impacts on water quality, affecting aquatic life.
Increase in evaporation	Reduction in open water storage e.g. in lakes, which may affect marginal habitats and abstraction.

Risks associated with the impacts are summarised in Figure 8.1. There are major threats associated with summer low flows (number 3 in Figure 8.1 and Table 8.4), higher in-stream temperatures (8) and storm discharges (14) and a number of minor threats, in many cases where other factors (e.g. socio-economic factors) are also significant. Some impacts (11, 12, 13) are more uncertain and will require further research or monitoring to determine the level of risk. There may be opportunities for manufacturers to develop products that may be required for adaptation e.g. water efficient fittings. The increase in winter rainfall represents a major opportunity to offset (at least partly) the major threat associated with lower flows, although there is uncertainty regarding where the increase in rainfall may fall, with a recent trend away from the Mourne Mountains (a vital area for water supply).

Climate change is recognised as a significant issue in the medium-long term. Issues identified as being more important include transfer of the Water Service into a Government Company, health and safety, and compliance with legislation, including new legislation.

Figure 8.1 - Risk Assessment: Water Resources



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 8.4)

Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

8.5 Actions Undertaken or Underway and Key Gaps

The Water Resource Strategy takes account of climate change to 2030. Apart from this, the sector is adopting a 'wait and see' approach, although it is involved with research. There is a need for further research to better define the likely impacts, incorporating the latest approaches involving risk and uncertainty, as well as specific adaptative actions to prepare the sector; these are discussed further below.

8.6 Adaptation Strategies

Further research is required to ascertain the impacts of climate change on aspects of water resources in Northern Ireland. This should focus on long-term impacts on supplies and water quality effects. The latter will require inter-disciplinary input spanning water resources, fisheries, agriculture and conservation. There are particular uncertainties associated with groundwater effects and with the future nature of rainfall e.g. distribution. Monitoring will be required to support this research.

Several adaptive actions are suggested (Table 8.4). In most cases they will provide additional benefits, including increased resilience to adverse climate weather conditions and improved environmental protection, and may be required by legislation such as the Water Framework and Nitrates Directives. Options for maintaining water quality and the health of aquatic ecosystems include:

- Source control, including changes to catchment management and farm practices and reduction of runoff to sewers.
- Creation of wetlands and buffer strips adjacent to rivers to attenuate run-off.
- Management of invasive species.
- Improved groundwater protection.
- Flow augmentation or water transfer.
- Addition of oxygen to depleted rivers.
- Improved wastewater treatment works.
- Improved effluent cleaning.

Options for maintaining a robust supply-demand balance include:

- Increase supplies or timing of supplies, by developing reservoirs and water transfer schemes.
- Manage demand through mechanisms such as metering, water efficiency measures (fixtures and fittings, processes), water re-use (e.g. rainwater harvesting) and water recycling (e.g. grey water use).

Opportunities also need to be realised e.g. in relation to the manufacture of water efficient products. Public bodies can facilitate this and take the lead in implementing adaptation in their own estates.

In the short-term the focus should be on research (see above) and also preparatory work for schemes with long lead times e.g. reservoirs. Adaptation to climate change may also be realised (at least partly) through compliance with legislation such as the Water Framework and Nitrates Directives and consideration should be given to adaptation in Programmes of Measures and similar action plans. Adaptation can be built in at lower cost when infrastructure is maintained or improved and therefore climate change should be factored in to asset management and renewal plans. Longer-term actions such as measures to maintain water quality may benefit from demonstration projects e.g. to determine the effectiveness of potential options.

Constraints to adaptation include uncertainty about future climate, lack of funding and lack of human resources.

8.7 Conclusions and Recommendations

The Water Service provides water and sewerage services to over 730,000 customers from domestic, agricultural, commercial and business sectors. At present, the main impact of the current climate on Water Service operations are predominantly caused by fluctuations in rainfall (low rainfall coinciding with high demand, while high rainfall can cause flooding and storm discharges from sewage works).

UKCIP02 scenarios indicate a likely reduction in rainfall for Northern Ireland, which could lead to the following:

- Strain on a reduced resource in warmer summers.
- Little evidence for large winter groundwater storage to support summer river flows.
- Decline of runoff by at least 20% during July, August and September by 2020s.
- Reduction in summer river levels, combined with water quality problems, will have adverse effects on water abstraction, aquatic ecology and recreational uses.

  - Increased temperatures affecting river water quality (e.g. dissolved oxygen depletion, algal blooms, and impacts on fish).
  - Increased frequency and intensity of storms causing sewer overflows.

At present, although the DRD Water Service Water Resource Strategy takes climate change into account, the sector is adopting a 'wait and see' approach. It is recommended that the following measures are considered / undertaken in order to help effectively prepare for a changing climate:

- Further research into the impacts of climate change in Northern Ireland is required; specifically on long-term impacts on supplies and water quality, which will encompass water resources, fisheries, agriculture and conservation.
- Several adaptive actions have been suggested, most of which include additional benefits such as environmental protection, and may be required by current and/or future legislation.
- Focus in the short-term should be concentrated upon research and preparatory work for longer term schemes such as reservoirs.
- Some adaptation may be realised through compliance with the Water Framework and Nitrates Directives.
- Changes to the planning processes and regulatory framework for the water sector in Northern Ireland will provide opportunities for the development of adaptive planning.
- Adaptation costs can be minimised by maintaining and improving current infrastructure.

Table 8.4 - Impacts and Adaptation Summary: Water Resources

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Increased rainfall causing erosion of soil and leaching of agrochemical and agricultural wastes with problems for aquatic life, abstractions and river users.	Water supply; Leisure; Conservation.	May affect ability to provide clean environment; lower compliance with water quality standards; will cost more to treat water.	Minor threat	Increase in costs	Changes to catchment management and farm practices, improved treatment works.	Water Service, Local Councils, EHS
2	Increased winter rainfall provides opportunity for water storage by Water Service and farmers.	Water supply; Business support.	Additional water available (to partly offset summer losses)	Major opportunity	Increase in costs – new infrastructure	Build or increase capacity of reservoirs.	Water Service, DARD
3	Lower flows cause problems for users relating to abstraction, ability to dilute effluent, aquatic ecology and recreation.	Water supply; Leisure; Conservation.	May affect ability to provide clean environment; lower compliance with water quality standards and effluent discharge consents; problems with abstraction.	Major threat	Increase in costs	Winter storage / recharge and summer augmentation; water transfer; improved effluent cleaning.	Water Service, Local Councils, EHS
4	Reduction in volume of sewer base flow may result in blockages, leading to environmental health and flooding problems.	Water supply.	Will require cleansing.	Minor threat	Increase in staff time	Cleansing; sewer re-design.	Water Service
5	Drier, hotter summers will increase demand for water and water-related products and activities affecting ability of abstractors to meet requirements.	Water supply; Leisure; Conservation; Community awareness.	May become more expensive or difficult to meet demand. Farmers may also have problems.	Minor threat	Increase in costs	Demand management; increase supply for peak periods.	Water Service, DARD, Local Councils, Community Groups
6	Drier, hotter summers will increase demand for water efficient products.	Business support.	Opportunity to facilitate new industry.	Minor opportunity	Staff time	*Assist business start-up*.	DETI, Invest NI
7	Lower summer runoff leading to reduced flushing of estuaries and lakes with implications for shell fisheries, lake ecology and abstractors.	Water supply; Health advice and promotion; Conservation.	Lower compliance with quality standards; will cost more to treat water.	Minor threat	Increase in costs	*More regular monitoring*; improved treatment works.	Water Service, EHS, Food Standards Agency, Local Councils
8	Increased temperatures may cause problems with river and reservoir water quality e.g. Dissolved Oxygen depletion, algal blooms, physiological impact on fish.	Water supply; Conservation.	Lower compliance with water quality standards.	Major threat	Increase in costs	Addition of oxygen to rivers; flow augmentation.	Water Service, EHS

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
9	Higher evaporation and lower inflows leading to reduction in open water storage e.g. Lake Neagh, which may affect marginal habitats and abstraction.	Water supply; Conservation.	Deterioration of designated sites; less water for abstraction.	Minor threat	Increase in costs	Augmentation; *strategies to cope with greater fluctuations in water level*.	Water Service, EHS
10	Increase in pests and change in life cycle of aquatic and land-based organisms.	Conservation.	Change quality of designated sites.	Minor threat	Increase in costs	Management of invasive species and site conservation.	EHS
11	Lower summer groundwater tables may increase risk of pollution infiltration.	Water supply; Conservation.	May damage groundwater-fed ecology and increase cost of water treatment for private abstractors. All public borehole abstractions will be closed by 2009.	Minor unknown risk	Increase in costs	Revision of areas of groundwater protection; *monitoring*.	Water Service, EHS
12	Increased soil wetness in winter may enhance leaching and threaten groundwater.	Water supply; Conservation.	May damage groundwater-fed ecology and increase cost of water treatment for private abstractors.	Minor unknown risk	Increase in costs	Revision of areas of groundwater protection; *monitoring*.	Water Service, EHS
13	Saline intrusion of freshwater aquifers due to sea level rise, affecting abstractions.	Water supply.	May increase cost of water treatment for private abstractors (public boreholes will be closed by 2009). Private abstractors may turn to public supply.	Minor unknown risk	Increase in costs	Freshwater recharge; accept loss.	Water Service, EHS
14	Storms may cause more Combined Sewer Overflows, damaging aquatic life.	Water supply; Leisure; Conservation.	Will affect fish, ecological status of rivers and use for leisure.	Major threat	Staff time for monitoring and clear-up	Upgrade sewage treatment works; reduce runoff to sewers.	Water Service, EHS, Local Councils
15	Summer storms, following dry periods, may lead to high pollutant loads, damaging aquatic habitats.	Conservation.	Will affect fish and status of rivers.	Minor threat	Staff time for monitoring	Source control; create wetlands and buffer strips adjacent to rivers.	EHS

* Public Services Areas from Table 2 of EHS (2005a).

^ *Building adaptive capacity*; delivering adaptive actions.

9 COASTAL & FLOOD RISK MANAGEMENT

9.1 Scope

In relation to Coastal and Flood Risk Management in Northern Ireland, the following chapter provides details of the potential future impacts of climate change on these features and provides an assessment of the actions which are already underway, as well as suggested adaptation strategies for changing current practices to those suitable under climate change. For further details on associated topics see the chapters on Water Resources, Fisheries and Insurance.

9.2 Background

Rivers Agency is an executive agency within the Department of Agriculture and Rural Development (DARD). It is the statutory drainage and flood defence authority for Northern Ireland.

Under the terms of the Drainage (Northern Ireland) Order 1973 the Department has discretionary powers to:

- Construct and maintain drainage and flood defence structures to reduce the risk to life and damage to property from flooding.
- Maintain watercourses and sea defences which have been designated by the Drainage Council for Northern Ireland which protect land and property from flooding from the sea.
- Administer advisory and enforcement procedures to protect the drainage function of all watercourses.
- Ensure that water flows freely in Northern Ireland's main rivers and certain other smaller watercourses. This is necessary to alleviate flooding and to assist field drainage. In open watercourses, works include clearing deposits of silt and gravel which build up naturally and slow the flow of water. Removal of debris such as fallen trees if the flow in a river channel is being inhibited is also an important function.
- Rivers Agency maintains many underground or piped watercourses and repair or rebuild defective culverts and clear debris from grilles as necessary.
- Rivers Agency carries out improvements to watercourses so that they can cope with extra rain water run-off from new housing and industrial developments throughout Northern Ireland.
- Rivers Agency monitors and regulates water levels on Lough Neagh and Lough Erne, taking account of the needs of farming, boating, fisheries, commercial and conservation interests and consulting with these parties as necessary.
- In the event of flooding from a watercourse Rivers Agency will try to help a property owner protect their property.

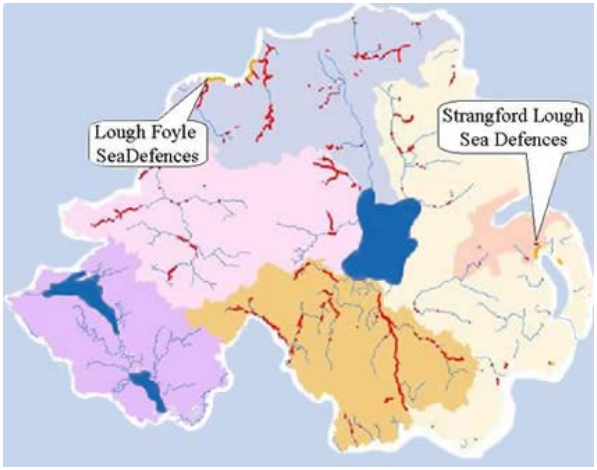
Rivers Agency only carries out work on approved or "designated" watercourses and sea defences. This is a term that applies to about 6,758 kilometres of main rivers and smaller watercourses in Northern Ireland and some 26 kilometres of sea defences. Watercourses and sea defences may be designated or de-designated only by the Drainage Council for Northern Ireland. This independent statutory body includes representatives from District Councils, drainage, agriculture, industry, fishery, tourism and environmental interests.

The Agency maintains coastal defences at Lough Foyle, Strangford Lough (including the Quoile Estuary). The defences protect airfields (Newtownards, Ballykelly and City of

Derry), roads and railways, commercial and residential properties and valuable agricultural farmland from the sea. Lough Foyle and Strangford Lough are internationally important conservation sites, and are protected by European designations.

In recent years, Rivers Agency has taken a more proactive approach to protecting the environment. All works carried out by the Agency are subject to the Drainage (Environmental Assessment) Regulations (Northern Ireland) 2006. This legislation commits the Agency to consider the effects on the environment of any works it proposes to undertake.

Figure 9.1 – Fluvial and Sea Defences



	Sea Defences
	Fluvial / River Defences

(Illustration taken with permission from Rivers Agency website)

Northern Ireland has a coastline 650km long (Atkins, 2004). The coastal environment is highly diverse, ranging from the high energy, rocky north coast to the low energy, high tidal range of the east coast (O'Hagan, 2003). Almost three quarters of the coastline is covered by some sort of environmental designation, ranging from local and national to European and global status, with the Giant's Causeway being designated as a World Heritage Site (O'Hagan, 2003). There are several competing pressures on the coast of Northern Ireland, including environmental and conservation activities, tourism and recreation, agriculture and development. Key responsibilities of organisations involved in managing the coastline are set out in Table 9.1. As in other parts of the UK and Europe, there is no overall body responsible for managing the coast of Northern Ireland, with coastal management split up into sectoral responsibilities (O'Hagan, 2003; Atkins, 2004).

Integrated Coastal Zone Management (ICZM) is a process that attempts to join up different coast-related policies whilst bringing together relevant stakeholders to inform, support and implement ICZM policies (Atkins, 2004). During the 1990s the European Commission funded a demonstration programme which identified problems in implementing ICZM and derived eight key principles for successful ICZM, which included taking a long-term perspective and employing adaptive management, both essential in dealing with climate change. In 2002, the member states of the EU adopted a European Parliament and Council Recommendation concerning ICZM, which committed countries to conduct a national stocktake and then develop a national strategy for ICZM. The UK stocktake was published in 2004 (Atkins, 2004) and national strategies for all home countries are due to be completed by 2006.

Table 9.1 - Key Responsibilities for Organisations Managing the Coast

Organisation	Responsibility
Rivers Agency	This organisation is responsible for maintaining a small amount of designated sea defences to prevent flooding.
Local Borough / District Councils	12 of the 26 local councils in Northern Ireland are bounded by the coast. All will have a role in maintaining features along their particular stretches, though the level to which this is achieved will vary from council to council and the nature of the features concerned. Activities may range from collecting litter to hard engineering of coastal protection or maintaining piers.
Crown Estates	Responsible for all land below the high water mark
Landowners	Responsible for maintaining their own stretches of coastline. Some landowners may have considerable areas of responsibility e.g. National Trust lease large areas of Strangford Lough.
DRD Roads Service	Responsible for coastal defences that are bounded by a public adopted road e.g. parts of A2 Antrim Coast Road.
Translink	This public transport body are responsible for short stretches of coastal defences which protect their physical assets – in particular short stretches of the Belfast to Larne and L'Derry to Coleraine railway lines.

In Northern Ireland, the Department of the Environment launched their document entitled *Towards an Integrated Coastal Zone Management Strategy* for Northern Ireland in June 2006. The proposed strategy recognises the importance of developing transparent policies on approaches to climate change. The strategy is organised around four priority themes: sustainable communities; safeguarding and improving the environment; maintaining and enhancing the economy; and integration of planning and effort. Objectives, actions and indicators are proposed for a series of aims under these themes. Objective SC1.5 is "to identify potential threats to coastal zones posed by climate change and consider appropriate actions for the safety, well-being and economic interests of coastal zone communities" (DOENI, 2005: 39). The research in this study forms one of the actions; the other is to develop spatial planning approaches that take predicted sea level rise into account. Other objectives relevant to climate change include ENV1.2 (monitoring of sea level change), ENV1.3 (species monitoring) and INT1.1 (adaptation). The DOE is currently setting up a Marine and Coastal Forum to oversee the implementation of the Strategy and to discuss strategic issues relating to the coastal area. The Rivers Agency Flood Management Review identifies this lack of overall responsibility and policy in regard to flood risk and erosion as a gap in existing policy and recommends that the Rivers Agency should be determined as the responsible Authority. This review itself is subject to the findings of the Review of Environmental Governance also due in 2007 (see also section 9.5 for more details of the Rivers Agency Flood Management Review).

9.3 The Issue Now

At present 45,000 properties in Northern Ireland are at risk from river and coastal flooding (Evans et al., 2004). The average annual damage from river flooding is £16 million, while £9.4 million is being spent by Rivers Agency in 2006 – 2007 on Capital and Maintenance costs (Rivers Agency 2006-07 Business Plan) for flood protection. Prolonged winter rainfall leads to major rural and urban flooding from the larger rivers, while high intensity summer storms are causing urban floods in small catchments. The Rivers Agency co-operates with Department of Rural Development agencies (which also have drainage infrastructure responsibilities) in the development of emergency plans and in the provision of year-round emergency response to flooding. There are currently no public Flood

Warning systems in Northern Ireland - although Flood Warning issues have been considered, no action has been deemed necessary to date. The Rivers Agency has an ongoing programme of flood defence works and drainage infrastructure schemes and has developed close strategic links with DoE Planning Service in provision of advice on development in areas of high flood risk. Flood mapping for strategic purposes is due to be completed by the end of 2006 and this will provide better information on areas in Northern Ireland at risk from flooding.

In addition to flood defences and government-led responses to floods, insurance plays a major role in addressing the medium-term consequences of flood events, particularly at the household and small business level. Insurance is reviewed in Section 12.

The issues surrounding flood and coastal defence and the associated policies are currently being comprehensively reviewed by the Rivers Agency who have the primary role in Flood Management in Northern Ireland. This is in recognition of the significant changes in this area in recent years, highlighted in the Foresight Report. These changes are across a broad spectrum from global economics to climate change and EU Directives and their interrelationships.

9.4 How Climate Change May Affect the Future

Future fluvial (river) flooding will be influenced by climate change principally through changes in rainfall and evapotranspiration. Wetter winters and more intense rainfall days in winter are likely to lead to greater flooding, although this will be tempered by an increase in potential evapotranspiration, which will reduce soil moisture content in autumn. Overall, this may lead to a later, but possibly more severe winter flood season, with higher winter and spring water tables.

Arnell (2003) provided factors for the change in mean monthly runoff for Northern Ireland for the 2020s. This was based on perturbation of three locally-calibrated catchment models using the UKCIP02 scenarios (low, medium and high). Two scenarios that represent climate model uncertainty range were also assessed ('warm and dry' and 'cool and wet'). The results (Table 9.2) show reduced mean flows from late spring to early autumn, with increased mean flows in winter. Although intended for rapid strategic-scale water resource assessments, the results illustrate the changing water balance, which becomes more seasonal and also shifts – with a later recharge season. The core UKCIP02 scenarios are very similar; this is because climate change over the next 20 years will be largely determined by historic emissions due to lags in the climate system.

Table 9.2 - Percentage change in mean monthly runoff by the 2020s, compared to 1961-1990

Scenario	J	F	M	A	M	J	J	A	S	O	N	D
Cool & wet	10	8	11	8	3	1	-3	-5	-2	6	11	10
Low	3	3	1	-1	-7	-13	-18	-22	-18	-7	0	3
Medium	4	3	1	-2	-7	-14	-20	-25	-19	-8	0	3
High	4	3	2	-2	-8	-15	-21	-26	-21	-9	0	4
Warm & dry	-2	-2	-2	-6	-13	-19	-24	-28	-25	-13	-4	-2

From Arnell, 2003.

Flood response to climate change will depend largely on extreme or prolonged rainfall events. The UKCIP02 scenarios show that daily rainfall totals in winter will increase, and although the pattern of daily rainfall is uncertain, the overall increase in winter rainfall is likely to lead to higher rainfall totals over a set number of days. Therefore, the likelihood of winter flooding will increase. Current climate models are not sufficiently detailed to

predict weather at fine spatial scales and therefore the effect on summer storms is uncertain.

Pluvial flooding (in particular urban flash flooding) will be largely influenced by changes in rainfall intensity and duration and is therefore likely to increase under climate change.

Coastal flooding and erosion will be affected by changes in sea level (mean and extreme), wave climate, extreme wave condition and coastal geomorphology (HRW and Atkins, 2002; SNIFFER, 2002). Relative sea level is the difference between eustatic sea level (thermal expansion of the ocean) and local effects including isostatic rebound, tectonic change and sediment consolidation. The UKCIP02 scenarios for eustatic sea level rise for the 2080s range between 23 and 36 cm depending on emissions. A wider selection of models suggests greater scientific uncertainty, producing a range between 9 and 69 cm. Regional sea level can vary due to the non-uniform nature of ocean warming and expansion as well as changes in ocean circulation and atmospheric pressure (Hulme et al., 2002). As there is little agreement between models, Hulme et al. (2002) advise applying a factor of +/- 50% in sensitivity studies. This would give a range extending as high as 104 cm.

Unlike for the rest of the UK, there is no apparent quantification of isostatic uplift or sediment consolidation, which makes prediction of net changes in future sea level problematic. Studies of recent sea level trends have suggested remnant isostatic uplift (SNIFFER, 2002), which would be consistent with evidence from Scotland (Shennan, 1989; Shennan and Horton, 2002). Establishing recent trends of sea level change have been complicated by the quality of tide gauge data and natural decade-scale oscillations (SNIFFER, 2002). However, EHS has recently commissioned the Quercus Centre at Queens University to carry out a research project on relative sea-level change in Northern Ireland. The project will merge historical evaluations of crust and sea level movement with modern instrumental measurements of relative sea level to reduce the uncertainty of contemporary values of isostatic readjustment and relative sea-level change. At present it is only possible to conclude that given the likely low level of isostatic uplift, relative sea level will rise under all but the lowest scenarios of eustatic sea level rise; under the highest emissions scenarios, relative sea level may rise by half a metre or more by the end of the century. The new research, due to report in March 2007, will provide a reliable baseline record. It is then recommended that a brief evaluation is undertaken to produce estimates of future sea level rise based on this and the UKCIP02 scenarios.

Extreme sea levels are of most importance in assessing the risk of flooding events. Hulme et al. (2002) provide simulations of the 50-year return period water levels, including change in storminess and the rise in global sea level. For the east coast the changes are no greater than the rise in mean sea level, while for the north coast the change in storminess adds up to 10 cm. However, it must be emphasised that the uncertainties in modelling patterns and magnitudes of change in storm-surge height are currently large.
The Foresight Flood and Coastal Defence Project (Evans et al., 2004a,b) provided a major broad-scale assessment of future flooding and coastal erosion risks over the 21st century. This was based on coupled scenarios of climate and socio-economic change, which were modelled conceptually under a framework of drivers and responses. The key impacts are summarised below:

- Annual losses from fluvial, pluvial and coastal flooding increases under all four scenarios considered, dramatically so under the socio-economic scenario of World Markets and High climate-forcing emissions. Expressed as a percentage of GDP, losses decline in the two community-orientated, lower emissions scenarios. This assumes no change in flood management policy and expenditure.

- Urban flooding risks increase under all scenarios – with the number of properties at high risk increasing by a factor of four. However, there is a large range of uncertainty and further research is required to better quantify the risk.
- Coastal erosion will accelerate and associated annual average damage will increase substantially.
- The number of people at risk will rise significantly.

The Foresight study examined a range of options for responding to the change in risk. An integrated portfolio of responses would:

- Offset the increase in annual average damage, but costs remain at least as much as they are at present.
- Reduce the number of people at high risk.
- Cost significantly more.

The Foresight study raised a number of questions for long-term flood management policy, particularly with regard to future climate change. However, the study does not replace the need for more detailed, catchment-based modelling studies which better quantify risk and inform responses at the local level. In England and Wales, these issues are being taken forward in Catchment Flood Management Plans, which will set the framework for lower-level strategy plans and specific flood management schemes.

Guidance on the application of the UKCIP02 climate change scenarios in coastal and flood defence was produced by HR Wallingford and Atkins in 2002 (HRW and Atkins, 2002). This includes recommendations on appropriate levels of impact assessment, sensitivity testing and full modelling for a range of coastal and fluvial applications. Although developed for England and Wales only, the approaches adopted may be useful to practitioners in Northern Ireland. A study to produce figures appropriate to Northern Ireland is recommended.

There are large uncertainties associated with predicting changes in future flooding and coastal erosion (see Table 3.2) and these need to be considered when making decisions. These have led to adoption of precautionary allowances in England and Wales, but improvements in modelling, including explicit representation of uncertainties, will lead to improved risk management.

The House of Commons Environment, Food and Rural Affairs Committee report on Climate Change, Water Security and Flooding (HoC, 2004) recognised the impact of climate change on flood risk and recommended that:

- The Government publish a white paper, containing a clear strategy for dealing with increased flood risk identified in the Foresight study and the implications for resources.
- The Government should indicate how and when it will decide what further protection is needed in response to the Foresight study.
- Planning policy guidance should take account of likely future flood risk, with new development in flood-prone areas built to be resilient to flooding.
- Sewers in new developments should be designed to cope with likely future volumes of flow, while existing sewers should be upgraded.
- The Government identify areas which may face problems obtaining insurance and explore alternative ways which flood risk can be managed in such locations.

Impacts on the coastal and flood defence sector are summarised in Table 9.3.

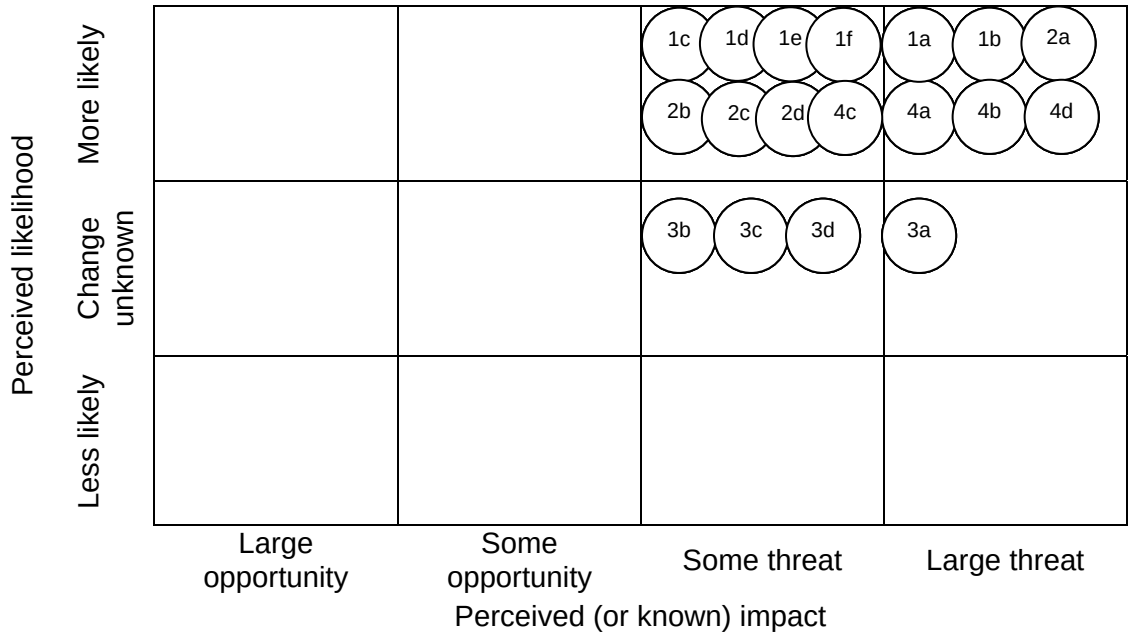
Table 9.3 - Climate Change Impacts: Coastal and Flood Risk Management

Climate change	Impact on receptor
Wetter winters	Increase in fluvial flooding, affecting floodplain areas including settlements, farms, agricultural land, natural heritage. Increase in pluvial flooding, with particular impacts on urban infrastructure, built heritage, businesses, homes, the economy and health.
Drier summers	May delay onset of flood season, with benefits in terms of flood risk.
Warmer winters	Will reduce snow-related flood events, with benefits to those floodplain areas which traditionally suffered from such events.
Hotter summers	May lead to more summer convective storms and flooding, with particularly severe consequences for urban infrastructure.
Sea level rise	Will increase flooding and erosion at the coast, with impacts on transport systems, coastal habitats, settlement and agriculture land.
Reduced soil moisture	May delay onset of flood season, with benefits in terms of flood risk.
Change in Storminess	May increase extreme sea levels leading to greater coastal flooding and erosion; may also increase inland flooding. Consequences for floodplain and urban areas, as well as coastal areas and infrastructure.

Risks associated with the main impacts are summarised in Figure 9.2. There is a clear risk associated with an increase in winter fluvial (number 1 in Figure 9.2 and Table 9.4) and pluvial (2) flooding. Risks associated with summer pluvial flooding (3) are more uncertain, but represent a large threat, in particular to those organisations which deal with drainage issues in urban areas e.g. DRD Water Service and DRD Roads Service. Although there is some uncertainty regarding the level of isostatic uplift, relative sea level rise is likely under climate change, especially later in the century and beyond, and therefore sea level rise and erosion (4) is classified as a major threat.

Climate change is recognised as a significant issue in the medium-long term and one which will affect the ability of organisations to meet their objectives. However, a number of other issues are considered more important than climate change. These include organisational changes, the Water Framework and Floods Directives and the increasing consideration for the environment in general.

Figure 9.2 - Risk Assessment: Coastal and Flood Risk Management



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 9.4).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

9.5 Actions Undertaken or Underway and Key Gaps

A number of actions are already underway in response to current flood risk e.g. flood mapping (see Section 9.3) continued programmes of flood alleviation and river maintenance and strategic assessment of flood risk in relation to development planning. In addition, there are some actions underway specifically in response to climate change, which is recognised as having an effect on the sector in the future. Actions include building adaptive capacity through research and networking and delivering adaptive actions by adding an allowance for climate change to flood defences (based on Defra allowances). Planning Policy Statement 15 (published June 2006) on planning and flood risk highlights the importance of climate change (see Section 10.5.2). The proposed Floods Directive will address the issues of flood risks and the potential response to them. A forum is being established to drive forward ICZM in Northern Ireland, to include objectives related to climate change. The principal gap for the sector is the level of future climate change, particularly in relation to sea level rise. This partly reflects genuine uncertainty about the future (c.f. emissions scenarios), but scientific uncertainty is also significant. The latter will be improved by current research into relative sea level change (see above).

Rivers Agency has also recently commissioned an independent review of its Flood Management Policy, in order to provide a policy framework for the future which reflects the changing role of the agency. This review has been prompted by a number of key drivers including the following:

- Following recent and severe floods in the UK and Europe, respective governments are now taking a more holistic approach to flood management by looking at flood risk on a River Basin District and Shoreline wide basis.

- There are ongoing proposals to implement a new European Union Floods Directive.
- The Department for Environment, Food and Rural Affairs (DEFRA) has recently issued 'Making Space for Water', which outlines their new strategy on Flood Risk Management.
- The UK Foresight report on Flood and Coastal Defence which concludes an increasing probability and impact of flooding.
- The EU Water Framework Directive (WFD) which was introduced in 2000 embodies the concept of the management of the water environment on an integrated river basin management approach.
- A new Marine Bill is being drafted in the UK which will enhance environmental protection and benefits for society who use and depend upon the coastal and marine environment.

Throughout this document (which has yet to be finalised as of November 2006), the theme of climate change and its implications are raised. For example under the issue of 'Flood Risk' it states "changes to the climate will increase the flood risk to both the built and natural environment", while under the issue of 'Coastal Management' it states that "at present the issue of coastal erosion is not perceived to be a major issue in Northern Ireland, but it will become more important in the future given the inevitable sea level rise which will result from climate change". Therefore Rivers Agency is clearly aware of the implications of a changing climate and is taking steps to incorporate this reality into their forward planning.

9.6 Adaptation Strategies

At present, the approach of the sector to climate change can be characterised as building adaptive capacity, although there are elements of 'wait and see' and the adoption of adaptive actions. It is clear that as the implications of climate change for the sector in Northern Ireland becomes clearer, then more significant activity will be required. At present, there is a lack of certainty about future climatic conditions. Flooding is not as severe as in other parts of the UK and the impacts of climate change, particularly at the coast are more uncertain. In this respect, more research specific to Northern Ireland is required in the short-term. This should include an evaluation of future sea levels based on current research into relative sea level change and use of fluvial models to assess changes in inland flood risk, concentrating on areas identified by the flood mapping project as being particularly vulnerable. This is an integral part of the flood mapping strategy being developed by Rivers Agency to satisfy the requirements of the proposed Floods Directive.

The strategic assessment of flood and erosion risk under climate change (most appropriate on a catchment or coastal cell basis) is identified as an initial adaptation strategy for many of the impacts identified (see Table 9.4). In addition, there is likely to be a need for more specific assessments at individual localities or sites at various size scales (e.g. small isolated heritage sites such as Dunluce Castle, or larger sites such as Belfast City centre) or for pieces of infrastructure (e.g. risk to coastal roads and railways such as the A2 Coast Road and the Londonderry to Coleraine railway line). These will determine the medium-term adaptation actions adopted in response. At the highest level, the strategic assessments should be used to inform development planning – decisions on whether and what to build in areas at risk. It will also help inform decisions on flood risk and shoreline management. It should be noted that operational linkages between Rivers Agency and Planning Service are already strong in relation to the provision of advice on

development in areas of flood risk and these linkages should be maintained and indeed enhanced where appropriate.

Options for reducing flood risk range from catchment scale options such as upstream source control or flood storage, to the defence of vulnerable areas such as towns, to the property level, where individual flood protection or flood proofing can be employed. Non-structural measures for reducing flood risk include flood warning and insurance. In urban areas adaptation may include source control (e.g. green roofs, permeable pavements), better design and maintenance of channels and culverts, and flood proofing. Provision of safe escape routes is also important, especially where water levels may rise quickly (e.g. in low-level apartments, below sea level or behind flood defences). Contingency planning should ultimately include climate change impacts, with provision made for an increase in staff and equipment resources during the winter season in particular. Moves in this direction have been taken by Rivers Agency as part of their flood mapping strategy to satisfy the requirements of the proposed Floods Directive.

Traditional options for managing coastal change range from do nothing to the construction of defences. In England, a more radical approach – managed realignment – has been employed in suitable areas, which has required a major shift in policy and social attitude. This recognises that defending against rising sea levels is not always sustainable, economically or environmentally. Such projects are yielding major environmental benefits, for example in restoring coastal habitats such as saltmarsh. In contrast, coastal defences for London, which currently provide some of the highest defence standards in the world, are being reviewed in the light of climate change. Here, as for many coastal settlements, a reduction in the standard of protection is unlikely to be acceptable. As in England, a variety of responses are likely to be required in Northern Ireland.

Constraints to adaptation identified in the coastal and flood risk management sector include uncertainty about future climate conditions, a lack of funding, a lack of human resources and potential public and political resistance to more radical adaptation measures.

9.7 Conclusions and Recommendations

There are a number of likely impacts on coastal and flood risk management associated with a changing climate. These impacts will include:

- Sea level rise and increased storminess causing greater coastal erosion.
- Wetter winters increasing both pluvial and fluvial flooding.
- Hotter summers may cause an increase in convective storms and pluvial flooding.

While there are a number of organisations responsible for managing different aspects of the coast, the main organisation with responsibility in Northern Ireland for dealing with the results of the above impacts is Rivers Agency, in their role as the statutory drainage and flood defence authority.

As a public body, with a finite resource base, Rivers Agency naturally face the imperative of dealing with existing flood risks. As a result, political, organisational and resourcing pressures tend to take priority over any planning for climate change, leaving a significant gap in response, though it is acknowledged that these are pressing matters, while a changing climate is more of a medium to long term issue. Nonetheless, there are a number of reviews taking place which seek to establish a sound base for policies to be fully and properly developed in the near future. The sector is also driving ahead

with building adaptive capacity through flood risk mapping, ICZM planning and other initiatives. However, there are gaps at a site scale both in terms of assessing risk of flooding and potential increased risk to existing and planned infrastructure projects.

At present the impacts of climate change in Northern Ireland remain uncertain and more specific research is required in the short-term. For example, a strategic assessment of flood and erosion risks is necessary, with more specific assessments for localised areas or individual sites and infrastructure as required in the future – though it should be noted that moves in this direction are taking place due to the need to meet the requirements of the forthcoming Floods Directive (e.g. Preliminary Risk Assessment, Catchments and Flood Risk Management Plans).

In relation to flood risk management there are a number of physical and non-structural methods which can be used. These range from such physical options as upstream source control, flood storage, flood-protecting and land management, as well as non-structural methods such as flood warning and insurance.

There are also many options for managing coastal change available, from construction of sea defences to managed realignment, the latter of which is especially suitable where the defence against rising sea-levels is not sustainable (though the scope for this option is considered to be limited in Northern Ireland).

Table 9.4 - Impacts and Adaptation Summary: Coastal & Flood Risk Management

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Increase in winter fluvial flooding:						
1a	Impact on settlements	Planning; Emergency planning; Housing; Watercourse management	Implications for spatial plans, emergency plans, homes and management of rivers.	Major threat	Staff time and associated costs	*Revise plans (development zoning), strategic assessment of flood risk,* local decision on options to reduce.	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations, Rivers Agency, EHS
1b	Impact on farms and agricultural land	Planning; Watercourse management; Business support	More support required for farmers.	Major threat	Staff time and associated costs	*Assessment of flood risk* and options to reduce.	DARD
1c	Impact on natural heritage	Planning; Conservation; Watercourse management	Implications for health of designated sites.	Minor threat	Staff time, remediation costs	*Assessment of flood risk* and implications for water management.	EHS
1d	Impact on transport infrastructure	Planning; Emergency planning; Transport planning	Damage to infrastructure; disruption to users.	Minor threat	Staff time, repair costs	*Assessment of flood risk* and options to reduce.	DRD Transport, DRD Roads Service
1e	Impact on the economy	Cross-cutting / treasury	Economic impact of damage and disruption.	Minor threat	Increase in costs	Increase funding or accept loss	Treasury
1f	Impact on health	Heath advice and promotion; Healthcare; Emergency planning	Increase in flood-related accidents; flood risk to hospitals.	Minor threat	Need for more staff at times of flood	Contingency planning	DHSSPS, Health Boards, Local Councils
2	Increase in winter and summer pluvial flooding:						
2a	Impact on urban infrastructure: buildings (including built heritage), utilities and transport	Planning; Emergency planning; Housing; Management of public buildings; Transport planning; Watercourse management	Direct flooding of public property; indirect need to respond to flooding.	Major threat	Staff time, repair costs.	*Strategic flood risk assessment*, source control, increased storage and conveyance.	DOE (Planning Control), Local Councils, Emergency Services, Housing Executive, Housing Associations, DRD Roads Service, Rivers Agency, EHS
2b	Impact on businesses	Business support	Need for support to vulnerable businesses.	Minor threat	Staff time	*Awareness raising of flood proofing measures*	DETI
2c	Impact on economy	Cross-cutting / treasury	Economic impact of damage and disruption.	Minor threat	Increase in costs	Increase funding or accept loss	Treasury
2d	Impact on health	Heath advice and promotion; Healthcare; Emergency planning	Increase in flood-related accidents; flood risk to hospitals.	Minor threat	Need for more staff at times of flood	Contingency planning	DHSSPS, Health Boards, Local Councils
3	Increase in summer storms and pluvial flooding.	Summer pluvial flooding will affect the same receptors as winter pluvial flooding – see (2). Risks classified as minor or major unknowns due to the uncertainty in the change in summer storms.					

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
4	Increase in flooding and erosion at the coast.						
4a	Impact on coastal settlements	Planning; Emergency planning; Housing; Management of public buildings	Implications for spatial plans, emergency plans and response and management of property.	Major threat	Staff time and associated costs	*Revise plans (development zoning), strategic assessment of flood and erosion risk*, decision on strategic options.	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations, Rivers Agency, EHS
4b	Impact on coastal transport infrastructure	Planning; Transport planning	Damage to infrastructure; disruption to users.	Major threat	Staff time, repair costs	*Assessment of flood and erosion risk* and options to reduce.	DRD Transport, DRD Roads Service
4c	Impact on coastal agricultural land	Planning; Business support	More support required for farmers.	Minor threat	Staff time and associated costs	*Assessment of flood and erosion risk* and options to reduce.	DARD
4d	Impact on coastal habitats	Planning; Conservation	Implications for health of designated sites.	Major threat	Staff time, remediation costs	*Assessment of flood and erosion risk* and implications for water management.	EHS

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

10 BUILDINGS, CONSTRUCTION AND PLANNING

10.1 Scope

This chapter of the report considers the potential impacts of a changing climate on buildings, construction and spatial planning. The chapter provides an assessment of how climate change may affect the future of these issues and details in particular buildings, urban infrastructure, internal and external human comfort, historic buildings and green spaces. This chapter details actions which are already underway, and also provides an overview of potential adaptation strategies for meeting the impact of climate change on these aspects. For further details on associated topics, see the chapters on Business and Insurance.

10.2 Background

Towns, cities and the structures within them are artificial environments designed to mitigate past and current climatic conditions for human comfort. Where future weather and climate departs from those conditions the structures available may prove maladapted. A good deal of research has been done and is continuing in this area, looking at both impacts and potential future adaptation (such as: research on building design, on urban environments and on growth areas).

In addition to climate change, other factors are also working to change the nature of buildings and how they respond to the environment, and to modify the layout of urban areas and the way in which they are used. Some of these factors may work in synergy to increase adverse effects (e.g. demographic trends and expectations of personal resource use by individuals), or act to offset each other. Some of these factors may be distinctive in Northern Ireland, such as specific measures in connection with government policies for Neighbourhood Renewal and Environmental Improvement Schemes, and the high rate of disrepair of homes.

10.3 The Issue Now

The built stock and infrastructure services present in towns and cities now have been in place for many years, sometimes much more than 100 years. Ways of creating areas and buildings better suited to changing climates are restricted to the replacement of built stock or new build, or technological change, or changed behaviour. Generally, development adds only 1% to the built stock each year, and replacement is usually a very slow process. The design of urban areas is constrained by patterns of ownership, transport, etc. as well as by land values, and consequently it is difficult to change urban design rapidly in significant ways, except within newly developed areas. However, more than 50% of the region's households live in houses built since 1965 (Smyth et al., 2002). Shaping the Future, the Regional Development Strategy for Northern Ireland 2025 (DRDNI, 2001) proposes high levels of housing growth. The current stock is 636,000; the Plan proposes an additional 160,000 by 2015 (an increase of 25%), and 250,000 by 2025. Urban and economic development will take place within a hub, corridor and gateway framework. There are therefore considerable opportunities for new development to demonstrate climate change adaptation.

However, parts of Northern Ireland experience conditions of poverty and deprivation, with household incomes in Belfast and the west lower than the regional average (Smyth et al., 2002). The impacts of climate change may affect particularly those households in property which is already in poor condition.

10.4 How Climate Change May Affect the Future

10.4.1 Buildings

A large number of research studies consider (i) the impacts of climate change upon the integrity of buildings and infrastructure; (ii) impacts upon the construction process and (iii) impacts on the comfort of building occupants. These impacts may result from many components and combinations of future weather/climate. The following paragraphs summarise impacts relating to temperature change, precipitation and flooding, and storm events.

Whereas milder winters may result in fewer problems such as burst pipes and chloride (de-icing) damage to buildings, milder damper winters may mean more pest impact upon timber e.g. house longhorn beetle and termites may extend their territories northwards (Graves & Phillipson, 2000). Increased humidity is likely to affect condensation in housing (already a problem acknowledged in SNIFFER 2002), with impacts on fungal and insect attack and secondary impacts on human health. Warmer, wetter conditions can also increase heave (BKCC, 2005), increase the threat to foundations from sulphates in soils, and may increase the mobility of water-based contaminants (Garvin et al., 1998).

Flooding risks to buildings include rot and impact, though the extent of this will depend on height of water and materials used (Garvin et al., 1998). Precipitation increase of 10-15% is predicted for spring and winter by the 2050s for Northern Ireland.

Windspeed predictions under the UKCIP02 scenarios are generally for little change in Northern Ireland, though confidence in this is low. An increase in storm damage to buildings may result from rain and from wind: wind-driven rain may penetrate walls and apertures, increasing weathering and therefore maintenance costs. Storm winds may damage roofs and cladding but also infrastructure (electricity and communications) (CURE & Tyndall Centre 2003). Vulnerability to storm damage is strongly dependent on building type, with bungalows shown to be at greater risk than high rise buildings. Older buildings are more likely to suffer wind damage (see also Section 12, Insurance). LCCP (2002) suggested that English buildings are less likely to withstand severe storms than buildings elsewhere in Europe, and this may also apply in Northern Ireland.

Higher temperatures may result in more rapid deterioration of the building fabric and lower air quality within buildings as solvents are released from building materials (Garvin et al., 1998). Drier soils, resulting from summer drought conditions, may lead to increased risk of shrinkage and consequently subsidence – this is a greater risk for old and tall buildings and on clay soils (ABI, 2002a). Ongoing research under the ASCCUE project, to be published in 2006, covers subsidence.

10.4.2 Urban infrastructure

Threats to infrastructure include stress on pipes, tunnels in clay and pylon foundations following movement in soils (subsidence and heave) with changing temperature and moisture conditions; risks to power and communications cables and pylons from wind (LCCP, 2002; CURE & Tyndall Centre, 2003). Storm lightning is also a risk for such assets (Baxter et al., 2002).

Flooding is a particular risk for infrastructure, including utilities such as electricity generating plants close to seas and rivers (CII, 2001 cited in Gill, 2004), as well as landfill sites, sewerage systems and pumping stations (LCCP, 2002). Sewer performance is at risk of groundwater infiltration and changed soil moisture deficits as well as the level of

receiving waters as a result of flooding (UKWIR, 2004). The overwhelming of storm drains was identified as a particular risk for Belfast during the consultation process.

Roads and other transport services are at increased risk both from flooding and from higher temperatures affecting materials, leading to damage to rails or asphalt surfaces (Palutikof et al., 1997; Atkins, 2005), though less need for grit and salt may reduce damage (LCCP, 2002). Climate change may also afford the opportunity to reduce the amount of salt used on the roads in Northern Ireland in winter and therefore reduce the cost implications for DRD Roads Service – the cost of salting the main road network in Northern Ireland stood at £5 million in 2001 (Hansard, 2001). Shrinking clay soils, in dry conditions, may lead to impacts for roads, bridges, embankments and tunnels. Embankments and tunnels may also suffer instability following severe rainfall. Impacts for airports include both the adverse (more winter storms) and the beneficial (reduced snowfall and frost frequency) (LCCP, 2002).

Impacts for the construction process are likely to include increased delays as a result of flooding or damage to infrastructure, or threats to human safety on cranes etc. (Garvin et al., 1998). The suitability of building materials is determined by climate and the concrete production process, for example, is affected by weather conditions, so adaptation of the process may be necessary. Recognition of these impacts is already leading to changes in practice, as discussed by Vivian et al. (2005) (see below).

Higher summer temperatures also have consequences for air quality (dust, odours) and for waste treatment within urban areas (LCCP, 2002).

10.4.3 External and internal human comfort

Svenssson and Eliasson (2002) have measured human comfort as physiological equivalent temperature (PET). PET values are higher within more densely built-up urban environments and in clear, calm conditions than in windy and cloudy conditions. Work on external thermal comfort is in progress (BKCC, 2005) looking at perceptions of thermal comfort, adaptive behaviour and the impacts on human health within conurbations and at neighbourhood level, especially with regard to heat stress and vulnerable populations. This work is using a set of urban morphology types for the analysis of urban areas. Preliminary results show that people adapt in outdoor environments to a wide range of thermal conditions (including via choice of clothing, activity and location), and that while there is less personal control than in the indoor environment, there is more scope for adaptation. Nevertheless, heat stress may be experienced by those, such as construction workers, working outdoors.

The use of outdoor spaces is likely to change significantly with warmer temperatures: spaces may be used more frequently or extensively for informal recreation, or may be used at different times of day. Opportunities may exist to develop the evening economy.

Issues for the comfort of building occupants include those associated with heat and dampness – with potential impacts on health and thermal comfort. Both damp and heat induce additional energy use, either to dry and warm, or to cool. Condensation and damp may encourage mould growth, with impacts for the durability of building materials (Graves and Phillipson, 2000).

Hacker and Holmes (2005) have researched climate change and the indoor environment. They conclude that already heat-load in buildings has been increased by changes in use (longer hours, higher energy use) and further increase in outside temperatures will have adverse effects for internal comfort. Impacts on 11 different types of building (houses,

schools, offices, etc.) were modelled as a guide for appropriate low-energy means of adaptation. The current UKCIP02 scenarios suggest an increase in average summer temperatures for Northern Ireland of 1.00-2.5 degrees C by the 2050s, and 1.00-3.5 by 2080s. It is expected that there will be an increase in frequency of extremely warm days, and in the frequency of longer duration events such as heat waves. Summer evenings will be warmer than now. While Northern Ireland might not experience the extremes of London, the study cited above also assessed some of the building case-studies for the projected climates in Manchester and Edinburgh. It was estimated that, under the medium-high scenario, discomfort (measured as a percentage of occupied hours over certain temperatures) would be experienced in Manchester in the 2080s comparable to London in the 2020s, with significant summertime thermal discomfort in 10-15% of occupied hours at over 280C in a mid-60s office building. The study concluded that buildings in which unnecessary external (solar) and internal heat gain can be reduced and where natural ventilation can be controlled will suffer least impact and lowest rise in energy demand (Hacker, Belcher and Connell 2005). Buildings with higher thermal mass will also be at an advantage.

10.4.4 Historic buildings

A recent report on the impacts of climate change on the historic environment (Cassar, 2005) highlighted increases in rainfall impacting on water disposal systems and inadequate rainwater goods, with consequent damage through rainwater penetration. Flooding will have direct and indirect impacts (such as post-flood drying practices), ground heave and subsidence. Extreme weather, wind-throw and high winds will have direct and indirect impacts. Higher temperatures will affect visitors, outdoor staff, and the materials and contents of historic properties.

Opportunities may exist for an increase in visitor numbers to outdoor properties.

10.4.5 Green spaces

Impacts within towns and cities include impacts upon the urban fabric and upon any green areas: parks, gardens, sports fields, etc. Climate change impacts for green areas are likely to include stress during extended hot dry periods as a result of high radiation, higher evapotranspiration and water shortage (BKCC, 2005), resulting in loss of cover and adverse aesthetic impacts. Plant growth during milder damper winters is likely to be greater, however, though increased survival of pest species might damage plant species. Species invasions (flora and fauna) resulting from changed conditions, and assisted by introduction, may affect the balance of species in created and semi-natural green spaces (CEH, 2006 in preparation). Flooding and poaching of soils during wet periods will also adversely affect green areas locally, at least in the short term. Any increase in storm frequency or intensity could lead to slope instability, soil erosion and tree damage.

10.4.6 Planning

A number of research programmes and projects have been commissioned in recent years to investigate impacts and adaptation approaches in relation to spatial planning:

- BRANCH programme (Biodiversity Requires Adaptation in Northwest Europe under a Changing Climate), funded by Interreg IIIb and led by English Nature, with partners in England, France and the Netherlands.
- ASCCUE project (Adaptation strategies for climate change in the urban environment) funded by EPSRC.

- ESPACE programme (European Spatial Planning: Adapting to Climate Events), funded under Interreg IIIb.

The BRANCH policy review project (Piper et al. 2006) within the BRANCH programme has examined policies and plans across the three partner countries for evidence of measures being taken, or proposed, to protect wildlife and promote biodiversity, mainly by increasing the resilience of sites and species to climate change. The study has encompassed coastal, rural and urban locations.

The study has established that recognition of the need to adapt planning policies for climate change impacts has appeared only within recent years, and that the particular needs of biodiversity under climate change are only beginning to be addressed. Existing measures include protection and enhancement of sites - for example with buffer zones; the creation and augmentation of networks and corridors for wildlife, the introduction of ideas such as "stepping stones" for biodiversity movement. In future such measures will also need to take account of and respond to climate change impacts. It is acknowledged that there is some controversy about the value of certain measures, such as wildlife corridors, and there are many uncertainties, such as the dispersal capacity of the range of species, and the conditions under which wildlife may move to new sites, as this becomes necessary.

The BRANCH study concludes that a flexible approach will be needed in planning and policy to enable wildlife to adjust to changing climatic conditions. Such an approach is already being introduced in the form of managed re-alignment along coasts. It is suggested that adaptation is needed at three levels. First, at the level of protection of sites and habitats individually or within networks, some re-evaluation of sites and measures maybe appropriate. Next, at the level of the wider environment within which protected sites are located, policy measures are needed to enhance the overall quality of this matrix, e.g. via agri-environment schemes, or within cities and towns, by retaining and enhancing corridors, gardens, parks, etc. as well as introducing new planted areas including green roofs and walls. Thirdly, there is also the "ecosystem level" for action - recognising the importance of ecosystem functions and aiming to restore them. This might take the form of restoring past flood regimes across a floodplain, and improving infiltration across urban areas.

Tools are available to spatial planners to bring forward actions at these three levels. A set of EU Directives (Birds, Habitats, those on EIA and SEA plus the Water Framework Directive) provides for assessment and mitigation of impacts, as well as for compensation in certain cases. Further directives now under discussion, on soil quality and floods, should also strengthen these measures. Other important measures will include the climate proofing of plans and policies (testing them for interactions with climate change), the integration of plans across sectors, moving to share objectives and timescales. The safeguarding of potential future sites of importance to biodiversity, the raising of awareness and promotion of communication, and developing a dynamic vision for biodiversity protection and conservation in the face of climate change are also seen as important to future action on adaptation to changing climates.

The ASCCUE project is investigating the vulnerability of towns and cities to climate change, and the development of adaptation strategies such as changing processes, practices or structures as necessary, or reducing the vulnerability of communities, regions or activities. The project is addressing a set of key issues for towns and cities (coastal and riverine flooding, subsidence, wind and storm damage, and the impacts of warmer summers on thermal comfort) and is developing testing tools for vulnerability assessment, followed by planned adaptation to change through strategic planning and urban design.

The work is focussing on the consequences for buildings, urban greenspace, human comfort and the interaction between them.

ESPACE is a four-year European programme that aims to promote awareness of the importance of adapting to climate change and to recommend that this is incorporated within spatial planning mechanisms at local, regional, national and European levels. Focussing on North West Europe, ESPACE is examining, for example, how water resources are managed and what plans are being made for a future with a changing climate. ESPACE is designed to develop a common strategy and policy guidance outlining mechanisms to integrate new policies.

10.4.7 Waste

Little research has been undertaken on the impacts of climate change on waste. However, in 2003 the Environment Agency of England and Wales published an initial risk assessment, focussed on municipal waste effects and responses (Entec, 2003). The most significant impacts were considered to be:

- Increased disruption to supporting infrastructure and site buildings.
- Increased risk of subsidence and slope instability.
- Changes to waste management processes e.g. degradation rates and leachate composition.
- Changes in the type and amount of flora and fauna and the choice of communities used in restoration.
- Increased health risk to workers from direct impacts (e.g. increased sunshine) and indirect impacts (e.g. increased vermin activity).
- Impacts will vary on a site by site basis (Entec, 2003).

10.4.8 Summary

Impacts on buildings, construction and planning are summarised in Table 10.1.

Table 10.1 - Climate Change Impacts: Buildings, Construction and Planning

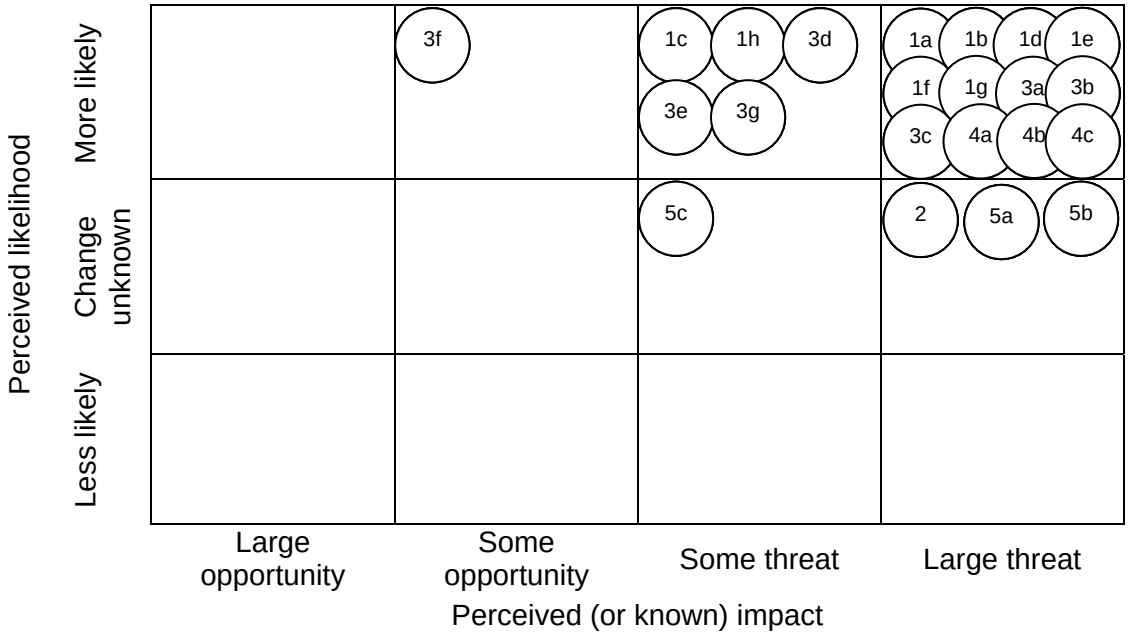
Climate change	**Impact on receptor**
Wetter winters	*Planning (strategic and local):* Emergency and essential infrastructure at risk of flood, scour and landslip. Drainage and sewerage infrastructure at risk of overflows. Risk of development diverted from flood plain affecting green and brownfield sites *Construction:* Delays in construction *Buildings:* Flood risk, damp in buildings *Urban greenspace:* Change in condition of spaces.
Drier summers	*Planning (strategic and local):* Water shortage - plan for location of new water resources. *Construction:* Shortage of water. Greater need to design for water efficiency. *Buildings:* Reduced condensation and deterioration. *Urban greenspace:*. Dry conditions in gardens help promote "urban creep". Change in condition of spaces.

Climate change	**Impact on receptor**
Warmer winters	*Planning (strategic and local):* Invasions and changes in survival of species leading to change in species balance. Plan for measures to promote landscapes to biodiversity *Construction:* Potential faster construction times *Buildings:* Reduced energy demand. Pest infestation *Urban greenspace:* Greenspace damaged by drought and overuse.
Hotter summers	*Planning (strategic and local):* Available greenspace at risk of drought and erosion from increased use. Impacts on air quality *Construction:* Conventional building design becomes ill-adapted *Buildings:* Deterioration of some materials (timber shrinkage, paint). Uncomfortable living/working conditions. Additional air-con use in poorly ventilated buildings. Pest infestation. *Urban greenspace:* Greenspace damaged by drought and overuse.
Sea level rise	*Planning (strategic and local):* Increase in risk of coastal flooding. increased risk to existing built development. implications for retaining / strengthening existing flood defences. *Construction:* **no impact identified** *Buildings:* Flood risk, damage and loss. *Urban greenspace:*. Flooding risk for plants and animals. Loss of coastal greenspace, deterioration and damage.
Reduced soil moisture	*Planning (strategic and local):* Change in species balance with changed soil conditions. *Construction:* **no impact identified** *Buildings:* Subsidence, foundations at risk. *Urban greenspace:* Drought risk to flora and fauna.
Change in storminess	*Planning (strategic and local):* Increased risk of flash floods and damage to emergency infrastructure *Construction:* Risk of storm damage at sites. *Buildings:* Increased risk of flash floods and damage to property Rain penetration. Mould damage. Damage to less robust structures *Urban greenspace:* Increased loss of mature trees
Increased variability, year on year	*Planning (strategic and local):* Need for flexible planning; wider safety margins. *Construction:* Greater risk of disruption of building in some years, less risk in others. *Buildings:* *Urban greenspace:* Less predictable weather calling for extra flexibility in management plans.

Risks associated with the main impacts are summarised in Figure 10.2. There is a clear risk associated with an increase in flooding, especially in the winter (1) with a less certain risk and smaller threat from summer storms and pluvial flooding. An increase in summer temperatures and drought (3) may give rise to some economic opportunities as well as a degree of threat. Sea level rise and associated flooding (4) is seen as more likely and also constituting a large threat, whilst the likelihood of increased storminess (5) is less

predictable but offers some threat. (See Table 10.2 for a breakdown of effects associated with each of the impact codes 1-5).

Figure 10.1 - Risk Assessment: Buildings, construction and planning



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 10.2).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

10.5 Actions Undertaken or Underway and Key Gaps

10.5.1 Building construction and property management

The National Trust is already reporting changes in its land and property management, with, for instance, an increase in hard path surfaces (in response to more severe rainfall), greater levels of maintenance (for instance inspection of rainwater goods), and changed mowing regimes (in response to earlier growing periods) (NT, 2005).

Vivian, Williams and Rogers (2005) have examined climate change risks in the construction industry and provide guidance for the identification and management of risks associated with climate change. Each of the consequences of climate change (delay to construction programmes, heave, mould, etc.) is discussed briefly and ways of integrating measures for dealing with the impacts into the decision-making process to account for risk are set out, with the risk of each impact to construction being a function of the likelihood of a climate change event (e.g. a storm) and the severity of the consequence of that event (e.g. dampness, delay).

The report by Vivian et al. (2005) for CIRIA emphasises that buildings built now and having an expected life of perhaps 50-120 years will still be in use when climate change is significant. The authors believe that whilst some allowance is now made for climate change in building standards and construction guidance, current guidance generally does not make climate change explicit. Difficulties - particularly with respect to uncertainties -

are recognised, and it is emphasised that up-to-date information on climate change should be used at all stages.

The Code for Sustainable Homes is a voluntary compliance approach sponsored by ODPM to improve the sustainability of new build stock; it would accompany increasing regulation of related issues. A consultation period on the Code ended in March 2006. The motivation for the Code is to reduce the impact of new development on the environment, and to mitigate climate change impacts. The six essential elements of the Code are energy efficiency of the fabric and appliances; water efficiency; surface water management; site and household waste management and use of materials. Minimum standards will be set for each of these, which will meet or exceed existing Building Regulations. Additional features are proposed for homes built to high Code standards. Five levels of achievement are proposed, from base level (minimum standards met) to an "aspirational" level: carbon-neutral and meeting 80% of the Code. Scores will be awarded and communicated to purchasers through a star system.

The Code draws on the expertise of BRE in developing the EcoHomes system - EcoHomes and the Code will converge over time, and subsequently continue to evolve. The Code deals with the sustainability of the new home, rather than that of a development - this aspect is being pursued via Sustainability Checklists for Developments which are to be region-specific. Following a consultation period the Code will be launched in 2006 with a user manual. The consultation document gives the statutory baseline for each of the six elements, identifies how a minimum standard might be met and proposes a Code threshold for each; the proposed system of code points is also outlined.

Principal issues with the application of the Code will be:

- how easily it is understood and used by prospective house purchasers
- whether it has an appropriate degree of flexibility to cover differences in sustainability across different elements
- whether it will be acceptable to house-builders
- whether it will influence house building design and raise sustainability and be more effective than a compulsory code. It has been suggested that house-builders would be prepared to accept a compulsory code, provided that it applied across the board and was enforced.

10.5.2 Development strategy and planning policy in Northern Ireland

The Regional Development Strategy for Northern Ireland (DRDNI, 2001) refers to climate change as an important emerging issue (together with air and water quality, energy, waste and biodiversity). The effects of climate change are predicted to have implications for lifestyles and the form of future development in the province - though the uncertainties surrounding the issue mean that the precautionary approach is proposed, especially with respect to flooding and development. Climate change is quoted in this strategy as a key environmental force driving change – along with international obligations under environmental law, the pace of technological, social and economic change, and pressures on the region's environments. The potential need for development land to accommodate a fast growing population, strong dispersal pressures and regeneration needs in urban and rural areas is emphasized (p 19). The "sensible use of resources and care for the whole environment" is seen as important in encouraging sustainable patterns of development.

The relevant RDS policy is as follows:

"Policy SPG-ENV 5: To respond to the implications of climate change and promote more prudent and efficient use of energy and resources, and effective waste management."

Increasing use of natural gas, following conversion of the largest power station, is expected to reduce greenhouse gas emissions. Other climate change mitigation actions proposed in the document relate to transport.

The Regional Transportation Strategy for NI 2002-2012 makes reference to the UK Government's Climate Change Programme of 2000 and its Northern Ireland chapter, which confirms that the RTS "whilst seeking to meet the economic and social needs of the population, will do so in a manner that reduces the threat to the environment."

In June 2006 DoE Planning Service published Planning Policy Statement 15 - Planning and Flood Risk which highlights the impact of climate change (in particular Annex A). A precautionary approach to decision-making is called for, taking account of climate change, which is expected to increase flood risk (p 3). Specific measures quoted in the PPS include minimising building developments in areas considered to be at risk from flooding, coastal erosion and land instability. Moreover, new development should not increase flood risk elsewhere, and the natural role of floodplains in flood defence is to be enabled. The preparation of Development Plans is seen as an opportunity to identify the direct and indirect flood risks which may affect a plan area. There is a requirement for consultation with specified consultees where planning applications affect certain categories of land which may be affected by flooding (p. 9). An approach to building development and the use of land which is supportive to the well-being and safety of people is required. The policy context surrounding this document includes the EC Water Framework Directive and NI government strategies on river conservation and biodiversity and this PPS was informed by the findings of the original SNIFFER report of 2002. Due to the evolving nature of our understanding of climate change, it is intended that the PPS will be reviewed within 5 years of publication.

Planning Policy Statement PPS 12 Housing in Settlements makes no reference to climate change. The only reference to climate change in PPS13 Transportation and Land Use is in the quotation of policy SPG-Env 5 from the Regional Development Strategy, cited above.

The issue of climate change is likely to be included in further Planning Policy Statements to be published in future. For example initial scoping work has started (as at April 2006) on a Planning Policy Statement that deals with renewable energy and while details of this proposed PPS are not available, it is likely to include reference to the issue of a changing climate.

10.6 Adaptation Strategies

Strategic actions:

- Consideration of longer-term horizons in all plans, especially those for built form and infrastructure with life-time of over 20 years.
- Integration of climate-change proofing in all strategic plan and project sustainability and environmental assessments, including flood defence planning.
- Consideration of cumulative effects of proposed developments and likely changes upon the built environment.

- Review of design safety factors.
- Integrated climate change risk assessments.
- Consideration of opportunities for quality of life benefits in a changing climate.
- Networking and partnerships, as appropriate, e.g. on flood defence.
- Raising awareness and seeking changes to planning policy (regional and local)
- Research into: implications of sea level rise for coasts, including erosion and impacts on built heritage; appropriate use of traditional materials (e.g. local stone, thatch). Also, research into issues concerning environmental justice and governance within the built environment.

Location and urban design actions:

- Appropriate location of built developments (residential, commercial, health, education and social services, and emergency services; and infrastructure services (e.g. substations, pumping stations) with respect to risk of flood, slope instability and/or subsidence.
- Adaptation: reinforcement / redesign of infrastructure at risk (e.g. bridges, roads).
- Reduction of flood risk by integrating sustainable water management in land use planning (Samuels et al., 2005).
- Multi-functional green and other open spaces in implementation of compact city/raised densities elements of Regional Development Strategy: to deliver benefits of urban cooling, run-off absorption, flood storage etc as well as recreation, and to maximise opportunities for adaptive behaviour.
- Modification of design (and management) of green spaces/landscaped areas for resilience to potential spring and summer drought conditions.
- Sustainable urban drainage systems.
- Controlling the conversion of permeable to impermeable surfaces; a requirement for rainwater catchment and grey-water recycling systems for all new development and retro-fitting existing development.
- Improvements to the quality of public open spaces, and conservation of urban greenspace.

Building design:

- Strategies to alleviate heat gain within buildings in high temperatures: Hacker and Holmes (2005) recommend preventing heat gain from outside by shuttering, and other external shade (planting shade trees), reducing heat generation within the building (space use density, power use) and adaptation to cool buildings down at night. Appropriate and controllable ventilation – including active low-energy mechanical ventilation as well as passive ventilation may become necessary (Hacker and Holmes, 2005). The need for adaptation for internal thermal comfort may be less in Northern Ireland than in South East England.
- Opportunities for adaptation exist within the high levels of anticipated house-building
- A study of green roofs has been carried out by BRE during 2005 (in preparation) promoting the use of green or garden roofs - such roofs may be better able to counteract and manage predicted higher summer temperatures as well as assist in managing increased rainfall in winter by buffering runoff during storms and storm run-off rapidly overwhelming drains (cited by Vivian et al., 2005).
- Opportunities exist in new-build to include flood-resilient, energy and water-efficient building designs and SuDS

Historic buildings:

- Improved monitoring of current conditions.
- Improved management and maintenance e.g. of condition of rainwater goods.
- Re-evaluation of value and significance.
- Development of adaptation strategies for historic buildings, archaeological sites, parks and gardens.

Waste management:

- Improve understanding of potential impacts e.g. though an industry forum.
- Develop indicators to help monitor change at a site level.
- Assess options to assist effective planning.
- Identify sites and processes most at risk.
- Constraints to the implementation of adaptation strategies identified during the consultation process (workshop and survey) focused on lack of awareness, uncertainty about future climate conditions, lack of necessary funding and skills, and in some organisations conflicts within the organisation or dependency upon action by other organisations.

10.7 Conclusions and Recommendations

Currently in Northern Ireland, the building stock and infrastructure have been in place for many years and it is possible that many of these features may have become unsuitable for a changing climate. However, an additional 160,000 and 250,000 houses are planned for 2015 and 2025 respectively and therefore there is considerable opportunity for climate change adaptation within construction.

A changing climate will bring many risks to buildings that could affect the integrity of the building structure, the construction process and/or the comfort of the building users. These risks include:

- Threat to foundations from heave in soil.
- Increased flooding risk.
- Storm damage from higher wind speeds.
- Higher temperatures may cause deterioration of building fabric and reduce air quality in the building.

As well as potential threats to individual buildings and structures there are also threats to current urban infrastructure in general. These include:

- Stress on pipes and tunnels from movement in soils (subsidence and heave).
- Risks to pylons and power and communication cables from wind and storm lightening.
- Flooding risk to utilities, sewerage systems, pumping stations and roads.
- Higher summer temperatures having consequences on air quality and material properties of transport infrastructure.

While the threat of a changing climate is a key driver for change in building practices and urban design, particularly in terms of mitigation, there would appear to be a lack of continuity in policies between the regional development strategy and specific sector strategies, though it is acknowledged that climate change is referred to in the Regional

Development Strategy for Northern Ireland as an important emerging issue and is also featured in many other consultations and planning policy statements. Research and development within the sector is also providing a significant basis for capacity building and adaptive planning given appropriate regulatory frameworks and incentives.

Adaptation strategies for a changing climate are divided between five areas:

- Strategic actions: research, raising awareness, consideration of longer-term plans and seeking changes to planning policy.
- Location and urban design actions: adaptation of infrastructure at risk, reduction of flood risk, use of green spaces and sustainable urban drainage systems.
- Building design: Reducing heat gain within buildings, use of green roofs, opportunities for energy and water-efficient new-build houses. It is acknowledged that legislation may be required for this and other changes to the 'Building Regulations' and this would be a matter for government (in the context of Northern Ireland, the Department of Finance and Personnel - DFP).
- Historic buildings: Improved management and maintenance of current buildings, development of strategies to adapt to changing climatic conditions.
- Waste management: assess potential impacts, sites at risk and options for effective planning.

Table 10.2 - Impacts and Adaptation Summary: Buildings, Construction and Planning

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Increase in winter flooding, fluvial and pluvial						
1a	Impact on settlements	Planning; Emergency planning; Housing; Watercourse management	Implications for spatial plans, emergency plans, homes and management of rivers.	Major threat	Staff time and associated costs	*Revise plans (development zoning), strategic assessment of flood risk,* local decision on options to reduce.	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations, Rivers Agency, EHS
1b	Impact on buildings and built heritage	Planning; Conservation;	Implications for spatial plans, emergency plans, homes and management of rivers.	Major threat	Staff time, remediation costs	*Assessment of flood risk* and implications for water management.	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations EHS
1c	Impacts on urban green spaces	Planning; Conservation	Implications for spatial plans, and management of rivers.	Minor threat	Staff time, remediation costs	*Assessment of flood risk* and implications for water management.	DOE (Planning Control), DRD, Local Councils, Emergency Services, EHS
1d	Impact on transport infrastructure	Planning; Emergency planning; Transport planning	Damage to infrastructure; disruption to users.	Major threat	Staff time, repair costs	*Assessment of flood risk* and options to reduce.	DRD Transport, DRD Roads Service
1e	Impact on water infrastructure (supply and drainage)	Planning, Emergency planning, Water planning	Damage to infrastructure and disruption to users	Major threat	Staff time, repair costs, new investment	*Assessment of flood risk* and options to reduce.	
1f	Impact on the economy	Cross-cutting; Treasury	Economic impact of damage and disruption	Major threat	Increase in costs	Determine appropriate level of funding support	Treasury
1g	Impact on health and comfort	Heath advice and promotion; Healthcare; Emergency planning	Increase in flood-related accidents; flood risk to hospitals.	Major threat	Need for more staff at times of flood	Contingency planning	DHSSPS, Health Boards, Local Councils
1h	Impacts on construction	Planning; Emergency planning; Transport planning	Delays, damage, accidents	Minor threat	Cost of delays and remediation	Contingency planning	DRD Transport, DRD Roads Service
2	Increase in summer storms and pluvial flooding.	Summer pluvial flooding will affect the same receptors as winter pluvial flooding – see (1). Risks classified as major unknown due to the uncertainty in the change in summer storms.					
3	Increase in summer temperatures and drought						

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
3a	Impact on buildings and settlements	Planning; Emergency planning; Housing; Management of public buildings	Implications for spatial plans, emergency plans and response and management of property.	Major threat	Staff time and associated costs	*Revise plans (development zoning), revise building codes, introduce energy and water neutral development policies*, decision on strategic options.	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations, Rivers Agency, EHS
3b	Impact on infrastructure	Planning; Transport planning	Damage to infrastructure; disruption to users.	Major threat	Staff time, repair costs	*Assessment of drought and heat impact risk* and options to reduce.	DRD Transport, DRD Roads Service
3c	Impact on green spaces and on soil moisture	Planning; Conservation	Implications for health of designated sites.	Major threat	Staff time, remediation costs	*Assessment of flood and erosion risk* and implications for green space management.	EHS
3d	Impact on construction	Planning, Housing, transport and communications planning	Implications for health of exposed workers	Minor threat	Staff time	*Assessment of health risks*	Emergency services, Health
3e	Impact on urban heat island	Health	Emergency services	Minor threat	Staff time, facilities provision	*Assessment of health risk* and options for facilities provision and management	Health Boards
3f	Impact on businesses	Cross-cutting. Treasury	Impacts on public services	Minor opportunity	Staff time	Assessment of likely change and support requirements	Local councils.
3g	Impact on waste management	Planning. Housing. Management of public buildings.	Implications for waste management staff	Minor threat	Staff time, new investment	Assessment of risks and options for management change	Local Councils
4	Sea level rise: Increase in flooding and erosion at the coast.						
4a	Impact on coastal settlements and buildings	Planning; Emergency planning; Housing; Management of public buildings	Implications for spatial plans, emergency plans and response and management of property.	Major threat	Staff time and associated costs	*Revise plans (development zoning), strategic assessment of flood and erosion risk*, decision on strategic options.	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations, Rivers Agency, EHS

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
4b	Impact on coastal infrastructure (transport, water, communications, waste)	Planning; Infrastructure planning (transport, water, communications, waste)	Damage to infrastructure; disruption to users.	Major threat	Staff time, repair costs	*Assessment of flood and erosion risk* and options to reduce.	DRD Transport, DRD Roads Service, Local Councils
4c	Impact on coastal urban green spaces	Planning; Conservation	Implications for health of designated and recreation sites	Major threat	Staff time, remediation costs	*Assessment of flood and erosion risk* and implications for green space management.	EHS, Local Councils
5	Increased storminess						
5a	Impacts upon buildings and infrastructure including built heritage	Planning; Conservation; Transport planning, Management of public buildings; Emergency planning	Damage to buildings and infrastructure	Major unknown risk	Staff time, remediation costs	*Assessment of storm risk* and implications for structures management	DOE (Planning Control), DRD, Local Councils, Emergency Services, Housing Executive, Housing Associations, EHS
5b	Impacts upon urban green spaces at coast	Planning; Emergency planning; Conservation	Implications for tree loss and consequent disruption	Major unknown risk	Staff time, remediation costs	*Assessment of storm risk* and implications for management of mature trees	Local Councils, EHS,
5c	Impacts on construction	Planning; Emergency planning	Implications for health and safety	Minor unknown risk	Delays, staff time	*Assessment of storm risk* and implications for construction planning	Local Councils; Health Boards

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

11 BUSINESS

11.1 Scope

Business cuts across many sectors and there are a number of generic business risks, as well as those specific to individual sectors. Generic risks are considered in this chapter along with risks to sectors not covered elsewhere – retail, manufacturing industry and services. The chapter also provides an assessment of the actions which are already underway, as well as suggested adaptation strategies for changing current business practices to deal with climate change. For further details on associated topics, see the chapters on Insurance and Tourism.

11.2 Background

As with other regions of the UK, the economy in Northern Ireland has been impacted by changes in the global economy and by a general decline in 'traditional' heavy industry. However, in recent years, this decline has been reversed with Northern Ireland's GDP having the largest increase between 1990 and 1999 of all the UK regions, growing 1% per annum faster than the UK during this period. It had grown to 3% in 2004 and was projected to grow by another 0.5% to 3.5% in 2005. Unemployment levels in Northern Ireland are at the lowest ever recorded rate, currently at 4.0% and by October 2005 there were an estimated 758,000 employee jobs in Northern Ireland (October 2005 – DETI website).

Within Northern Ireland, there has been a dramatic increase in the 'knowledge led' economy, which now contributes almost 70% to GDP. Northern Ireland has also been found to be now the fourth best performer amongst 12 UK regions according to the latest PwC Quarterly UK Economic Outlook. Northern Ireland has also been successful in attracting nearly 700 foreign-owned companies employing almost 70,000 people.

Northern Ireland manufacturing companies now export over £4 billion beyond the UK, almost 40% of their total sales. Export sales in manufacturing companies in Northern Ireland grew by almost 30% in the five years from 1998 to 2003.

However, despite the successes of recent years there are economic variations within Northern Ireland with various areas still suffering high levels of unemployment and associated social deprivation.

Until recently, consideration of climate change within business has been focussed on mitigation and although this still dominates, the need for climate adaptation is gaining prominence (e.g. ACBE, 2001; Metcalf and Jenkinson, 2005).

11.3 The Issue Now

The relationship between business and climate is largely dependent on the business in question (e.g. for tourism there are clear links), but weather is important for all businesses. There is little research available, and none specific to Northern Ireland, but the findings from elsewhere in the UK are generally applicable. For example, a survey in the South East (Arkell et al., 2004) revealed that a high proportion of businesses (47/52 respondents) thought that weather does affect their organisation in some way. However, the relative importance of weather for business is generally lower than other influences. The South East survey revealed that 30 businesses considered the weather as important, 17 less important and 5 more important. Risk Solutions' review of impacts in the railway and supermarket sectors found that short-term drivers dominate business decision

making, with responses to extreme weather events being increasingly effective (Risk Solutions, 2005).

Any business is potentially vulnerable to the weather. A survey by Zurich insurance company found that more than 300,000 small and medium-sized businesses were affected by a flood in the 5 years up to 2004, costing a total of £864 million (Leicester Mercury cited in Metcalf and Jenkinson, 2005). Businesses were typically unable to use their premises for 2 weeks.

Weather also affects the demand for products. The heat wave in June 2005 saw a surge in sales, particularly for ice cream, barbecue food, alcohol, clothes and sandals (BBC News cited in Metcalf and Jenkinson, 2005). Cold weather in February 2005 affected retail performance; DIY and gardening were sales slow, while plumbing and heating products were in demand (The Retail Bulletin cited in Metcalf and Jenkinson, 2005).

It is also apparent that business is currently at a disadvantage by not considering the weather. Research by Datamonitor suggests that by not incorporating weather into decision-making processes, retailers are missing out on sales in excess of £4.5 billion per year (cited in Metcalf and Jenkinson, 2005).

The emerging picture is that business is sensitive to generic risks such as flooding as well as weather-related effects on product demand. It has been possible to respond to some of these risks, but further effort is required to both minimise impacts and maximise opportunities, particularly as the climate changes.

11.4 How Climate Change May Affect the Future

The Advisory Committee on Business and the Environment (ACBE) believes that "UK business needs to move now to address the risks and realise the opportunities associated with the expected change in climate" (ACBE, undated-a). They identify the following generic implications:

- Increased cost of capital and insurance for operations vulnerable to extreme weather events.
- Increased operating costs.
- Shifts in customer demand.
- Possible disruption to supply and distribution routes.
- Possible disruption to operations and availability of workforce.
- Acquisition and growth strategies must incorporate climate change impacts.

ABCE (undated-b) includes example risks and opportunities for specific sectors – those relevant to this chapter are reproduced in Table 11.1.

Table 11.1 - Impacts of Climate Change on Industry Sectors

Industry sector	Risks	Opportunities
Chemical / Pharmaceutical	Shelf life of temperature sensitive products impacted. Shift in demand for certain drugs due to changes in disease distribution.	First mover advantage in anticipating consumer demand for agrochemicals and pesticides to protect against incoming insects / diseases.
Environmental Technology Services	Failure to factor in long term policy implications due to inappropriate technology and inappropriate strategic advice.	Growth in new services such as carbon accounting and emissions trading, amendments to existing risk evaluation and environmental impact assessment. Growth in renewable energy projects.
Manufacturing	Responding to changing patterns of customer demand and shifting process sensitivities. Changing specifications of machines and shifts in process sensitivities.	New products to suit changing customer demand.
Retail	Disruption to supply and distribution. Changing customer demand – clothing and food sensitive to changes in seasonal and annual variability in climate.	Anticipating shift in consumer demand – products and services.

From ABCE (undated-b).

UKCIP has produced a Business Areas Climate Impacts Assessment Tool (BACLIAT) which provides a checklist for organisations to assess the potential impacts of climate change on their business or sector (Metcalf and Jenkinson, 2005). BACLIAT considers seven elements:

- Logistics: vulnerability of supply chain, utilities and transport infrastructure.
- Finance: implications for investment, insurance and stakeholder reputation.
- Markets: changing demand for goods and services.
- Process: impacts on production processes and service delivery.
- People: implications for workforce, customers and changing lifestyles.
- Premises: impacts on building design, construction, maintenance and facilities management.
- Management implications.

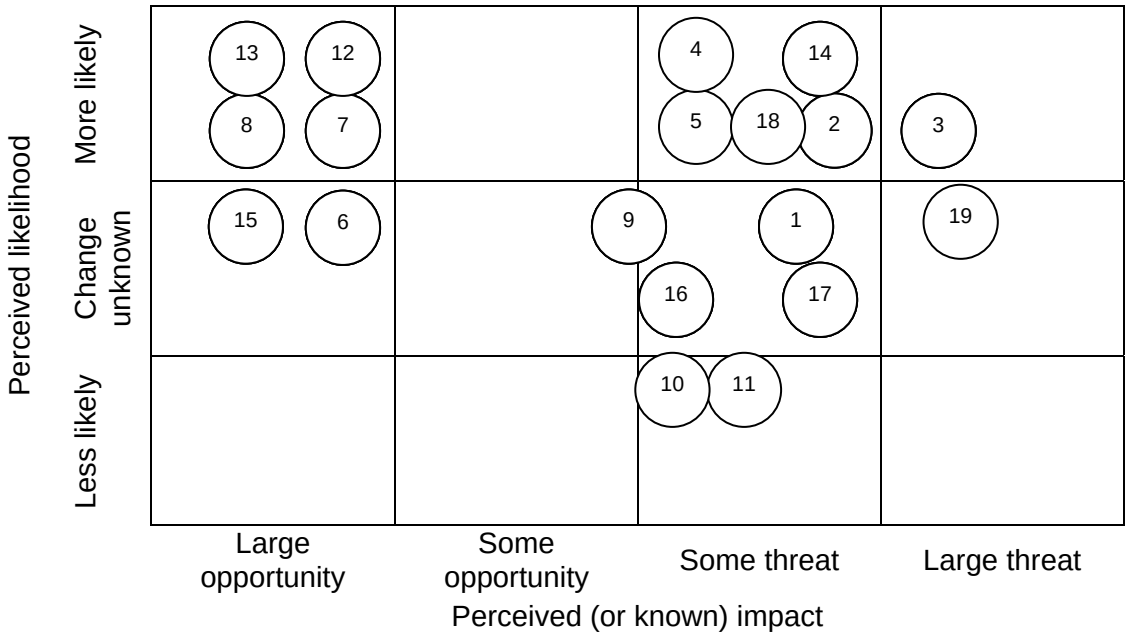
These should be set in context of time, location, emissions scenario, socio-economic scenario, sector, business area and climate variables (Metcalf and Jenkinson, 2005) – all of which are necessary in any climate change impact assessment.

Tables 11.2 and 11.3 summarise the key impacts identified for business – focussing on retail, manufacturing industry and services, with the latter grouping impacts based on the BACLIAT checklist.

Table 11.2 - Climate Change Impacts: Business

Climate change	Impact
Wetter winters	Increase in flooding, leading to: • difficulties for mineral extraction • disruption to supply chains • damage to stock and premises • loss of reputation • investment and insurance problems opportunities for environmental services.
Drier summers	Boost sales of seasonal goods, water retention products (e.g. water butts) and drought-tolerant plants. Opportunity for business growth in outdoor activities and al-fresco retail.
Warmer winters	May lead to increase in need for pest control, representing problems for facilities management but opportunities for environmental services and manufacturing. Decline in current weather problems. Reduction in heating costs.
Hotter summers	Boost sales of seasonal goods (food, drink, clothes etc). Increase demand for domestic and industrial cooling products (fans, fridges, shades). Problems associated with exposure of external workforce. Opportunity for business growth in outdoor activities and al-fresco retail. Decline or shift in demand for other goods.
Sea level rise	Potential increase in flooding and blight of coastal businesses.
Reduced soil moisture	May lead to subsidence problems.
Change in Storminess	May lead to delays in transport of goods, particularly across the Irish Sea.

Figure 11.1 - Risk Assessment: Business



The numbers in the above matrix relate to the identified potential climate impacts on agriculture as detailed in Table 11.2. These are as follows:

1 = Wetter Winters – Difficulties in mineral extraction
2 = Wetter Winters – Disruption to supply chains
3 = Wetter Winters – Damage to stock and premises
4 = Wetter Winters – Loss of reputation
5 = Wetter Winters – Investment and Insurance problems
6 = Wetter Winters – Opportunities for Environmental Services
7 = Drier Summers – Boost to sales of seasonal goods, water retention products, drought tolerant plants
8 = Driers Summers – Opportunity for business growth in outdoor activities and al-fresco retail
9 = Warmer Winters – Increased need for pest control
10 = Warmer Winters – Decline in current weather problems
11 = Warmer Winters – Reduction in heating costs
12 = Hotter Summers – Boost in sales of seasonal goods
13 = Hotter Summers – Increased demand for cooling products
14 = Hotter Summers – Problems of exposure to outdoor workers
15 = Hotter Summers - Opportunity for business growth in outdoor activities and al-fresco retail
16 = Hotter Summers – Decline or shift in demand for other goods
17 = Sea Level Rise – Potential increase in flooding and blight of coastal business
18 = Reduced Soil Moisture – May lead to subsidence problems
19 = Change in Storminess – May lead to delay in transport of goods particularly across Irish Sea

Please note that the impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are considered to be of the same scale.

11.5 Actions Undertaken or Underway and Key Gaps

Many businesses are already considering climate change, often with or in response to awareness raising and research undertaken by trade associations and professional bodies e.g. Association of British Insurers, UK Water Industry Research, The Chartered Institution of Building Service Engineers and The Society of Motor Manufacturers and Traders. ACBE and more recently UKCIP have been actively engaged in highlighting potential impacts and in promoting adaptation – especially through the UKCIP Changing Climate for Business (CCFB) pilot programme (Metcalf and Jenkinson, 2005). Regional climate change partnerships have been furthering this e.g. South East Climate Change Annual Forum on Business (2004), Yorkshire Forward's Business Adaptation Toolkit.

11.6 Adaptation Strategies

The Tyndall Centre ADAPT project explored how businesses can adapt their practices, policies and technologies to protect themselves from climate risks as well as maximising opportunities (Berkhout et al., 2004). The project developed an organisational model of adaptation, which sees adaptation as a process of learning, focussing on nine companies in the house-building and water services sectors. The research concluded that (Berkhout et al., 2004: 2):

- Awareness of climate change impacts varies markedly.
- Rather than posing entirely new problems, climate change will often add to existing pressures on companies.
- Indirect impacts (e.g. rising insurance premiums or tighter regulation) will generally be more significant stimuli to adaptation than direct climatic impacts.
- Organisations have available to them a potentially wide set of opportunities to adapt, but their ability to implement them is severely constrained by a range of factors, including the weakness of climate signals, the ambiguity of the link between adaptation and business advantage, and obstacles to receiving feedback about the benefits of adaptation.
- Adaptation measures are often complex, involving multiple adjustments.
- In the absence of feedback about benefits, the attitudes to risk held by the company will determine which adaptation measures are adopted.
- The adaptive capacity of companies depends not only on internal characteristics, but also on external relationships. Effective adaptation will often involve cooperation with regulators, suppliers, competitors and customers.

Risk Solutions' recent report for Defra (Risk Solutions, 2005) examined adaptation and barriers to adaptation in business, with a focus on strategic decision making and capacity building. Case studies were developed in the railway and supermarket sectors. The study found that long-term climate change is not a current priority, with non-climate factors dominating short-term decisions and socio-economic trends often being more important in the long-term. Barriers to adaptation exist because there is no clear climate change signal, responses are counter to industry routines and customer expectations and due to external constraints such as regulatory regimes. The report recommends that climate change should be considered in any decision sensitive to the weather, regardless of whether it is intended to address weather or climate risks directly, to ensure that vulnerability is not increased and to maximise win-win solutions. Three key actions were suggested:

1. Adaptation should be embedded into established risk management and decision support procedures.

2. Sector specific tools, guidance and climate data matched to business needs should be developed.
3. Awareness of adaptation needs to be improved, with clear leadership provided in both the private sector and by government.

The conclusions of these projects are useful in deriving effective adaptation strategies for the business sector. It is clear that adaptive capacity needs to be enhanced – through awareness raising, risk assessment and a full appraisal of alternative adaptation options. There is also a need to implement adaptation actions and to monitor their effectiveness.

ACBE (2001: 1) recommend that Government should agree a prioritised strategy which:

- Clarifies Government policy on climate change adaptation, setting out clearly the key actions for business and prioritising sectoral support.
- Improves channels of communication with business on this issue through a tailored communication strategy.
- Sets out a series of actions to encourage business to develop new products and services capitalising on the impacts of climate change.
- Reinforces business action, by supporting adaptation by other bodies.

Since 2001, the Government, in association with UKCIP, has gone some way to addressing these issues, but much work is still required. The CCFB pilot programme has highlighted the kind of risks that businesses need to consider and has produced a bespoke tool – BACLAIT – to facilitate risk assessment. This has also helped communication with the business sector. However, there remain few incentives to encourage creation and uptake of measures to support adaptation, in contrast to mitigation. These will be required to offset the costs of adaptation to business and consumers who may only evaluate costs and benefits over a short time horizon. Furthermore, it is essential that other bodies also adapt to climate change to ensure that businesses can operate without undue risk to their supply chain and within a transparent and fair regulatory framework.

11.7 Conclusions and Recommendations

While the impact of climate on business is largely dependent on the type of business involved; the predominant risks are generic (such as flooding) or as weather-related effects on product sales.

On a generic level, climate change may affect business through increased capital, operating and insurance costs, shifts in customer demand and possible disruption to supply, distribution, operations and workforce availability. It is worth noting that the BACLIAT produced by UKCIP provides a checklist for assessment of impacts of climate change and these cover the seven areas of: logistics, finance, markets, process, people, premises and management implications.

In relation to the specific potential impacts of a changing climate, to Northern Ireland, the following have been identified:

- Damage to stock and premises under wetter winter conditions.
- Delay of transport of goods, especially across Irish Sea, under increased storminess.

As with the potential impact, adaptation measures to be adopted are often complex and specific to each business. However, climate change adaptation should be embedded into existing risk management and decision support strategies.

There are also measures that can be taken across sectors. Whilst many businesses are already considering the impact of climate change, partly in response to awareness by trade associations and professional bodies, climate change lacks any priority due to short term business and economic pressures. A Northern Ireland business sector review of risks and adaptation should be undertaken. However, the variable nature of impacts from business to business requires the sector to have specific tools, guidance and climate data to match business needs. It should also be noted that awareness to climate change needs to be improved, including clear guidance on adaptation measures.

Table 11.3 - Impacts and Adaptation Summary: Business

Ref.	Impact on Receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
1	*Logistics* Disruption to extraction and distribution of raw materials and products due to flooding, but fewer cold-weather issues.	Emergency Planning Transport Planning	Greater requirement for maintenance – staff and cost issues	Minor Threat Unknown	*Review of adequacy of drainage systems; Review of adverse weather maintenance procedures.*	DRD Roads Service Translink Rivers Agency
2	*Finance* Flood or other extreme events may increase cost of insurance, create difficulties in obtaining investment and damage reputation.	Business Support	Potential cost issue in allocation of grant aid	Minor Threat	*Review of need for grant aid.*	Invest NI DETI
3	*Markets* Market for some products may shift or decline in response to weather; other products including new products will be in demand, as will risk management services.	Business Support	Need for promotion of NI business in new markets – cost issue	Minor Threat or opportunity	*Identification of where new markets / opportunities may lie*.	Invest NI DETI CBI
4	*Process* Greater need for temperature monitoring and control.	Building Control	N/A – issue for individual businesses	Minor Threat	*Review of building regulations to include climate control systems*.	Local Councils
5	*People* Increased need to provide cooling / shade or implement new working arrangements to protect internal and external staff.	Building Control Health Advice and Promotion	Cost issue to provide educational material and staff to carry this out	Minor Threat	Education on likely impacts to workers from a changing climate – to be provided to both employees and employers.	Local Councils Health Promotion Agency Trade Unions CBI
6	*Premises* Flooding may damage stock and premises. Reduced soil moisture may lead to subsidence problems. Warmer winters will reduce heating costs, but cooling will be required in summer.	Building Control	Maintenance of drainage systems – staff and cost issue; Allocation of staff to provide advice / technical support.	Minor Threat	*Review of building standards / regulations;* *Review of area plans and locations of new proposed development; Review of drainage systems.*	Local Councils Planning Service Rivers Agency

Ref.	Impact on Receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
7	*Management implications* Threat to business if climate change not appropriately managed; opportunities if well managed.	Business Support	Cost issue to provide educational material and staff to carry this out	Unknown	Potential need for grant aid; Potential need for education to business community on threat / opportunity of climate change.	Invest NI CBI

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

12 INSURANCE

12.1 Scope

This chapter of the report considers the potential impact of a changing climate on Insurance and considers issues such as changing customer needs, changing pattern of claims, new / tightened regulation and risk to reputation. The chapter provides details on measures that Insurance providers are currently undertaking and suggests some measures which providers and customers may consider in the future. For details on associated topics, see the chapters on Buildings, Construction & Planning and Business.

12.2 Background

The insurance sector will be significantly affected by climate change and is likely to have a major role in influencing responses to climate change across socio-economic sectors. It is largely for these reasons that the insurance industry is one of the most advanced in assessing climate change impacts and in identifying ways in which to adapt. A large number of research studies have been published in recent years (e.g. CII, 2001; Crichton, 2001; Brauner, 2002; ABI, 2003; Crichton, 2003; ABI, 2004a; Hanson et al., 2004; ABI, 2005a) and these have been accompanied by company activities to better quantify risks, along with industry lobbying.

A wide variety of insurance is available in an increasingly sophisticated market, covering general (non-life) insurance risks related to property, contents, travel, motor, and business continuity, as well as life assurance, health cover and pensions. All of these are potentially affected by weather and climate change may alter the level of weather-related risk. In addition, new products have emerged, for example Alternative Risk Transfer (ART).

Insurance also has strong interactions with the wider socio-economic setting, not least the ability of individuals and business to purchase insurance.

12.3 The Issue Now

Storms (mainly) and floods (secondary) contributed over 90% of the total costs of weather-related natural catastrophes classified by re-insurers as ‘significant’ between 1970 and 2004 (ABI, 2005a). Over this period the number of significant events and insured losses has increased hugely – insured losses from 1970 to 1989 averaging $3bn per annum compared to $16bn per annum from 1990 to 2004 (ABI, 2005a). The upward trend relates predominantly to socio-economic factors, including population growth, urbanisation and the increasing value of assets at risk (ABI, 2005a).

In Europe, losses from floods (at $8-10bn per annum) are greater than those related to wind storms (at $3bn) (ABI, 2005a). In the UK, storm and flood losses between 1998 and 2003 totalled £6.2bn, twice that of the previous 6 year period (ABI, 2004a). Table 12.1 summarises the costs of recent extreme weather events in the UK.

Recent catastrophic events (some of which were weather-related) have led to big losses for insurance and re-insurance companies. These events have led to re-insurance constraints and a hardening of the insurance market. In response, insurance companies have been forced to re-evaluate risks. For flooding this involved development of a better understanding of the risk (e.g. through more detailed flood mapping) and by considering withdrawal from areas considered too risky (e.g. frequently flooded areas). The latter led to the ABI Statement of Principles (ABI, 2002b), an agreement between industry and

Government on the provision of flood cover related to flood defence standards and provision of better defences, which has recently been renewed (ABI, 2005b).

Table 12.1 - Recent extreme weather events in the UK

Year	Extreme weather event	Cost (Insured)
1987	Storm	£1.2bn property damage
1990	Winter storms and coastal flooding	£2.1bn
1995	Hot, dry summer	Subsidence claims rise to £326m in 1995 and £333m in 1996
1998	Easter floods	£500m
2000	Autumn floods	£1bn
2003	Hot summer	Subsidence claims rise to £400m

Source: adapted from ABI (2004a).

Northern Ireland escaped the major flooding of Easter 1998 and Autumn 2000 which led to huge insurance losses in England and Wales and triggered much concern regarding the potential of climate change. However, Northern Ireland has experienced a number of severe-weather related events, including widespread floods in September 2000 and localised flooding in June 2002 and August 2004.

Northern Ireland may be particularly vulnerable to wind storms, as external design wind pressures for typical domestic dwellings built prior to 1970 were probably underestimated by over 60% (ABI, 2003). Of Northern Ireland's 603,000 homes, 53% were built before 1965 and 32% were built before 1944, when the UK's first design guidance for wind loading was introduced and these are likely to be among the most susceptible (ABI, 2003). State of repair is also important and as many as 38% of Northern Ireland homes have some disrepair associated with a roof element (ABI, 2003).

Current weather directly affects the insurance industry, which is highly experienced at managing weather-related risks. Customers are able to manage their own risks by taking out insurance cover which protects them from financial loss. Other issues of equal importance to the industry are demographics and science and technology. These factors will alter the customer base and risks to which insurance providers are exposed.

12.4 How Climate Change May Affect the Future

The ABI report A Changing Climate for Insurance (ABI, 2004a) identified the main implications of climate change as:

- Changing customer needs. Customers will increasingly value insurance services as a way of transferring risk in a cost efficient manner. Alternative risk transfer markets will expand to cater for exposure to weather-related impacts.
- Changing pattern of claims. Climate change will increase the frequency and severity of extreme weather events and associated losses, particularly in household, property and business interruption, but also in other general insurance lines. Insurers will have to examine both insurability and capacity, with implications for the availability and cost of insurance premiums. Indirect impacts on health and longevity could affect health and pension products, but demographic and economic factors are likely to be more significant.
- New and tightening regulation. This is largely related to climate change mitigation, where tighter building regulations may increase immediate claims costs (regulations aimed at increasing resilience may lower claims costs).

- Reputational risk. The insurance industry is often the messenger of potentially unwelcome change through their policies, which stresses the importance of good communication. However, customers require the industry to help manage their risk and to lobby on their behalf. Climate change may also affect the in-house operations of insurance companies and many have incorporated environmental measures into Corporate Social Responsibility policies.

The most direct impact of climate change on the insurance industry is in the changing pattern of claims. In Northern Ireland, extreme wind speeds are not expected to increase and although homes may be vulnerable this means that current scenarios suggest no increase in wind storm damage as a direct result of climate change. However, changes in wind speed are only predicted with low confidence in the UKCIP02 scenarios.

Flooding may increase under climate change, due in particular to higher winter rainfall intensities and totals. Inland flooding in the UK may result in a doubling of the annual average costs of insurance claims by the 2050s (ABI, 2004a). This is likely to increase domestic and commercial insurance premiums and lead to the greater use of policy conditions (e.g. larger excess), particularly in floodplains. In some cases, this may mean that flood cover is too expensive to purchase. In areas where risks become unacceptable, insurers could withdraw cover altogether. The ABI Statement of Principles (ABI, 2005b) states that in areas of significant flood risk (greater than 1.3% annual probability) where no flood defence improvements are planned, insurers cannot guarantee to maintain cover. Flooding will also increase construction and motor claims (ABI, 2004a).

Subsidence may also increase under climate change as a result of much warmer and drier summers. This will be concentrated on vulnerable soils such as clays. Preliminary estimates suggest that the UK annual average costs of subsistence-related insurance claims may double by the 2050s (ABI, 2004a). As with flood cover, the increased risk will be reflected in the cost and conditions of insurance policies.

Climate change will also bring insurance-related benefits. A reduction in cold weather may reduce claims in the construction and motor sectors; fine weather may reduce health-related claims while encouraging more activity based travel (ABI, 2004a).

Changing customer needs will drive new insurance products such as catastrophe bonds and weather derivatives, where companies can hedge weather-related risk, thereby protecting themselves financially against unexpected weather conditions. These products may help companies to adapt, financially, to climate change impacts.

The impacts of climate change are summarised in Table 12.2. Insurance has been considered in a broad sense i.e. including customers as well as the insurance industry itself. If insurance companies accurately assess their risks, then they should be in a position to benefit from any insurance policy i.e. will take a share of the premium as profit, although climate change will make the assessment of risk more complex. Wider society will continue to use insurance as a way of managing risk, but only if it is available and affordable. This may mean that more deprived parts of the community are disproportionately affected by climate change.

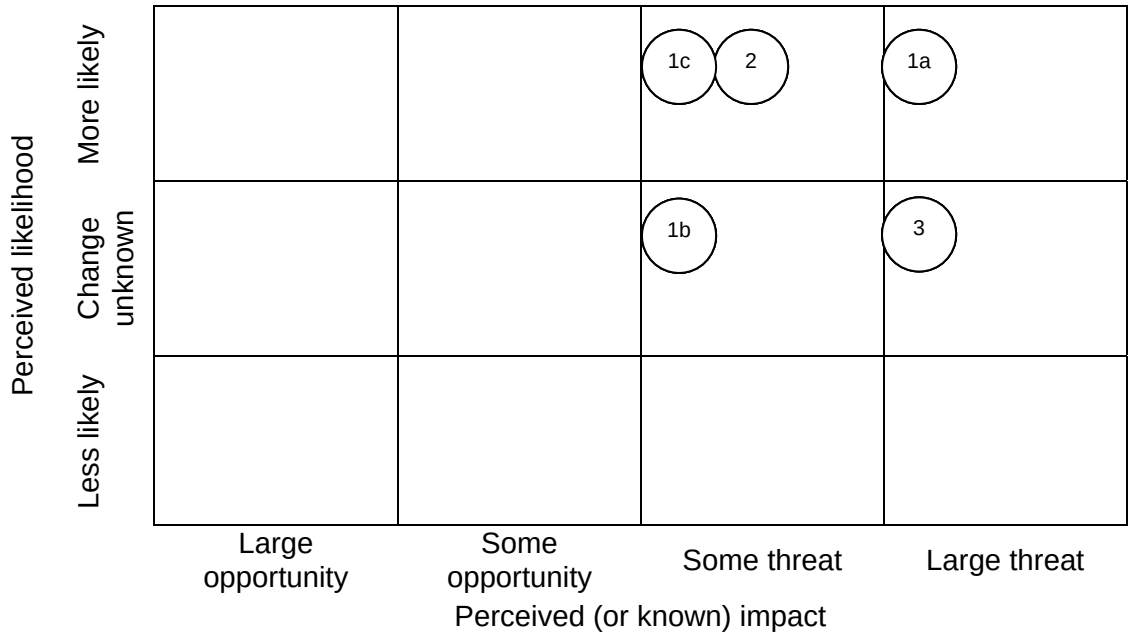
Table 12.2 - Climate Change Impacts: Insurance

Climate change	Impact on receptor
Wetter winters	Increase in flooding, leading to property, motor, construction, health and business continuity claims.
Drier summers	Increase in subsidence claims.
Warmer winters	Reduction in cold-weather and fog may reduce motor and construction claims. Reduction in cold weather related morbidity and mortality and associated claims.
Hotter summers	Increase in subsidence claims. Increase in motor claims in hot weather; increased mileage in fine weather. Potentially less overseas insurance as people holiday closer to home; however, may be more activity-based holidays requiring insurance. Less depression, but greater morbidity and mortality and associated claims resulting from heat stress, food poisoning, accidents etc.
Sea level rise	Likely to increase flooding, leading to property, motor, construction, health and business continuity claims.
Reduced soil moisture	Increase in subsidence claims.
Change in Storminess	Unlikely to be an increase in claims.

The impacts of primary relevance to the public sector are considered further in Table 12.3. The risks associated with these impacts are summarised in Figure 12.1. The main risk for public services relates to insurance cover for public buildings and council-owned property, particularly in relation to floods, but there may also be implications for publicly owned vehicles and transport infrastructure. Subsidence may pose similar problems, but this is a minor risk when compared to that from flooding. Businesses may find it harder to obtain business continuity cover, which will reduce their ability to recover following a flood. This could have knock-on implications for investment and regeneration. There are large uncertainties associated with changes in windstorms, but the potential impact is high.

Climate change is recognised as an immediate and significant issue for the insurance industry and for society in general. Issues of equal importance for the industry include pensions, reputation and legislation / regulation.

Figure 12.1 - Risk Assessment: Insurance



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 12.3).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

12.5 Actions Undertaken or Underway and Key Gaps

The insurance industry has been highly proactive in preparing for the impacts of climate change and in many respects insurance has been the most progressive sector. Several of studies have been published by ABI, CII and others (see above for review) providing an overview of impacts, as well as more detail associated with flooding and windstorms. Gaps remain in determining the impact at the regional to local level, which will be required in an increasingly sophisticated market.

12.6 Adaptation Strategies

The current approach of the insurance industry is to produce and implement adaptation strategies, which are likely to involve new approaches, tools and techniques to assess impacts. Insurance offers the public sector, business and private individuals a method for managing the risks associated with weather-related impacts under climate change. The insurance industry is expert at dealing with risk, but use of insurance is only sustainable if risks can be shared and losses minimised (Brauner, 2002). If climate change alters risks associated with natural perils such as flooding, then insurance risk must be re-assessed, which may lead to higher premiums or conditions, or withdrawal of cover, in order to balance an insurer's overall risk. Insurance should be employed alongside other adaptation measures e.g. flood defences, flood proofing, floodplain protection, which reduce the level of exposure. Information is important in this respect and the database of flood defences in Northern Ireland requires further work (ABI, 2005c: 7). There is also a need to keep a watching brief on wind scenarios given the vulnerability in Northern Ireland to wind storm damage.

Constraints to adaptation include uncertainty about future climate conditions, a lack of funding and a lack of appropriate skills.

12.7 Conclusions and Recommendations

Climate change will have a substantial impact on the insurance industry. For example storms and floods caused over 90% of the costs associated with weather-related claims between 1970 and 2004. Recent catastrophic events have resulted in some insurance and re-insurance companies recording large losses. The onset of climate change may bring about increases in flooding and subsidence, two key areas for insurance claims. All these facts therefore mean that this industry is already advanced in assessment and adaptation.

However, in relation to Northern Ireland, while the insurance industry are one of the most proactive sectors for climate change research, impacts at regional to local level still require more detailed impact assessment.

Insurers are expert at dealing with risk and as such should be employed alongside other adaptation measures. However, insurers rely on sharing the burden of risk and the associated losses, changing conditions under climate change may result in higher premiums or withdrawal of cover. It is possible that this may lead to public perception difficulties in Northern Ireland, as there is already a perception (whether correct or not) among the general public that premiums are at a high level.

Table 12.3 - Impacts and Adaptation Summary: Insurance

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Increase in inland and potentially coastal flooding under wetter winter and rise in sea level:						
1a	Increase in flood-related property claims.	Planning; Housing; Management of Public Buildings; Building Control.	Premiums may rise for public buildings. Homeowners and businesses may find it harder to obtain or afford insurance, which may impact on public services.	Major threat	Increase in cost of insurance.	Flood proof; *change insurance conditions*.	All who own insured assets; Housing Executive, Housing Associations, Local Councils, EHS, DETI.
1b	Increase in motor-related (public transport) claims.	Transport Planning	Premiums may rise if transport infrastructure flooded frequently.	Minor unknown	Increase in cost of insurance.	*Contingency planning*.	DRD Transport.
1c	Increase in business continuity claims.	Business Support	Businesses may find it harder to obtain or afford insurance to cover lost income following a flood.	Minor threat	Harder to attract business and encourage regeneration.	Flood defences, flood proofing; *public insurance*.	DETI, Invest NI.
2	Increase in subsidence claims in hotter, drier summers.	Planning; Housing; Management of Public Buildings; Building Control; Business Support.	Premiums may rise for public buildings, homes and businesses; building regulations may need to be altered.	Minor threat	Increase in cost of insurance.	Reduce risk to vulnerable property e.g. underpin; *potential review of building regulations*.	All who own insured assets; Housing Executive, Housing Associations, Local Councils, EHS, DETI.
3	Potential change in storminess leading to alterations in insurance policies related to property.	Housing; Management of Public Buildings; Building Control.	Insurance cover may be affected in relation to publicly owned or managed buildings; building regulations may need to be altered.	Major unknown	Potential increase in cost of insurance and construction.	*Watching brief with regards to change in storminess*; *potential review of building regulations*.	All who own insured assets; Housing Executive, Housing Associations, Local Councils, EHS.

* Public Services Areas from Table 2 of EHS (2005a).

^ *Building adaptive capacity*; delivering adaptive actions.

13 TRANSPORT

13.1 Scope

This chapter provides an overview of transport sector and the policy context in which it operates and deals with what the likely future impacts on roads, railways, aviation, shipping and ports. Detail is also provided on actions which are currently undertaken to advise travellers on weather impacts, as well as strategies which may be adapted in the future.

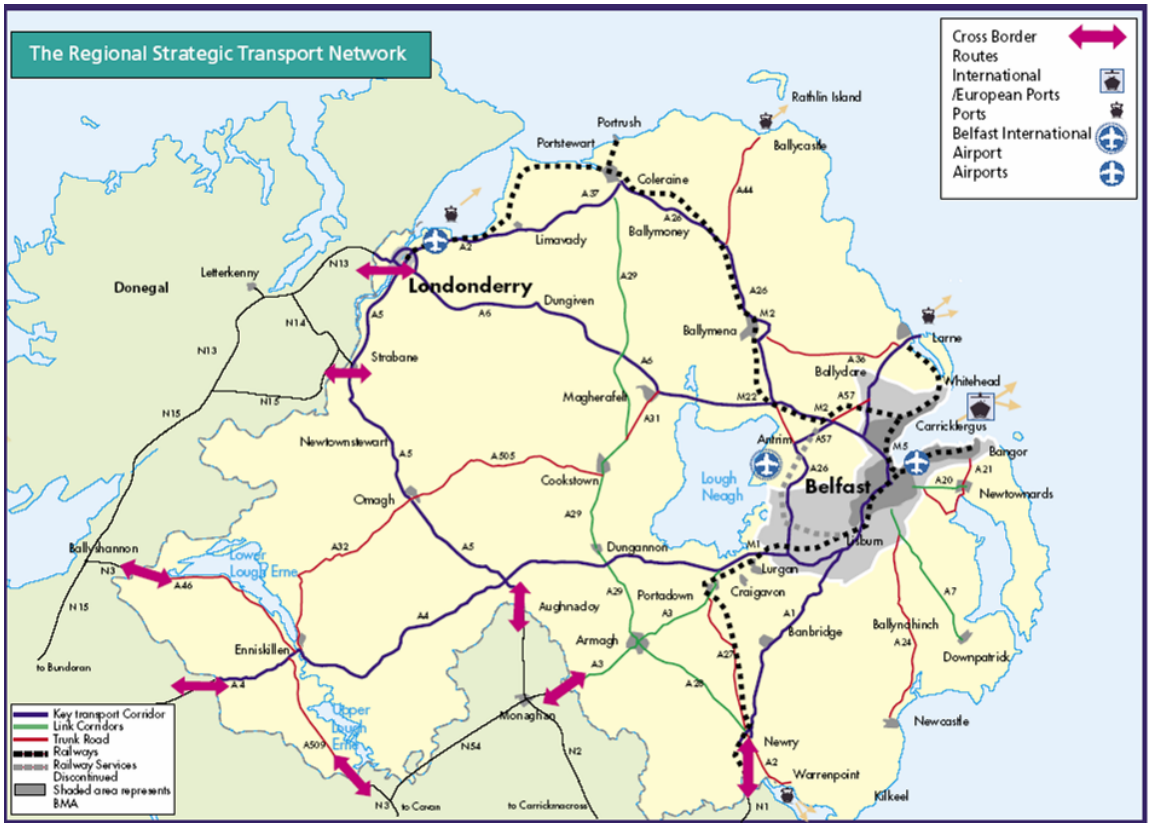
13.2 Background

13.2.1 Northern Ireland Transport System

Northern Ireland (NI) is almost totally dependent on a roads based transport system reflecting the small internal transport market and dispersed settlement pattern. The road network is very extensive at 25,000 kilometres. The dispersed nature of the population has resulted in the Region having about 2.5 times the kilometres of road per capita when compared to the average for the rest of the UK. The main road and rail network for NI is shown in Figure 13.1 below.

Unclassified roads account for the largest proportion of all roads (60%) followed by Class III (18.9%), Class II (11.6%), Class 1 (9.1%) and motorways (0.5%). Analysis of the urban/rural split reveals that 20% of road lengths are urban and 80% are rural. 87% of motorway length in NI is considered to be rural as is 66% of Class I dual carriageways.

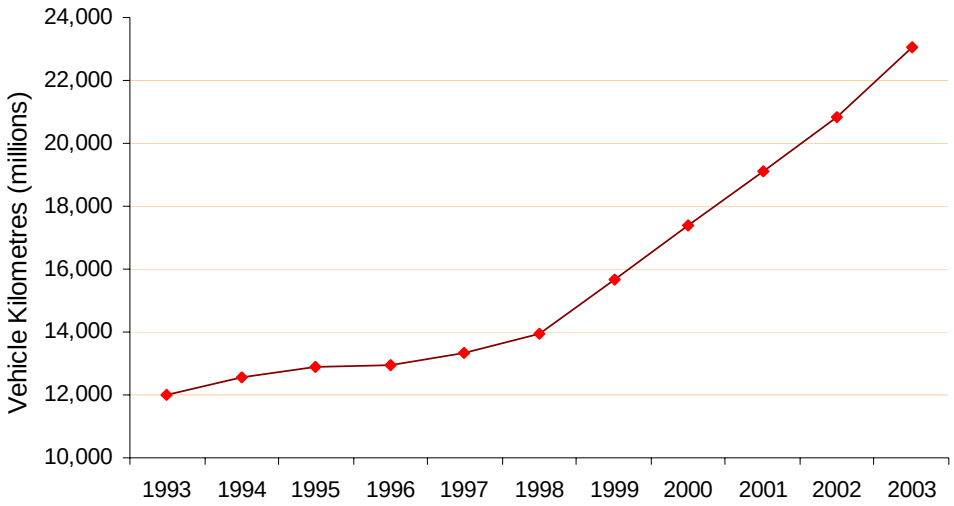
Figure 13.1 - Regional Strategic Transport Network, Northern Ireland



Source: Regional Strategic Transport Network Transport Plan, DRD, March 05.

The total distance travelled in the Region has increased from an estimated 4.5 billion kilometres in 1971 to over 23 billion kilometres in 2003. Figure 13.2 overleaf shows the increase in travel by cars and vans on the road network over the period 1993 to 2003.

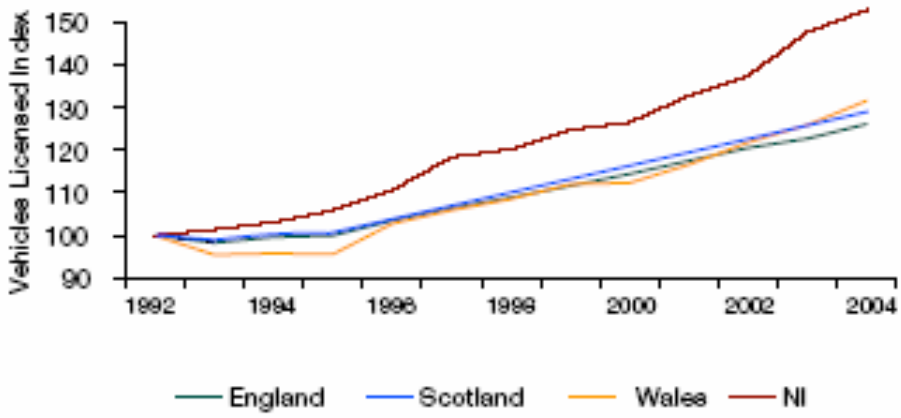
Figure 13.2 - Vehicle Kilometres of Travel (VKT) for Class 1 Vehicles (car, taxis and vans) 1993-2003



Source: Traffic & Travel Information 2003

An increase in GDP has contributed to increases in personal wealth, which along with other factors, has lead to an increase in car ownership. Car ownership rates in NI continue to rise and there were 883,261 vehicles licensed in Northern Ireland by the end of 2004. Over the 12 year period from 1992 to 2004, licensed vehicle stock in NI has increased by 53% compared with 29% in Scotland, 32% in Wales and 26% in England (see Figure 13.3 below). However, in absolute terms, NI lags considerably behind GB and this suggests that car ownership in NI still has considerable potential to increase further.

Figure 13.3 - Index of vehicles licensed in NI and GB 1992-2004

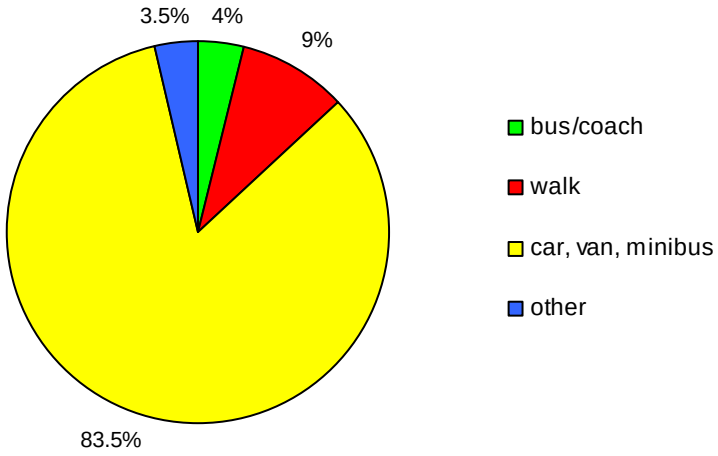


Source: Northern Ireland Transport Statistics 2004/05

Many of the current transport problems in NI occur in the weekday morning and evening peak periods when people are travelling to and from work. Levels of public transport use are also greatest then and have the greatest potential to effect a switch from the private

car. The latest available estimates of method of travel to work are shown in Figure 13.4 overleaf. This shows that by far the highest percentage of the workforce in NI (83.5%) travels by car, van or minibus. Bus and coach amount to only 4% with the balance of 12.5% made up principally by walk (9%).

Figure 13.4 - Method of Travel to Work, Northern Ireland 2004



Source: Northern Ireland Transport Statistics 2004-05

Northern Ireland Railways (NIR) is the sole provider of rail passenger services in NI and looks after c.360 kilometres of track. The rail network in Northern Ireland mainly serves the eastern half of the Region, and providing commuter rail services for the Belfast Metropolitan Area. With the exception of the Belfast to Dublin service, rolling stock and infrastructure are in general need of upgrading, although considerable investment has been made in new rolling stock and the maintenance of the most heavily used parts of the network. It also now appears that a previous downward trend in passenger numbers has been reversed.

Almost all of NI's bus services are operated by Translink, through its Ulsterbus and Citybus services. The networks have evolved to meet demands, while retaining socially necessary services where possible. However, there are often only limited services available – particularly in the evenings, outside Belfast and in rural areas. In general there has been a decline in the number of passenger journeys on Ulsterbus and Citybus services from 1995/96 to 2004/05 by 18% and 22% respectively (though Citybus may have halted this decline by 2004 / 05).

Northern Ireland has good modern port facilities providing high quality shipping services and freight handling with Belfast, the largest port in Ireland by tonnage, performing a shipping role of international / European importance. The Region's ports offer an extensive range of services with, in particular, the ports of Belfast and Larne providing key links to the rest of the UK and Europe, and Lisahally and Warrenpoint ports adding to the range of shipping services. There were approximately 2.5 million domestic sea passengers using NI ports in 2004. Those travelling to and from Stranraer in Scotland make up over half (51%) of the NI total.

The three main airports – Belfast International, Belfast City and the City of Derry – offer an extensive range of air services and facilities and are increasing their number of air movements. During 2004, 6.7 million terminal passengers passed through Northern Ireland Airports, representing an increase of 10% on the 2003 figure.

In terms of terminal passengers, Belfast International is the busiest in Northern Ireland and was the 11th busiest commercial airport in the UK. In the 5 years between 1999 and 2004, Belfast International saw an increase of 46%, while Belfast City saw an increase of 63% in the number of terminal passengers.

13.2.2 Northern Ireland Transport Policy Context

Transportation was established as an essential element of Government's plans for the future of Northern Ireland in the first Programme for Government agreed by the Assembly in March 2001. Within the context of the Programme for Government, there is an explicit recognition of the strategic importance of transport infrastructure and services to the future of the region.

The Regional Development Strategy (RDS), agreed by the Assembly in September 2001, sets out the strategic planning framework for the spatial development of Northern Ireland up to 2025. The approach of the RDS to transportation is to place emphasis in the future on enhancing accessibility which enables people to get to goods, services and facilities, whilst minimising the number and scale of negative impacts.

An integral feature of the RDS was the production of a Regional Transportation Strategy which will work towards the achievement of the vision "to have a modern, sustainable, safe transportation system which benefits society, the economy and the environment and which actively contributes to social inclusion and everyone's quality of life."

The Regional Transport Strategy (RTS), agreed by the Assembly in July 2002, aims to support the RDS and move significantly towards achievement of the longer-term transportation vision. Through the implementation of the RTS, it is envisaged that the future transportation system in Northern Ireland will have the following characteristics:

- Exploiting the latest technology, innovative practices and communication techniques to ensure that best use is made of the transportation network and services;
- Roads (including footways and cycle paths) being the predominant feature of the transportation infrastructure;
- A high quality strategic transport network constructed, operated and maintained to ensure rapid and predictable journey times for public transport (including taxis and community transport as well as conventional bus and rail), goods vehicles and cars;
- Integrated with land use planning and contributing to a healthy and environmentally aware society choosing to walk, cycle and use public transport for many journeys;
- Best practice maintenance strategies applied to all infrastructure (road and rail), with no maintenance backlog;
- Modern and innovative public transport services planned, managed, operated and regulated to meet the needs of travellers' regular journeys, thereby providing a realistic alternative to the use of the car and making a major contribution to the mass movement of people, especially commuters;
- An extensive, customer-orientated public transport system fully integrated with all modes of travel through high quality interchanges;
- Efficient and affordable forms of public transport operated to regulated service standards providing all passengers, including people with disabilities, with access to services and facilities;

- Rural areas served by different types of accessible public transport drawn from a varied range, including flexible and community based services, responsive to local needs;
- All infrastructure and services used responsibly and managed, operated and maintained to the highest contemporary European standards of safety;
- A safe environment for pedestrians in general and older people and children in particular, with vehicle access and speeds limited in residential areas;
- Contributing to the creation of attractive central areas in cities and towns for living, working and leisure, with management of traffic levels, congestion and vehicle pollution and priority for pedestrians, cyclists and public transport; and
- Safe and extensive walking and cycling networks, used regularly for travel to work, shops, education centres and leisure.

The delivery of the RTS is being progressed through three transport plans: the Regional Strategic Transport Network Transport Plan, the Belfast Metropolitan Transport Plan and the Sub-Regional Transport Plan.

The Regional Transport Network Transport Plan (RSTN TP), published in March 2005, represents the skeleton framework for the RSTN connecting all the main centres of economic and social activity and the major transport hubs. The £1.57 billion plan contains a series of proposals to help reduce reliance on the private car. The RSTN TP also identifies a £529.4 million programme of strategic road improvements that will see enhanced access to air and sea ports and cross border links with the Republic of Ireland.

The Belfast Metropolitan Transport Plan (BMTP), published in November 2004, is the first of its type for the Belfast Metropolitan Area (BMA) and takes forward the strategic initiatives of the RTS. The BMTP is a local transport plan for the BMA which will deliver a phased and costed implementation programme of transport schemes to 2015 to deliver an integrated transport network.

The Sub-Regional Transport Plan (SRTB) will deal with the Rural and Other Urban Areas outside the BMA. The measures will range from highway infrastructure through to traffic management schemes, public transport facilities and parking schemes to low cost walking and cycling measures.

13.3 The Issue Now

Transport is affected by the weather and climate in different ways. Transport infrastructure including bridges, drains and railways, are designed to cope with current climate and weather events. Weather conditions also affect transport users – including decisions regarding travel and safety when travelling. Wooller (2004) collated examples of the impact of weather events on transport systems:

- Two rail bridges collapsed suddenly in the late 1980s at Glanrhyd and Inverness, following scouring and undermining of foundations from high river levels.
- Floods in autumn 2000 left many parts of the country inaccessible for days.
- Heavy snow in eastern England in January 2003 caught out thousands of drivers, many of whom were trapped in their vehicles overnight or had to abandon their vehicles.
- The high temperatures of summer 2003 caused deformations in road surfaces and widespread speed restrictions on the rail network due to actual and potential rail buckling.

- In addition, Thornes (1997) reviewed the impacts of the hot summer of 1995 in detail.
- Current-weather related effects in Northern Ireland, noted during the consultation, include:
- Melting of the Westlink highway in a recent heatwave.
- Congestion in wet weather.
- Road closures due to flooding.
- Issues with operating double decker buses in windy conditions.
- Maintenance tasks influenced by weather.
- Bank collapse on Waterways following heavy rainfall events.

Adaptation measures include the alteration of specifications for road dressings in hot weather, automated water level monitoring on Waterways and contingency plans for flooding and landslides.

Climate change was viewed as less important than other factors currently faced by the transport sector. Other issues include: making the transport system more inclusive; achieving a more balanced, sustainable system with more public transport; safety; congestion; fuel prices; funding and human resources; environmental legislation; tourism; and provision of mooring facilities.

13.4 How Climate Change May Affect the Future

The potential impact of climate change on transport infrastructure was reviewed by Wilson and Burtwell (2002) and the impact on the Department for Transport (DfT) was reviewed by Wooller (2004). In addition, a number of reports have addressed specific transport modes (AEA Technology, 2003; DfT, 2004a,b; TRL, 2001), while Arkell and Darch (2005) assessed the impacts in a specific region (London).

13.4.1 General Impacts

There are a number of common threats across modes, including (based on Wooller, 2004):

- Flooding of infrastructure and terminals, relating to storms and rising sea level.
- Subsidence and land stability problems affecting structures such as tunnels, embankments, bridges and buildings, caused by drier summers and wetter winters.
- Passenger comfort, with increasing demand for air-conditioning or shade in summer.
- Soft estate impacts associated in particular with changes in biodiversity.
- Demand effects related to climate change abroad (e.g. change in holiday destination).
- Modal shift, which although unpredictable, could alter travel patterns and affect transport plans.

In addition, there are likely to be several benefits or opportunities including:

- Reduction in cold-weather related maintenance and disruption.
- Less need for heating in winter.
- Greater opportunities for walking and cycling, particularly in summer.

13.4.2 Impacts on Roads

Roads are likely to be affected by more flooding, particularly in winter, and by heat-related problems e.g. deformation in summer. A large number of impacts were identified in Wooller (2004) and in particular DfT (2004a). The key risks are described below:

- Flooding from rivers, sea and relating to inadequate drainage and culvert capacity.
- Scour at the base of bridges.
- Deterioration of highway infrastructure, including road surface deformation, earthwork failure and subsidence caused by street trees.
- Changes in road safety.
- Changes to landscape and biodiversity.
- Health implications relating to poorer summer air quality.

Impacts on roads are likely to be particularly significant given the importance of roads to Northern Ireland's transport system.

13.4.3 Impacts on Railways

Railways face similar issues to roads, but are more severely affected by high temperatures and storms. Key risks identified (AEA Technology, 2003; DfT, 2004b; Wooller, 2004) include:

- Increased flooding from rivers and the sea and in relation to the impact of urban runoff particularly on stations.
- Deterioration of earthworks during periods of heavy rain and from subsidence in dry conditions.
- Scour at the base of bridges.
- Storms, affecting signalling and electronic equipment.
- Changes in the autumn fall of leaves.
- Higher summer temperatures causing rail buckling.
- Impact of high winds on overhead cables, trains, trees etc.

Specific impacts have been identified with regards to coastal railways in County Down.

13.4.4 Impacts on Aviation

Airports experience many of the same physical impacts on infrastructure as roads (Wooller, 2004). The major implications of climate change may be indirect – through changing demand patterns in response to climate change elsewhere. However, socio-economic factors e.g. cost of travel, affluence and environmental legislation (e.g. carbon taxes) may have a more significant influence.

13.4.5 Impacts on Shipping and Ports

Shipping and ports are likely to be affected by changes in sea level and wind behaviour (Wilson and Burtwell, 2002; Wooller, 2004). A rise in mean and extreme sea levels will affect ports, leading to more frequent flooding and structural damage. An increase in storminess will cause problems for shipping movements in the Irish Sea and at ports.

13.4.6 Summary

The impacts on the transport sector are summarised in Table 13.1.

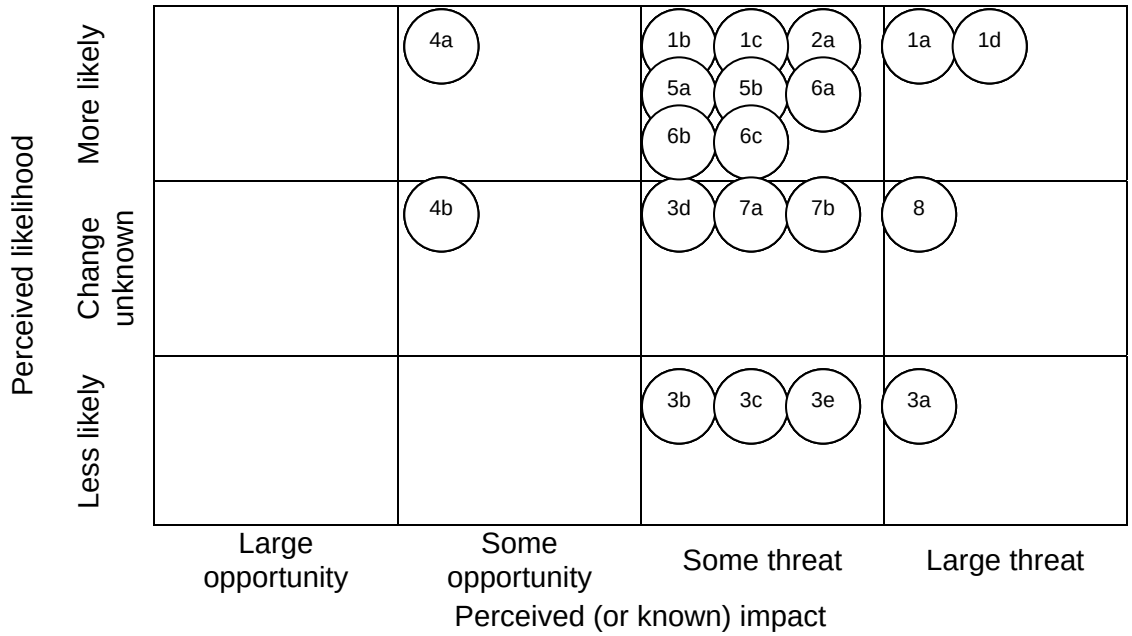
Table 13.1 - Climate Change Impacts :Transport

Climate change	Impact on receptor
Wetter winters	Increased flooding of infrastructure and terminals. Increased scour at base of bridges.
Drier summers	Greater opportunities for walking and cycling. Increased risk of fire. Increased risk of subsidence (on clay soils).
Warmer winters	Reduction in cold weather-related maintenance and disruption. Less need for heating. Changes in fall of autumn leaves.
Hotter summers	Increased discomfort / exposure for travellers. Infrastructure damage. May encourage more local and inward tourism. Deterioration in air quality.
Sea level rise	Increased flooding and erosion of infrastructure and terminals.
Reduced soil moisture	Increased risk of subsidence in summer.
Change in Storminess	Increased flooding of infrastructure and terminals. Disruption to railways, airports, road bridges and shipping.
Other (*stated)*	***Greater seasonality in rainfall:*** Subsidence and land stability problems affecting structures such as tunnels, embankments, bridges and buildings.

Risks to the transport sector are presented in Figure 13.5. There are a number of threats, with infrastructure damage (1a) and access problems for emergency services (1d) in floods being identified as major threats. There will be a number of benefits associated with improvements to the climate e.g. reduced need for cold-weather related maintenance (3a). In addition there may be opportunities to exploit the change e.g. to encourage walking and cycling (4a), with potential health benefits (4b). The risks associated with some impacts are unknown as the level of change in climate, and consequential effects, are not clear at this stage.

Climate change is largely recognised as a significant issue in the medium-long term and one which will affect the ability of some of the organisations consulted to meet their objectives. A number of issues were identified as being more significant than climate change, including review of bus regulation, congestion, fuel prices, sustainable practices, safety, funding, resources and consultation with other statutory organisations.

Figure 13.5 - Risk Assessment: Transport



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 13.2).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

13.5 Actions Undertaken or Underway and Key Gaps

The transport sector is currently adopting a 'wait and see' approach to climate change adaptation, with only a few indirect actions underway. Therefore the transport sector in Northern Ireland will need to consider the impacts of climate change identified in this study and to start planning for adaptation.

The Roads Service has been very proactive in the procurement and operation of Intelligent Transport Systems (ITS) in NI, which pre-warn motorists of difficult driving conditions. The Traffic Information and Control Centre in Belfast integrates both urban and inter-urban traffic control with an electronic driver information system. Traffic flows and driving conditions are monitored by a comprehensive network of CCTV cameras throughout Belfast and on the motorway system into Belfast. Variable Message Signs and radio broadcasts can pre-warn drivers of hazardous driving conditions at these locations. The implementation of improved ITS is a key element of the Belfast Metropolitan Transport Plan (BMTP) and Regional Strategic Transport Network Transport Plan (RSTN TP). Future work on developing ITS in NI will include further extension of the network of CCTV traffic monitoring cameras and also the provision of automatic incident detection on many key routes. Roads Service is also keeping abreast of the latest technology in traffic control and driver information e.g. a European funded project called INSTANT (between Roads Service and National Roads Authority (Republic of Ireland)) is studying the benefits of traffic control and travel information on the Belfast-Dublin corridor.

Both Northern Ireland Railways and Translink are in the process of updating the current train and bus stock. The new C3k trains which are being slowly introduced onto the NI railways will have air-conditioning.

13.6 Adaptation Strategies

Adaptation strategies have been identified for the transport sector in several studies (e.g. AEA Technology, 2003; Arkell and Darch, 2005; DfT, 2004a,b; TRL, 2001; Wilson and Burtwell, 2002; Wooller, 2004), with a particular focus on roads and railways. The development of detailed adaptation strategies will benefit from consulting those studies relevant to the strategy in question, but the priority actions relevant to Northern Ireland are summarised below (and against the impacts identified in Table 13.2):

- New highway infrastructure development should include additional capacity to account for climate change in terms of storm drainage, culvert sizing and flow attenuation. Further research may be required to determine suitable factors or methods.
- Existing highway infrastructure assets should be assessed with regards to flood risk and scour and a programme of improvements should be undertaken to include climate change adaptation. This should focus first on current areas of flooding and erosion.
- A review of hot weather impacts on highways should be undertaken, with particular reference to use of materials.
- Emergency planning should take account changing climatic extremes.
- Although there are limited railways in Northern Ireland, links should be made with research programmes elsewhere in the UK with regards to adaptation measures such as coastal defences, flood risk and embankment stability.
- Transport planners should make provision for more outdoor recreation involving transport such as cycling and walking.

Constraints to adaptation articulated include uncertainty about future climate, lack of human resources and some lack of funding.

13.7 Conclusions and Recommendations

Northern Ireland has an extensive road network of some 25,000 kilometres, though the dispersed nature of settlements is reflected in 60% of the roads being unclassified. While there are rail and bus services, modern port facilities and three main airports, these are relatively small scale and the Regional Transport Strategy identifies a future transport system which is heavily reliant on roads.

Current extreme weather events such as snow, heavy rainfall and high summer temperatures disrupt the transport system, particularly in rural areas. In future the key risks to the transport sector associated with climate change have been identified as the impact on infrastructure caused by flooding and subsidence, and the disruption to all areas of transport caused by a potential increase in storminess.

At present, there is very little specific planning for the impacts of climate change on transport within Northern Ireland – in general a ‘wait and see’ approach to climate change adaptation is being followed. However, there are actions being undertaken that will be adaptable to the future climate, including improving warning of driving conditions for motorists and the updating of train and bus rolling stock.

There are constraints though associated with adaptation for the transport sector; these include uncertainty of future climate, lack of human resources and some lack of funding.

There is an opportunity for transport and research organisations to work in tandem for tailored research into future climate impacts. New developments in infrastructure and intelligent transport systems provide an opportunity for sharing knowledge and increasing adaptive capacity.

Adaptation strategies should refer to the available literature from several studies already undertaken; many strategies will require contingency planning and improvement of current infrastructure. Adaptation strategy requires improved public awareness, both of the wider impacts of climate change and early-warning systems for severe weather. There is also a requirement for a review of current standards for infrastructure such as drainage, earthworks, roads, railways, bridges, sea defences and tunnels.

Table 13.2 - Impacts and Adaptation Summary: Transport

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Wetter winters and inland flooding:						
1a	Infrastructure damage.	Transport planning	Cost of repair.	Major threat	Increased costs	Protect roads; improve drainage.	DRD Transport, DRD Roads Service.
1b	Delay to users.	Transport planning	Economic impact of delays.	Minor threat	Increased costs	*Continue with ITS*; upgrade roads.	DRD Transport, DRD Roads Service.
1c	Road safety issues.	Transport planning; Healthcare	Higher accident rate in wet weather.	Minor threat	Staff time	Contingency planning	DRD Transport, DRD Roads Service, DHSSPS, Health Boards.
1d	Problems for emergency services.	Emergency planning; Healthcare	Access problems.	Major threat	Increased costs	Contingency planning; alternative / more versatile vehicles / locations.	DRD Transport, DRD Roads Service, DHSSPS, Health Boards, Local Councils, Emergency Services.
2	Wetter winters with increased flooding and scour:						
2a	Destabilisation of bridge / embankment foundations.	Transport planning	Cost of repair.	Minor threat	Increased costs	*Asset survey*; *monitoring*; protection.	DRD Transport, DRD Roads Service.
3	Warmer winters with a reduction in snow and frost:						
3a	Reduction in cold weather-related maintenance.	Transport planning	Less need for winter gritting, warming of railway points etc.	Major benefit	Save money and staff time	Re-deploy equipment and staff.	DRD Transport, DRD Roads Service.
3b	Reduction in disruption to users.	Transport planning	Fewer delays due to icy roads etc.	Minor benefit	Benefit to economy	Accept benefit.	DRD Transport, DRD Roads Service.
3c	Less need for heating of trains, terminals etc.	Transport planning	Reduced need for winter heating.	Minor benefit	Save money	Turn heating off when not required.	DRD Transport, DRD Roads Service.
3d	Soft estate impacts related to changes in biodiversity e.g. changes in fall of autumn leaves.	Transport planning	May alter timing of maintenance, travel conditions and times.	Minor unknown	Shift in timing	*Further research and monitoring*.	DRD Transport, DRD Roads Service, EHS.
3e	Safer travel	Transport planning	Potential reduction in accidents.	Minor benefit	Save money	Alter safety communications.	DRD Transport, DRD Roads Service, DHSSPS, Health Boards.
4	Drier, warmer summers and more amenable weather:						

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
4a	Greater demand for walking and cycling.	Transport planning	Increased demand for safe and secure foot and cycle paths.	Minor opportunity	Increased costs	Provide safe, secure foot and cycle paths.	DRD Transport, DRD Roads Service.
4b	Health benefits	Transport planning; Health advice and promotion.	Opportunity to improve health; threat from potential rise in accidents.	Minor unknown	Uncertain	Encourage walking and cycling; promote safety.	DRD Transport, DRD Roads Service, DHSSPS, Health Boards.
5	Drier summers with drier soils and vegetation						
5a	Increased risk of fire.	Transport planning	Increase in travel disruption.	Minor threat	Effect on economy	*Identify high risk locations*; reduce risk through raising awareness, watering, change to planting etc.	DRD Transport, DRD Roads Service, Emergency Services.
5b	Increased risk of subsidence (on clay soils).	Transport planning	Damage to roads, railways etc and delays.	Minor threat	Costs, economic effect	*Identify high risk locations*; alter substrate, underpin etc.	DRD Transport, DRD Roads Service.
6	Hotter summers with more extreme temperatures:						
6a	Increased discomfort / exposure for travellers.	Transport planning; Health advice and promotion; Healthcare.	Potential increase in demand for medical care.	Minor threat	Increase in costs, staff time in summer	Reduce risk by increasing awareness, introducing sustainable cooling, shade etc.	DRD Transport, DRD Roads Service, DHSSPS, Health Boards.
6b	Economic cost of infrastructure damage e.g. road rutting.	Transport planning	Increase in damage to public infrastructure.	Minor threat	Increase in costs.	Alter materials, introduce shade.	DRD Transport, DRD Roads Service.
6c	Respiratory problems associated with deterioration in air quality.	Health advice and promotion; Healthcare	Potential increase in demand for medical care.	Minor threat	Increase in costs, staff time in summer.	Reduce risk by increasing awareness, contingency planning and reduction in air pollution.	DRD Roads Service, EHS, DHSSPS, Health Boards, Local Councils.
7	Sea level rise causing flooding and erosion:						
7a	Economic impacts of damage.	Transport planning	Damage to roads, railways and delays.	Minor unknown	Costs, economic effect.	*Identify high risk locations*; build defences; accept loss.	DRD Transport, DRD Roads Service.

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
7b	Risk to users.	Transport planning	Potential increase in accidents.	Minor unknown	Costs.	*Identify high risk locations*; *monitor*; close when at risk.	DRD Transport, DRD Roads Service, Emergency Services.
8	Change in storminess:						
8a	Disruption to railways, airports, road bridges and shipping.	Transport planning	Delays to users, reputation effect.	Major unknown	Economic costs.	Increase resilience; inform users.	DRD Transport, DRD Roads Service.

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

14 ENERGY

14.1 Scope

This chapter provides details of the potential future impacts of climate change on the Energy sector and provides an assessment of what, if any, actions are already underway in preparing for climate change, as well as suggested adaptation strategies which may be adopted in future. The chapter primarily focuses on the electricity industry and government policies in relation to this sector – in particular generation and transmission as well as the impact of changes to the energy market on the public sector (who are a major consumer of energy due to the nature and range of public sector activities in Northern Ireland). For further details on associated topics see the chapters on Buildings, Construction & Planning and Transport.

14.2 Background

Northern Ireland has three major electricity generating stations: Ballylumford Power Station, Islandmagee, Co Antrim (gas fired) (operated by Premier Power Ltd); Coolkeeragh Power Station, Londonderry (gas fired) (operated by ESB); and Kilroot Power Station, Carrickfergus, Co Antrim (dual coal/oil fired) (operated by AES Kilroot Power Ltd).

Northern Ireland Electricity (NIE) has some 685,000 customers (620,000 domestic, 54,000 commercial and 11,000 industrial) out of a total in excess of 710,000 customers.

The Northern Ireland Grid system comprises 400 km of 275kV double circuit lines, 894 km of 110kV double circuit and single circuit lines which link the province's three power stations and external interconnectors to 30 main sub stations. These in turn supply energy at 33kV for onward distribution to NIE's customers.

14.3 The Issue Now

Northern Ireland has significant energy problems due to its near complete reliance on imported fossil fuels and high levels of fuel poverty in the population.

The built environment is affected by extreme weather and there have been a number of examples where severe storms have caused damage to the transmission network. For example on 22/09/06, 100,000 homes across Northern Ireland were left without power after severe gales.

On a strategic level, at present there is a major cross border review of the energy supply market on the whole of the island of Ireland. The Department of Enterprise, Trade and Investment (DETI) is working with the Department of Communications, Marine and Natural Resources in the Republic of Ireland and the two regulatory authorities (NI Authority for Energy Regulation and the Commission for Energy Regulation) on development of an All-island Energy Market. The aim is to provide competitive, sustainable and reliable markets in electricity and natural gas on the island of Ireland at the minimum cost necessary. The market must operate in the context of the EU internal energy market and should deliver long-term economic and social benefits that are mutually advantageous to Northern Ireland and the Republic.

On 30 June 2004 the DETI published a new Strategic Energy Framework for Northern Ireland. The development of the Framework has been informed by a series of consultation exercises.

The document states that despite the advances made in the past decade there are a number of ongoing challenges for the energy sector in Northern Ireland. Often actions to help meet one of these challenges will impact on progress towards one or more of the others. Many of the elements of this Framework are complementary, but others are not, so a balance needs to be struck. The main challenges are:

- narrowing the differential between electricity prices in Northern Ireland and other regions of the UK and the EU, particularly the RoI;
- opening the markets in both electricity and gas which brings both competition and choice;
- developing an all-island energy market by pursuing greater harmonisation of energy systems with the RoI, aimed at providing substantial economic and social benefits, notably in areas of investment planning, pricing and reliability of supply;
- ensuring a proper balance of fuel diversity, cost and security of supply for power generation;
- reducing emissions by securing the most efficiency from power generation and reducing demand for energy by enhancing energy efficiency in homes and businesses;
- efficiently expanding the gas network beyond the Greater Belfast area;
- increasing the use of renewable energy for heat and power generation; and
- tackling fuel poverty.

The primary objective of this framework is to achieve a competitive, sustainable, reliable energy market at the minimum cost necessary in an all-island, UK and European context. To help achieve this objective four goals have been set. They are to:

- reduce energy costs relative to other UK/EU regions;
- build competitive energy markets;
- protect our future by enhancing the sustainability of our energy supply and consumption; and
- maintain the reliability of energy supplies.

The aim is to reconcile and meet the challenges through these four goals.

As part of the All Island strategy Strategic Energy Framework, consideration has been given to the issue of climate change and emissions. Although in the immediate future it is anticipated that Northern Irelands fuel requirements will continue to be met mainly by a combination of natural gas, oil and coal, over the longer term the use of natural gas and renewables for power generation and domestic fuel is likely to reduce demand for the other fuels (though oil is likely to remain the primary fuel for home heating). Coal is likely to see the largest reduction in market share.

The strategy recognises that enhancing sustainability in the Northern Ireland energy market in a cost effective manner is a key challenge over the coming decade. While this move to sustainability is driven mainly by environmental issues it is recognised that this will also enhance security of supply. Diversification also affords opportunities to communities and individuals, particularly in rural areas, to develop an additional source of income. It is government policy to promote the development of indigenous renewable energy generation to the extent that it will be capable of providing 12% of electricity consumed by 2012 and requiring that from 2007, overall consumption of energy in Northern Ireland is reduced by 1% per annum. In order to achieve these targets the renewables market will need to be adequately incentivised, with greater emphasis on

community level embedded generation, commitment from energy suppliers to pursue more sustainable consumption patterns from their customer base and higher levels of energy efficiency built into the design and construction of buildings in Northern Ireland.

It is anticipated that the above measures will help enable the UK government to meet its targets on carbon emissions. The above measures are also consistent with the Northern Ireland Regional Development Strategy (RDS) which seeks to promote a wider choice of energy supply, including the use of renewable energy sources.

14.4 How Climate Change May Affect the Future

A review of "A scoping study on the examination of climate change on the UK energy industry (Met Office 26 May 2006)" has been conducted. Although this report does not relate specifically to Northern Ireland it provides examples of several fundamental energy industry processes that are likely to be affected by climate change, or are vulnerable to weather changes that are not well understood and which are likely to be applicable to the situation in Northern Ireland. The report states that more than a third of the energy industry process elements had a fundamental sensitivity to temperature, with many others sensitive to wind, precipitation, sea level and soil moisture.

The highest priority climate change impacts identified were damage to generation infrastructure by subsidence, flooding, icing and strong wind; underground cable de-rating due to higher temperatures and drier soils; inundation of coastal power stations due to sea level rise and storm surge; lack of water for generation plant cooling, reduced efficiency of Combined Cycle Gas Turbines due to lower air density and altered seasonality of demand. Seasonality of demand is expected to change as milder winters reduce space heating requirements in winter but hotter summers increase energy use for air-conditioning and refrigeration in summer.

The medium priority climate change impacts identified were: changes to wind power capacity; changes to wind power intermittency; increased biomass for combustion; impacts of climate change on offshore design criteria; damage to distribution and transmission infrastructure by subsidence, flooding, icing and strong wind; increased requirement for de-rating overhead cables to keep above sag limits; impacts of sea-level rise and changes to coastal flow on tidal barrages.

Power generation and supply infrastructure including power stations, pipelines overhead and underground cables, sub-stations are designed largely to cope with current climate and weather events. However, as witnessed, adverse weather patterns can affect power supplies, causing power outages over large areas. For example, the UK storms in October 2002, resulted in circa 2 million domestic consumers losing supplies for up to 10 days and highlighted the need to improve electricity network resilience in adverse weather conditions. An equivalent event in Northern Ireland would wipe-out supplies to all consumers. Soon after these events, The Network Resilience Working Group was set up to take forward the recommendations that to improve the network performance in storms, it is necessary to improving the management of trees and branches in proximity to overhead lines.

Trees coming into contact with overhead power lines and poor company vegetation management practices were also significant factors in the major blackouts affecting circa 50 million consumers on the east coast of the USA and Canada in August 2003, and a similar number of consumers in Italy in September.

Drier summers are likely to in turn generate drier soil conditions. These present a heightened risk of subsidence and heave, leaving structures such as pylons etc vulnerable to damage or collapse. This has been highlighted in the transport section and also impact upon power supply infrastructure too.

Rising sea levels, leading to increased incidence of flooding in the region may also affect infrastructures associated with power generation, supply and distribution.

Weather conditions also affect energy demands of consumers. Greater summer demand for air conditioning during hotter summers and reduced winter demand for heating etc as a result of warmer winters will provide for operational variations by the power generating companies.

The impacts of climate change on the energy sector are summarised in Table 14.1.

Table 14.1 - Climate Change Impacts: Energy

Climate change	Impact	Receptor
Drier summers	Heightened risk of subsidence and heave, leaving structures vulnerable to damage or collapse.	Infrastructure damage, power supply disruption
Warmer winters	Reduced demand for heating.	Reduced system loading, improved operability/reliability
Hotter summers	Greater demand for air conditioning in summer, altered demand profile and operational variations by power suppliers.	System overload, increased black-outs. Health implications.
Sea level rise	Leading to increased incidence of flooding in low-lying region where power stations are situated, affecting power supply and distribution.	Infrastructure damage, power supply disruption
Reduced soil moisture	Heightened risk of subsidence in vulnerable areas.	Infrastructure damage, power supply disruption
Change in Storminess	Greater levels of damage to power supply infrastructure (e.g. trees coming into contact with power lines).	Infrastructure damage, power supply disruption

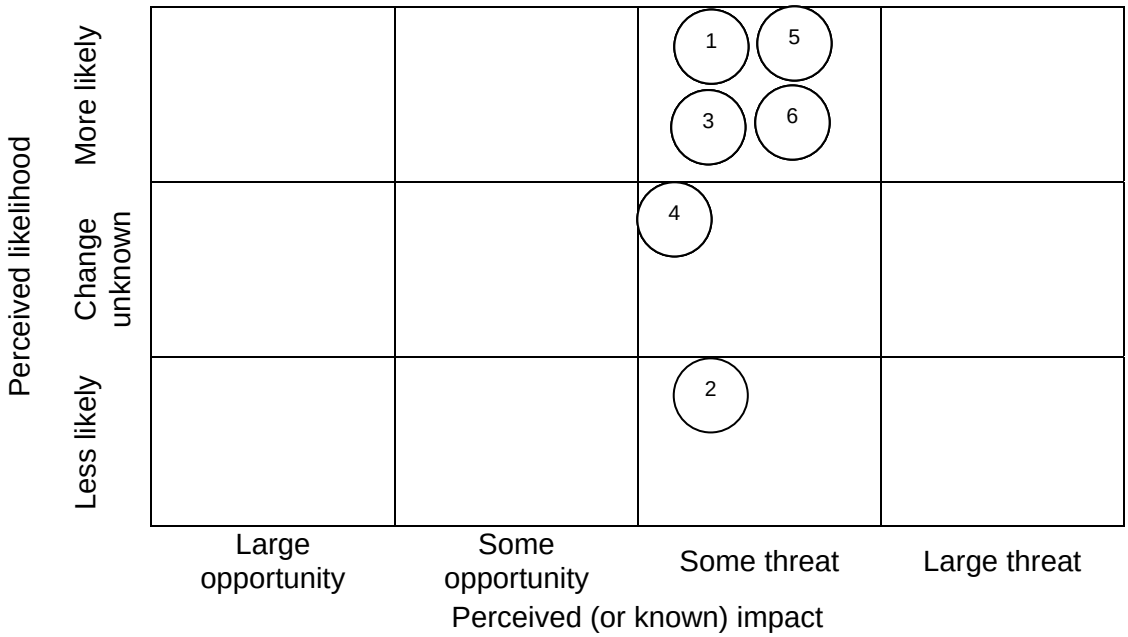
The risks associated with the main impacts detailed above have been presented Figure 14.2.

It is evident that the above climate change related impacts will generate risks to the energy sector, primarily in terms of the risks to infrastructure. In the majority of cases, it has been concluded that these risks are more likely to become manifest and, when they do, will present some threat. It is fair to say that there will be some opportunities for the energy sector that may result from warmer winters as the reduced energy load will place

fewer demands on the infrastructure. However, this could be equally viewed as a threat, in the form of reduced revenues to the power supply company. This effect, however, could be countered by an increase in energy demand during the summer months (i.e. to meet increased demands for air conditioning), levelling the demand profile throughout the annual period.

In summary, climate change is perceived to have little direct impact on the energy sector in the short term. However, it is considered more likely to become a more significant issue in the medium-long term and one which could affect the ability of organisations to meet their objectives. However, a number of other issues are considered more important than climate change in the near future. These include security and cost of fuel supplies, availability of alternatives/renewables and clean technologies.

Figure 14.1 - Risk Assessment: Energy



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 14.2).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

14.5 Actions Undertaken or Underway and Key Gaps

A number of actions are underway concerning energy and climate change in Northern Ireland, but these are related to mitigation e.g. through energy efficiency and supply security. In contrast there is a major gap in terms of adaptation in the energy sector. While some research exists, there is no strategy or evidence of adaptation in practice within Northern Ireland.

14.6 Adaptation Strategies

There is a need for increasingly robust design of long-term infrastructure for the energy sector. The climate impacts are largely determined by the location of energy supply infrastructure. This includes the transmission and distribution networks and the siting of near-coastal power stations. In each case at present, the market is the determinant of the location of the infrastructure, within the usual planning guidelines.

Of the existing transmission and distribution network, the low-voltage wood pole network, carrying 11kV, appears to be most vulnerable to current extremes of weather and therefore by extension is likely to be the most vulnerable aspect of the infrastructure in future if no steps are taken to remediate the situation. Storm damage to this component of the network has, on a number of occasions in recent years, severely disrupted electricity supplies in different parts of the British Isles. While the change in storminess remains uncertain, a theme of good adaptation strategies is to adapt to current climate extremes since this is consistent with adapting to future changed conditions. The vulnerability of the wood pole network is compounded by the following:

- Poles are often in exposed positions.
- The infrastructure is ageing, in some cases 30-40 years old.
- It is not clear that appropriate maintenance has been undertaken over the course of the network lifetime.
- It is not clear what design standards were used.

The existing policy framework, which is encouraging substantially more embedded and renewable generation, coupled to an assessment of the climate risk to the energy supply sector suggests that the immediate priorities are:

- Developing an increasingly robust distribution network.
- Risk assessment of power stations in areas that may be vulnerable to flooding.

The former priority is a matter for discussion between the public electricity suppliers and the energy regulator, while the latter reflects the needs for effective physical planning of climate change defences and the future location of power stations.

In addition, it will be necessary to consider adaptation in the planning of new energy infrastructure, particularly renewables infrastructure, with which there is little experience of weather impacts.

Further work should be completed to examine the impacts on the growing gas infrastructure. In addition, research should examine the implications for demand and consumption of energy (electricity, gas, coal, peat and oil). This should consider future socio-economic scenarios as well as climate change scenarios.

14.7 Conclusion and Recommendations

Northern Ireland has a traditional energy supply network that relies heavily on imported fossil fuels and natural gas. There are three major electricity generating stations that supply 685,000 customers. Domestic fuel supply is also heavily dependant on fossil fuels – particularly oil and coal.

It has been shown that the energy network is currently vulnerable to extreme weather conditions. While these conditions do not normally lead to a long term supply problem, there have been a number of relatively short term supply problems caused by severe gales.

At present there is a major cross border review of the energy market on the island of Ireland. The main aim of this review is to ensure the provision of a competitive, sustainable and reliable market in electricity and natural gas on the island of Ireland at the minimum cost necessary.

It is recommended that consideration is given to a review of the supply infrastructure in Northern Ireland in order to assess whether it is 'future proof'. In the absence of detailed future scenarios it is suggested that current extreme weather conditions are used as a bench mark for ensuring that infrastructure can survive an increase in storm events. Similarly it is recommended that there are risk assessments carried out for energy infrastructure facilities that are located in areas prone to flooding. Finally it is suggested that consideration is given to further improve maintenance programmes – in particular in relation to issues such as management of trees and branches in proximity to powerlines.

Table 14.2 - Impacts and Adaptation Summary: Energy

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
1	Heightened risk of subsidence and heave, leaving structures vulnerable to damage or collapse.	All (emergency services, schools/college, hospitals, housing, planning, industry, agriculture etc).	Potential disruption to users.	Minor Threat	Improve resilience of power supply infrastructure design	Northern Ireland Electricity (NIE) & power station operators
2	Reduced demand for heating during winter	All (emergency services, schools/college, hospitals, housing, planning, industry, agriculture etc).	Reduced heating demands for buildings during winter months. Levelling of demand throughout the year.	Minor benefit	Adjusted power supply to suit altered summer time demand patterns.	Power station operators
3	Greater demand for air conditioning in summer, altered demand profile and operational variations by power suppliers. Health implications for those without access to cool buildings, homes etc.	All (emergency services, schools/college, hospitals, housing, planning, industry, agriculture etc).	Increased demand for cooling during summer months. Levelling of demand throughout the year.	Minor Threat	Adjusted power supply to suit altered summer time and demand patterns.	Power station operators
4	Sea level rise leading to increased incidence of flooding in low-lying region where power stations are situated, affecting power supply and distribution.	All (emergency services, schools/college, hospitals, housing, planning, industry, agriculture etc).	Potential disruption to users.	Minor unknown risk	Short term – protection structures/measures Long term – relocation/design of major power stations	Power station operators
5	Reduced soil moisture content and heightened risk of subsidence in vulnerable areas.	All (emergency services, schools/college, hospitals, housing, planning, industry, agriculture etc).	Potential disruption to users.	Minor Threat	Improved resilience of power supply infrastructure design	NIE & power station operators

Ref	Impact on receptor	Public Service Area*	Effect on public services	Risk	Adaptation strategy^	Responsible public sector body
6	Greater levels of damage to power supply infrastructure (e.g. trees coming into contact with power lines)	All (emergency services, schools/college, hospitals, housing, planning, industry, agriculture etc).	Potential disruption to users.	Minor Threat	Short term - increased maintenance of network Long term – improved resilience to design of structures	NIE & power station operators

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

15 TOURISM, SPORT AND RECREATION

15.1 Scope

This chapter of the report provides an overview of the current Tourism, Sport and Recreation sectors in Northern Ireland and provides an assessment of what, if any, actions are already underway in preparing for climate change, as well as suggested adaptation strategies which may be adopted in future in response to a changing climate. For further details on associated topics, see the chapter on Health.

15.2 Background

15.2.1 Tourism

The political situation has been the dominant factor for tourism in Northern Ireland in the past with tourism numbers severely affected by the perceived terrorism threat as highlighted by the growth in visitors during periods of cease-fire (Boyd, 2000). However, the major changes brought about in recent years have meant that tourism has been able to benefit and now plays a vital role in the social and economic regeneration of Northern Ireland. Tourism numbers have increased by over 60% since 1994 and tourism spend has so far increased by almost 80%. This has resulted in the tourism industry becoming the second most important indigenous industry in Northern Ireland (Northern Ireland Office, 2005).

Northern Ireland has excellent natural resources, including the traditional and unspoilt countryside, some unique natural features and a strong cultural heritage, all enabling diverse tourism opportunities. It has also benefited from increased and low budget, air transport providing excellent accessibility. This is crucial to enable short break and weekend trips which are increasing as people are able to invest in a more recreational lifestyle and are able to afford numerous holidays. The Northern Ireland Tourist Board (NITB) is responsible for the development of tourism in Northern Ireland and the promotion of the area as a tourist destination. The latest tourism figures produced by the NITB show that tourism in Northern Ireland has increased by 4% from 2003 to 2004 with over 2 million visitors arriving in 2004. This generated over £409 million in revenue, with £81 million in revenue generated from domestic tourism, and supports over 20,000 jobs in the industry (Northern Ireland Office, 2005; NITB, 2005).

The majority of these tourists came from Great Britain (67%) followed by the Republic of Ireland (17.2%). Regional tourism figures for Northern Ireland included any out of state visitors visiting for one night or more for any reason including visiting friends and relatives, holidays or business. In 2004 the majority of tourists were visiting friends and relatives (42%), whilst business tourism also played a very important role accounting for 30% of tourism. Holiday, leisure and recreation tourism accounted for 19% whilst other factors contributed 9% (NITB, 2005).

Regional tourism data has also been published to present estimates of tourism within Northern Ireland's Regional Tourism Organisations (RTOs). RTOs were created to co-ordinate and implement marketing activities on behalf of and in collaboration with private and local authority members and also to help advise local businesses on tourism. This was an important step to help generate tourism growth as the vast majority of tourism businesses are small or medium sized enterprises requiring more training, financial support and better marketing to promote Northern Ireland as a tourist destination. Partnerships are also important to try to improve the tourism industry and reduce some of

the problems caused by much of the tourism industry being initially very fragmented (NITB, 2005).

There are currently five RTOs with members comprising businesses from a range of sectors, all benefiting from tourism, including accommodation, attractions, restaurants, café's, transport sectors, tour operators, golf clubs and activity providers. The five RTOs are comprised of Belfast, The Causeway Coast and Glens, The Kingdoms of Down, Derry and Fermanagh Lakeland. Statistics from 2002 highlighted Belfast as the most popular tourist destination equating to £108.5 million in tourist spend with this pronounced growth continuing in to 2004. This was followed closely by the Causeway Coast and Glens equating to £96.2 million in tourism spend in 2002 (NITB, 2005).

As well as RTOs other tourism strategies and partnerships have been established to continue to promote Northern Ireland as a tourist destination and allow sustainable and equitable growth. Other tourism management plans to be initiated include Tourism Ireland, a new body which was set up, funded jointly by the British and Irish governments to promote tourism for the entire island of Ireland. This is beneficial as it has created a 'spill-over' effect of tourists between Northern Ireland and the Republic Of Ireland (Gooroochurn et al., 2005) and also highlights the benefits which can be gained from trans-jurisdictional tourism partnerships (Greer, 2001).

Tourism has also been boosted by the rise in attractions such as those owned by the National Trust which have increased since 1990 due to a wave of investment prompted by the increased political stability and improved business management (Wilson, 2004). It is these attractions as well as natural, cultural and sports tourism which are the specific reason that many tourists visit Northern Ireland each year. In 2003 the most popular attraction and activity that prompted tourists to specifically visit Northern Ireland was special interest sports such as Gaelic Football and Hurling (NITB, 2005). This type of sports tourism has also benefited from increased political stability as it was previously seen as a contentious issue and, as result, was not developed as a tourism product (Devine et al., 2004). Tourists also specifically visited Northern Ireland for other attractions and activities such as golf, sea fishing and game fishing, attending festivals and events, genealogy and to visit historic properties. However many tourists who visit for other purposes also participate in these and other activities whilst in Northern Ireland with some of the most common activities undertaken, visiting historic properties, museums and exhibitions, walking and golf (NITB, 2005). Although activities such as visiting historic properties and museums/exhibitions were the most popular activities in 2004 receiving 97,700 visitors and 88,600 visitors respectively outdoor activities tend to dominate the most popular activities available, such as special interest sports, golf, fishing, cycling, horse riding and walking.

15.2.2 Sport and recreation

Sport and recreation not only provide numerous tourism opportunities in Northern Ireland but are also beneficial to the residents of Northern Ireland providing an important social and economic function. Local culture and art events are popular types of recreation in Northern Ireland as well as traditional sports like Gaelic Football and Hurling. More universal sports such as football, rugby and golf also form an important part of Northern Ireland's sport and recreation. The majority of the population in Northern Ireland participate in some form of sport or recreation. Out of the adult population in Northern Ireland 59% participate in at least one or more sports with the three most popular activities in adults walking, swimming and keep fit. Almost all of the young people in Northern Ireland also participate in some form of sport and recreation (Northern Ireland Sports Council, 2005).

Sport and recreation not only provides enormous health benefits to individuals and helps to instil local and national pride in teams and sports, but sport and recreation also benefits the economy of Northern Ireland. Everyday a total of £600,000 is spent on sport related activities contributing £254 million to Northern Irelands GDP and supporting 12,500 jobs (Northern Ireland Sports Council, 2005). The main sporting body in Northern Ireland is the Northern Ireland Sports Council which aims to increase and sustain participation in sports, especially in young people, and raise standards of sporting excellence. However, there are also many other local sporting initiatives to raise participation and to encourage people with disabilities and from disadvantaged backgrounds into sport in Northern Ireland.

15.2.3 The natural environment and climate sensitivity

Although many sports require purpose built facilities, the natural environment including the unspoilt countryside and forest areas also contributes significantly to the estimated benefits from outdoor recreation such as walking (Hutchinson et al., 2001). Countryside recreation provides a growing area of leisure enabling people to escape the routines of daily life as promoted by the Countryside Access and Activities Network (CAAN, 2005). Work by Viner et al, 2006 has shown the potential for the diversification of traditional rural economic activities (e.g. agriculture) to adopt new recreational and tourism based activities. It is also of increasing economic value to Northern Ireland, especially at a time when rural areas are under severe pressure through diminishing agricultural returns and the collapse of traditional values (CAAN, 2005). The natural environment is therefore a very important factor for certain types of sport and recreation. These activities such as fishing and countryside recreation will therefore be more vulnerable to changes in the climate system. However, as the dominant sports in Northern Ireland are not heavily climate sensitive there has been very little research into the impact of climate change on sports and recreation.

However, as one of the most essential resources for tourism and its continued growth is the natural environment, and furthermore as tourism can be climate sensitive, it is very vulnerable to changes in the climate system (Budeanu, 2005). And as tourism is highly dependent upon the natural environment it is likely to feel the effects of climate change sooner than other industries however this is often overlooked when addressing sustainable tourism policies. Currently there has been very little research on the interrelations between climate change and sustainable tourism and although research on the subject is developing it is still a relatively new scientific area.

The signature projects and Regional tourism partnerships planned under the NITB's marketing and strategic action plan to develop the tourism industry in Northern Ireland do adopt a sustainable tourism approach. Yet this framework fails to recognise the impacts that a changing climate will have upon the tourism industry and any potential impacts of mitigation or adaptation strategies implemented. However, the Environment and Heritage service has produced a 10 year action plan to tackle climate change which will have benefits for tourism. The plan also investigates the positive and negative impacts that climate change will have on both tourism and sport and recreation (Environment and Heritage Services, 2005).

15.3 The Issue Now

Changes to our climate could have profound implications for tourism, the leisure industry, as well as the wider visitor economy. Having a better understanding of those future impacts and how best to adapt to them is critical. Work by McEvoy et al, 2006 attempted

to address how the visitor economy of the North West of England would be impacted by climate change. This study based upon a limited number of case studies in the north west of England reinforced the view of Viner and Amelung (2003) that the relationships between tourism and climate change are not that straightforward. The work in the North West of England also failed to take into account the adverse changes in climate in other key tourism destinations (e.g. the Mediterranean) will impact upon the macro flows of tourism. Climate change scenarios suggest that the climate of Northern Ireland will produce drier warmer summers and that these will benefit tourism. This may appear the case, however in reality there are a range of complex interrelationships that determine how tourism will develop. We need to consider: the precise nature of climate change in Northern Ireland; the socio-economic environment; and environmental conditions.

Three main interactions between climate change and tourism have been identified (Viner et al., 2003 and Viner, 2006). Firstly climate change can affect the natural resources on which tourism is dependent both directly such as changing weather or travel patterns (Harrison et al., 2001; Maddison, 2001; Hamilton et al., article in press) and indirectly such as changing flora and fauna (WTO, 2003) and coral reef bleaching (Salvat, 1998). However not all impacts of climate change are negative and new opportunities such as longer, more economically sound tourist seasons in Britain are predicted as changing weather patterns attract more domestic and international tourists (Maddison, 2001 and Amelung and Viner, 2006). Nevertheless it is important to be aware that any shifts in tourism patterns will also be associated with a shift in environmental impacts. This should be an incentive for all tourism stakeholders to develop sustainable tourism policies with climate change scenarios in mind to exploit opportunities and minimise environmental degradation and consequently changing tourism behaviour.

Secondly the relationship between climate change and tourism is bi-directional as tourism contributes to climate change through the emission of greenhouse gases primarily through energy use. Tourism is extremely energy intensive especially as tourists tend to indulge in water and electricity. Global tourism energy use can be divided into transport related, accommodation related and leisure related activities and has been assessed by Gössling (2002) at 14,081 PJ, equivalent to 1399Mt of CO2 annually. This is comparable with the entire worlds CO2 emissions in 1950 (Earth Policy Institute, 2004). Although this is an initial estimate based on a poor data set it has been supported by additional studies which show how energy intensive tourism can be on local and regional scales with regards to transport (Becken et al., 2003), leisure (Becken et al., 2002) and accommodation (Becken et al., 2001; Tabatchnaia-Tamirisa et al., 1997). Energy is also an important factor to be considered as its usage can be affected by temperature changes (Warnken et al., 2004) with this being especially important in light of potential extreme weather events predicted for the future. The high energy consumption of the tourism industry means that much of the industry is presently unsustainable and without implementing some form of mitigation, policies will become increasingly so in the future as the industry expands.

Thirdly, any climate change mitigation policies which are implemented will ultimately result in a new set of stresses and stimuli (IPCC, 2001b; Becken, 2004). This is an area which is currently largely ignored and potential impacts of any mitigation policies on the tourism industry need to be considered and better understood both to reduce negative effects (Viner et al. 2003) and to investigate the benefits and reduced damages to tourism (OECD, 2004).

15.4 How Climate Change May Affect the Future

Spatial and temporal patterns in tourism are greatly influenced by climate. A large share of international tourism is determined by climate factors, such as temperature and sunshine,

which often exhibit considerable seasonal variability. The 'triple-S' of sun, sea, and sand is widely viewed as an important success factor of destinations. This is evidenced by the broad application of climate related images in tourism brochures and other PR material. Whilst the climate of Northern Ireland may not currently meet the "triple-S" criteria, changes in climate may alter the competitive balance of the region's tourist economy.

The proof for this central position of climate, however, is not merely anecdotal. Statistical analyses by Maddison (2001), Lise and Tol (2002), and Hamilton (2003), and a simulation study by Hamilton, Maddison and Tol (2003) show the relevance of climatic factors as determinants of tourist demand. According to Maddison (2001) the maximum daily temperature should ideally be close to 29.7ºC, while Lise and Tol (2002) estimate the optimal (24 hour) mean daily temperature to be around 21ºC. According to Lise and Tol (2002) people choose a holiday destination with a climate that suits their plans.

Climate has been traditionally regarded as a fixed property of destinations, with only climate variability being of interest. This position is no longer tenable as the rate of climate change increases. Climate change would induce tourists to visit different holiday destinations, or travel in a different season (Lise and Tol, 2002). What is more, many tourist resorts are located in coastal and mountainous zones, which are particularly vulnerable to climate change. It is likely that the simultaneous changes in demand and supply will open up new possibilities for tourism development in some areas and close down options in others.

The systematic study of the effects of climate change on tourism patterns has started only recently, although a collection of more or less isolated studies existed beforehand. Perry (2001; 2000a; 2000b) addressed the implications for the Mediterranean region; he concludes that summer increases in summer temperatures may produce an unsuitable climate, a situation aggravated by an increased risk of droughts, this finding is supported by Amelung and Viner (2006). Prognoses for the shoulder seasons of spring and autumn are more favourable, however, indicating a potential shift from the summer season towards the shoulder season. Perry's qualitative findings on the Mediterranean are supported by numerical model exercises with the ESCAPE model (Rotmans et al., 1994) to explore the consequences of climate change in Europe. Integrations with the Escape model suggested that the geographical zone with ideal climatic conditions in summer would shift from the Mediterranean towards the North. Such a shift would have profound economic, social and ecological impacts. For example, an estimated 100 million tourists visit the Mediterranean region on an annual basis, spending close to 100 billion dollars (Mather and Viner, 2006, employing millions of people, and using a lot of water and energy.

Agnew and Viner (2001) explored the impacts of climate change on a range of different destinations; this was the first definitive attempt to examine the multi-sectoral and global changes in tourism flows as a result for climate change. Viner and Amelung (2003) report on the wider issues that surround the interactions of climate change with tourism and the environment. Mather et al. (in press) take this approach further and examine the policy responses required to address the impacts of climate change on tourism, and tourism on the climate system. Hamilton et al. (2003) introduced climate factors into tourist demand modelling, which is traditionally focused on price and distance factors. They developed a model for estimating bilateral tourist flows between all countries in the world. Apart from population, income, country size and several other variables, their model included temperature as a determinant for the size and direction of tourist flows. With this model, Hamilton et al. (2003) analysed the effects of climate change on tourism patterns. This line of research has so far mainly focused on temperature and disregarded factors such as precipitation and sunshine, which are also of obvious importance for tourism. What is

more, the spatial and temporal concentration of tourism has not yet been properly addressed. The issue of concentration, which is central to tourism, calls for analyses with short timeframes and small areas, whereas reliable datasets for travel patterns are available only on a country-by-country level and on an annual basis. Although largely springing from a lack of reliable data, these shortcomings cast doubt on the relevance and reliability of the statistical results.

It is important therefore that we do not isolate the tourism environment from the rest of the global market. The region's tourism industry is competing with a myriad of other destinations around the world.

Gardening also provides a widespread recreational activity which is sensitive to changes in weather (at seasonal scales) and climate change. Climate change will bring both negative impacts to existing gardens but also opportunities for change (Bisgrove and Hadley, 2002).

The impacts of climate change on tourism and sport & recreation are summarised in Tables 15.1 and 15.2.

Table 15.1 - Climate Change Impacts: Tourism

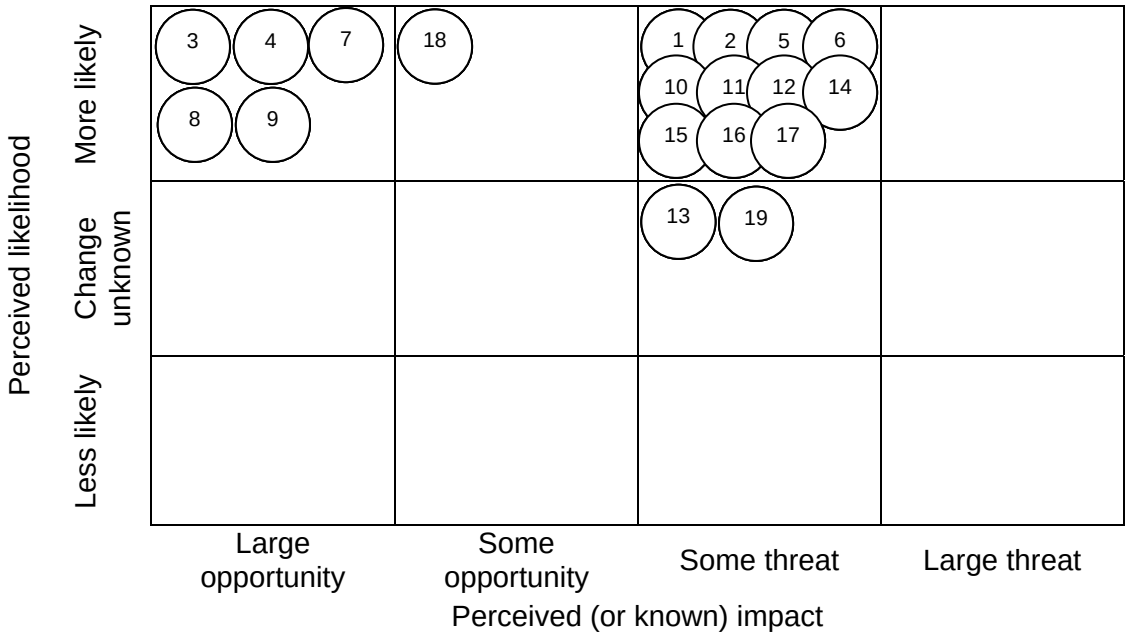
Climate change	Impact
Wetter winters	Will affect outdoor activities for tourism. Flooding may affect tourism infrastructure and disrupt tourism services.
Drier summers	Increased tourism opportunities. Increase in outdoor tourism activities. Water resources will be put under pressure. Water shortages will affect tourism facilities.
Warmer winters	Opportunities for more year round tourism.
Hotter summers	Increase in domestic and international tourism. Increase in outdoor tourism activities. Increase in water based tourism activities. More demand on natural attractions. Increased demand on tourism infrastructure.
Sea level rise	Coastal flooding and erosion will degrade beaches. Coastal squeeze will reduce beach size. Reduced accessibility to coastal locations and unique scenery. Damage to tourism infrastructure and sea side resorts. Increased risk from storm surges??
Reduced soil moisture	Will affect natural landscapes and scenery which is very important for attracting tourism.
Change in Storminess	Increased winter storm intensity and frequency may damage tourism facilities and property. Increased storm intensity and frequency will affect coastal zones with an increased risk from storm surges, causing flooding, beach erosion and damage to coastal resorts.

Climate change	Impact
Other (*stated)*	***Changing Seasonality:*** Less well defined tourism seasons will result in unreliable tourism numbers. Could have positive and negative affects on tourism numbers. May cause a reduction in domestic holidays as people travel abroad for 'guaranteed' sunshine.

Table 15.2 - Climate Change Impacts: Sport & Recreation

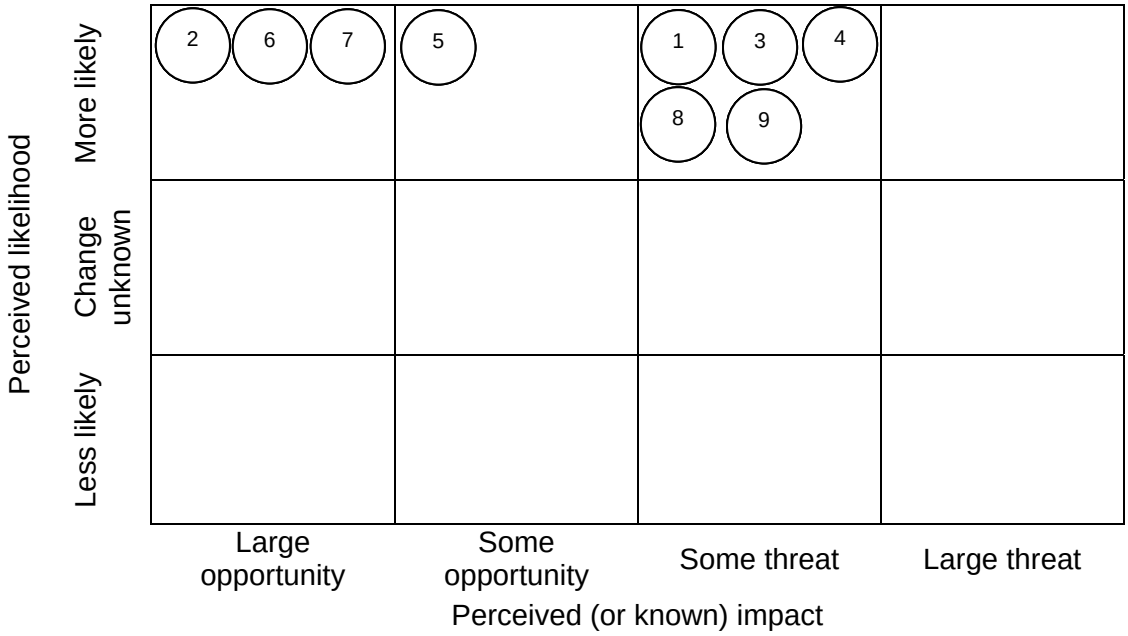
Climate change	Impact
Wetter winters	Will affect outdoor sports and recreation and may cause cancellation of events. More 'weather proof' facilities required.
Drier summers	Increase in outdoor sport and recreation. Affects on species and habitats will affect nature based recreation.
Warmer winters	Opportunities for more year round outdoor sport and recreation.
Hotter summers	Increase in outdoor recreation. Increase in water based activities
Sea level rise	No impacts for sport and recreation?
Reduced soil moisture	Affect local habitats which may cause a reduction in countryside and nature based recreation.
Change in Storminess	May cause the cancellation of outdoor activities. Can damage sporting and recreation facilities.
Other (*stated)*	

Figure 15.1 - Risk Assessment: Tourism



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 15.3).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

Figure 15.2 - Risk Assessment: Sport & Recreation



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 15.4).
Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

15.5 Actions Undertaken or Underway and Key Gaps

As a result of the lack of dedicated work that has been undertaken to access how climate change will impact upon tourism within Northern Ireland it is difficult to assess precisely what specific actions are being undertaken. In order to assess stakeholder awareness and adaptation and mitigation responses undertaken by tourism and recreation operators there is a requirement to undertake assessments of the attitudes of tourism stakeholders to climate change. Examples of such a study to undertake are provided by Jenkins et al. (2006). Generic actions (e.g., sea wall strengthening) may aid tourism infrastructure but are more often planed with wider economic issues at heart. Couple this with the long term sustainability issues surrounding most coastal management schemes the tourism industry is often overlooked.

15.6 Adaptation Strategies

The tourism industry is characterised by a high level of fragmentation and being composed of SMEs. The importance of the natural environment and climate to tourism is highlighted by the fact that businesses recognise the significance of factors such as a clean environment, beaches, sea and reliable climate (Jenkins, 2005). Yet most businesses fail to recognise the link between their businesses environmental performance, environmental degradation and climate change which could ultimately prove a cost to their business.

In Torbay, England only 14.7% of businesses had environmental policies in place and many businesses especially bars, cafés and restaurants showed a lack of interest and concern in current climate change issues. Larger scale problems such as loss of beaches or clean sea water are concerns the council must address within adaptation policies and sustainable tourism policies however, to develop sustainable tourism in the area it is also important for individual businesses to recognise the part they play.

Climate change is seen as an important issue for tourism as impacts which are already evident and are set to increase in the future. A large percent (60%) of tourism businesses in Torbay for example have already been affected by climate change impacts with immediate risks from increased storm intensity and frequency, damage to property, flooding and changing seasonality. The most important impact noted by 35% of businesses in Torbay was that of changing seasonality. It is likely that attitudes in Northern Ireland would reflect those found at Torbay.

Changing seasonality has been shown to limit tourisms profitability and growth (Getz et al., 2004) however warmer, drier summers and warmer winters will provide opportunities for the tourism season to expand in the UK. Most sectors of the industry within the UK appear to concentrate on the negative effects of climate change. If opportunities are present and they are to be exploited, sustainable tourism policies incorporating climate change scenarios are required as the tourism industry has proved inadequate to cope with current conditions and future impacts such as loss of beaches, poor water quality and water shortages may prove even more damaging.

A lack of information is often seen as a barrier to implementing adaptation measures. Tourist education also needs to be increased and tourism businesses are in an ideal position to disseminate this information. Results have highlighted particular business categories which could be exploited to ensure tourists are informed about climate change issues and advised on ways of reducing their environmental impact such as tourist education at attractions. This will also help provide a demand for more environmentally

friendly services as low consumer demand and a perceived unwillingness to pay made tourism businesses reluctant to offer them, a problem also witnessed with tour operators in other areas (Budeanu, 2005).

The research undertaken by Jenkins (2005) was the first time that the attitude of the tourism industry to climate change had been examined. Although 64% of businesses did have some form of adaptation measures many businesses which had not felt the effects of climate change were less concerned or willing to change behaviour. There were significant differences between business categories with attractions and accommodation providers generally more environmentally aware either due to their dependence on the environment as a natural resource or for economic reasons. Bars, cafés and restaurants on the other hand proved quite ignorant to climate change issues, they didn't feel they contributed to the problem nor would they be able to improve the situation. In the future as the severity of impacts increase more businesses may be forced to implement some form of adaptation or mitigation measures, however currently although the impacts of climate change are clear, positive responses are not. This short-term outlook of the tourism industry is not only a local problem but one reflected around the world (Hall et al., 2005) and the present lack of action only succeeds in increasing the vulnerability of the tourism industry.

15.7 Conclusions and Recommendations

Tourism is a growing industry in Northern Ireland, with numbers increasing by 60% since 1994. The numbers involved and the level of economic activity this generates has resulted in tourism becoming the second most important indigenous industry in Northern Ireland.

Sport and Recreation not only provide numerous tourism opportunities in Northern Ireland, but are of course beneficial to residents of Northern Ireland by providing an important social and economic function.

For Tourism and Sport / Recreation, the natural environment is one of the most essential resources. Any impact on the natural environment will therefore have an impact on these activities. It has been shown that a changing climate will have an effect on the natural environment of Northern Ireland.

No Northern Ireland specific research has been undertaken to assess the risks of climate change and requirements for adaptation, although clearly cross-sector issues have been identified. Climate change provides both a threat and opportunity. However, whilst these may be considered at a strategic / regional level, both tourism and recreation tend to have a very short term outlook that prevents effective planning for a changing climate.

While protection of the natural environment is being undertaken for reasons other than tourism and sport / recreation, these measures will have the benefit of also aiding tourism, sport and recreation development and should be borne in mind. There are also recommendations which can be made more specifically for tourism, sport and recreation and these are as follows:

- Specific research into the impact of a changing climate on tourism in Northern Ireland should be undertaken. There are different techniques available for doing this and the strengths and weaknesses of each technique should be examined before undertaking this work. The research should also examine the opportunities for increased tourism, sport and recreation that a changing climate may provide. The results of this research should be analysed and sustainable tourism, sport and recreation policies should be developed, with the specific Northern Ireland

situation in focus (though it is acknowledged that these policies could be based on those used elsewhere).

- Education – both for tourists and operators into their impacts on the climate. It has been shown that a lack of information can act as a barrier to the implementation of new adaptation measures and education can be seen as one way of overcoming some of the difficulties involved. Lack of education can also result in new opportunities being lost and attempts should be made to remedy this in light of the results from the research recommended above.

Table 15.3 - Impacts and Adaptation Summary: Tourism

Ref.	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource Implications	Adaptation strategy	Responsible public sector body
1	Wetter winters will affect outdoor tourism activities.	Tourism boards Attraction providers e.g. forest parks, Stately Homes	Reduced outdoor tourism activities.	Minor threat	Investment needed for indoor activity	*More year round tourism* facilities required and indoor attractions.	Local Councils NITB Forest Service EHS National Trust
2	Flooding due to wetter weather especially in coastal tourism resorts.	Planning Watercourse management	Flooding can damage tourism infrastructure and cause closure of coastal areas.	Minor threat	Review of maintenance procedures Staffing issues	Improved coastal defences and better planning regarding new developments.	Rivers Agency Local Councils
3	Drier summers will allow increased tourism opportunities in the summer.	Tourism Boards	Staffing issues for public sector run attractions Increase in turnover	Major opportunity	Staffing issues	Development of market and facilities	Local Councils NITB Forest Service EHS National Trust
4	Increase in outdoor tourism activities	Attraction providers e.g. forest parks, stately homes	Staffing issues for public sector run attractions Increase in turnover	Major opportunity	Staffing issues	Development of market and facilities	Local Councils NITB Forest Service EHS National Trust
5	Increased risk from water shortages due to dry weather and increased demand.	Water Supply	Potential need for grant aid	Minor threat	Increased demand on water resources	Reduction of leakage. Identification of and bringing online new sources of water.	Water Service EHS Rivers Agency
6	Dry weather may be detrimental to natural environment which is a vital resource for tourism	Water Supply Watercourse / lake management		Minor threat		*Review of impact of abstraction on water resources* Potential need to restrict visitors to attractions	EHS
7	Warmer winters will allow more year round tourism	Attraction providers e.g. forest parks	Warmer weather may encourage more out of season tourism	Major opportunity	Staffing issues	Development of market and facilities	Local Councils NITB Forest Service EHS National Trust
8	Hotter summers will encourage more international and domestic tourism	Attraction providers e.g. forest parks	Hotter weather will increase tourism numbers.	Major opportunity	Staffing issues	Development of market and facilities	Local Councils NITB Forest Service EHS National Trust

Ref.	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource Implications	Adaptation strategy	Responsible public sector body
9	More outdoor and water based activities due to hotter weather	Attraction providers e.g. forest parks	Increase in demand for outdoor tourist attractions. Increase in beach holidays and water sports.	Major opportunity	Staffing issues	Development of market and facilities	Local Councils NITB Forest Service EHS National Trust
10	Increased demand on tourism infrastructure.	Attraction providers e.g. forest parks	Will require a strong tourism infrastructure, increased transport links and good management of facilities and attractions.	Minor threat	Staff and cost issues	*Research into and review of current facilities and potential future need*	Local Councils NITB Forest Service EHS National Trust Roads Service Translink
11	Coastal flooding and erosion will degrade beaches.	Landowners e.g. local councils	Make areas less attractive to tourists who desire nice clean beaches and sea.	Minor threat	Maintenance and engineering issues	*Review of potential impacts for individual beaches* *Research into whether some areas may become more attractive than at present*	Local Councils NITB
12	Coastal squeeze will reduce beach size.	Landowners e.g. local councils	Loss of beaches will be detrimental for beach tourism.	Minor threat	Maintenance and engineering issues	*Review of potential impacts for individual beaches* *Research into whether some areas may become more attractive than at present*	Local Councils NITB
13	Reduced accessibility to coastal locations and unique scenery.	Landowners e.g. local councils	Loss of a major attraction for tourism in NI.	Minor unknown threat	Maintenance and engineering issues	*Review of potential impacts for individual beaches* *Research into whether some areas may become more attractive than at present*	Local Councils NITB
14	Damage to tourism infrastructure and sea side resorts.	Landowners e.g. local councils	Make areas unattractive to tourists. Reduce tourist amenities	Minor threat	Maintenance and engineering issues	*Review of potential impacts for individual beaches* *Research into whether some areas may become more attractive than at present*	Local Councils NITB
15	Increased risk from storm surges.	Landowners e.g. local councils	Damage tourism infrastructure and property.	Minor threat	Maintenance and engineering issues	*Review of sea defences and potential issue of managed retreat*	Local Councils NITB Rivers Agency
16	Increase in storm intensity and frequency damage tourism facilities and property.	Landowners e.g. local councils	Beach erosion and damage to coastal resorts.	Minor threat	Maintenance and engineering issues	*Review of sea defences and drainage network*	Local Councils NITB Rivers Agency

Ref.	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource Implications	Adaptation strategy	Responsible public sector body
17	Increased storm intensity and frequency will affect coastal zones with an increased risk from storm surges and flooding	Landowners e.g. local councils	Beach erosion and damage to coastal resorts.	Minor threat	Maintenance and engineering issues	*Review of sea defences and drainage network*	Local Councils NITB Rivers Agency
18	Changing seasonality gives less well defined tourism seasons.	Attraction providers e.g. forest parks	Less reliable weather for tourists could either hinder or increase tourism numbers.	Minor opportunity	Staffing issues – perhaps too many / too few employed	*Research into the viability of a wider range of attractions that can be used in any type of weather*	NITB Local Councils
19	Unreliable weather	Attraction providers e.g. forest parks	May cause a reduction in domestic holidays as people travel abroad for 'guaranteed' sunshine.	Minor unknown threat	Staffing issues – perhaps too many / too few employed	Advertising of benefits of a holiday in NI	NITB Local Councils

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

Table 15.4 - Impacts and Adaptation Summary: Sport & Recreation

Ref.	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource Implications	Adaptation strategy	Responsible public sector body
1	Wetter winters will affect outdoor sport and recreation	Leisure	Will affect sport and recreation facilities and cause cancellation of events.	Minor threat		More indoor sports centres and weather proof facilities.	Sports Council Local Councils IFA GAA IRFU
2	Drier summers will allow increased outdoor sport and recreation	Attraction providers e.g. forest parks	Potential change in sports 'seasons'	Major opportunity	Need for greater irrigation Staff issues		Sports Council Local Councils IFA GAA IRFU Water Service
3	Dry weather may be detrimental to local habitats and species which are vital for nature based recreation	Attraction providers e.g. forest parks	Potential difficulties in maintaining viability of certain attractions	Minor threat		Potential need to restrict visitor numbers	EHS
4	Will reduce soil moisture which will affect pitches and sports grounds.	Sports pitch owners / operators	Potential change in sports 'seasons'	Minor threat	Need for greater irrigation		Sports Council Local Councils IFA GAA IRFU Water Service
5	Warmer winter weather will allow more year round outdoor sport and recreation	Sports pitch owners / operators	Potential change in sports 'seasons'	Minor opportunity	Staffing Issues – move away from temporary contracts / employment		Sports Council Local Councils IFA GAA IRFU
6	Hotter summers will increase in outdoor recreation.	Attraction providers e.g. forest parks	Potential increase in visitor numbers.	Major opportunity	Issues of Health & Safety for outdoor workers / visitors		Health Promotion Agency Sports Council Local Councils

Ref.	Impact on receptor	Public Service Area**	Effect on public services	Risk	Resource Implications	Adaptation strategy	Responsible public sector body
7	Increase in water based recreation and sports.	Attraction providers e.g. forest parks		Major opportunity	Staffing issues – greater need for lifeguards?	*Review of current facilities to see if these can be expanded and research into other areas where these could be provided.*	Sports Council Water Service
8	Increase in storm intensity and frequency may cause the cancellation of outdoor activities.	Attraction providers e.g. forest parks	Potential cost issues	Minor threat	Greater levels of weather insurance cover may be required	*Liaison with insurance industry*	No identified bodies – rather all those who may hold outdoor events
9	Storms can damage sporting and recreation facilities.	Sports facility owners / operators	Potential cost issues	Minor threat	Greater levels of weather insurance cover may be required	*Liaison with insurance industry*	Sports Council Local Councils IFA GAA IRFU

* Public Services Areas from Table 2 of EHS (2005a).
^ *Building adaptive capacity*; delivering adaptive actions.

16 HEALTH

16.1 Scope

This chapter of the report considers the potential impact of a changing climate on the health of the population of Northern Ireland. The chapter provides an overview of the current situation and assesses the future possible implications of a changing climate, with emphasis on heatwave planning, emergency preparedness, Health Boards, Social Services, food safety, occupational health, communicable disease, health promotion and the impact on health of town planning. The chapter provides an indication of actions which are already underway in preparing for climate change, as well as suggested adaptation strategies which may be adopted in future in response to a changing climate. For further details on associated topics see the chapters on Buildings, Construction & Planning and Tourism, Sport and Recreation.

16.2 Background

Maintaining good health requires clean air, water, soil, and the maintenance of shelter, as well as protection from a range of environmental hazards, including chemical, biological and radiation hazards and physical hazards such as road traffic and flood events.

The potential impacts of climate change on human health therefore are the responsibility of a wide range of agencies, both within the traditional public health sector, and beyond. Public Health is here defined as the science and practice of protecting and improving the health of a community. Public health practices are therefore multi-disciplinary, multi-agency and inter-sectoral. Bodies that are also essential in protecting health include the agencies that are responsible for the public water supply, flood defence, and for the built environment (as addressed in the previous chapter).

The Department of Health, Social Services and Public Safety in Northern Ireland (DHSSPS) is responsible for Health and Personal Social Services, which includes policy and legislation for hospitals, family practitioner services, community health and personal social services. The Public Safety remit of DHSSPS encompasses responsibility for the policy and legislation for the Fire Authority and emergency planning. The health protection remit of DHSSPS includes:

- Disease and injury prevention
- Communicable disease control
- Environmental health hazards

The structure of public health and health protection in Northern Ireland is complex. It was recently recognised that public health services are in urgent need of reform. In 2004, the DHSSPS Review of Public Health Function in Northern Ireland was undertaken. The review was overseen by a Steering Group chaired by the Chief Medical Officer and a summary report containing 8 key recommendations was published at the end of 2004. This work is now informing the public health elements of the reconfiguration of the health sector under the Review of Public Administration (RPA).

The Health Protection Agency (HPA) was created in 2003 and primarily covers England and Wales. Scotland has its own organisation, Health Protection Scotland. The Communicable Disease Surveillance Centre (CDSCNI) is based at Belfast City Hospital and is the only regional presence of the GB Health Protection Agency. CDSCNI was established in 1999 to provide a regional communicable disease surveillance and epidemiology service.

The HPA provides other services to NI through various arrangements and agreements, but the relevant public health structures within Northern Ireland remain as they were prior to 2003. The local medical health protection function is currently delivered by Public Health teams reporting to a Director of Public Health in each of the 4 Health and Social Services Board areas. The local functions include surveillance, investigation and control of communicable disease and environmental hazards, with support from district council Environmental Health Departments and Health and Social Services Trusts. Contracts between the Boards and the HPA provide for HPA support on chemical incidents. Board health protection staff also have overall responsibility for coordinating and monitoring vaccination programmes, training Trust and Primary Care staff in health protection and leading on Board emergency planning.

The Review of Public Health Function in Northern Ireland identified emergency planning as an area which many of those involved in the consultation process felt required particular attention.

- Specific findings of Review of Public Health Functions in Northern Ireland in relation to Emergency Response Planning were as follows:

- There needs to be a clear(er) definition of what emergency response planning constitutes in NI – for example, where are the boundaries between the HPSS agencies and other emergency services/agencies outside the health service?

- There is also a need for a clear(er) definition of what is NI's strategic response to the challenges posed by major threats, and how this response integrates with UK- and EU-wide approaches.

- Emergency response planning undertaken by Public Health professionals needs to be accounted for separately, and resources allocated to ensure its effective discharge as an important, core element of their work.

- Given the significance and scale of the threats being planned against, nothing short of a regional approach, linked in with wider UK and EU plans, will suffice.

The Health Promotion Agency covers a wide range of health promotion activities. Most relevant for climate hazards are current initiatives for healthy schools, and healthy workplaces. Although these do not directly address any climate issues, they would improve the capacity to cope with such environmental hazards. Its statutory functions are advising the DHSSPS on matters relating to health promotion, commissioning and carrying out research and evaluation, providing training and professional development, providing information to the public and professionals through a range of media and working with and supporting other organisations involved in health.

The Review also noted the increasing contribution of Environmental Health Professionals (EHPs) within public health and the need for their role to be further developed. At local government level, EHPs are responsible for food safety, health and safety, air quality, waste management, other chemical hazards, such as contaminated land, and a range of other statutory functions. The review recommended strengthening the public health role of environmental health within DHSSPS, to develop and influence policy and strategy and to provide a link between the DHSSPS, regional and local bodies and the Environmental Health service. The review further recommended the establishment of EHP posts linking local government, regional health protection and health improvement bodies and Public Health departments.

16.3 The Issue Now

There are large inequalities in the health of the citizens of Northern Ireland. Consultation rates for respiratory diseases increase with decreasing socio-economic status in all age groups (HPA 2005). Men from semi-skilled or unskilled groups tend to die earlier and report more chronic illness than those from professional and managerial groups. Poverty, social inequality, deprivation and social and health policy drive the health sector.

Sections of the population who are marginalised, such as Travellers, have a particularly heavy burden of chronic illness (including mental illness, asthma, cancer) and premature death (HPA 2005). In the last decades, the inequalities in health have not improved, and in some cases, the gap between the health of the rich and the poor has increased. Northern Ireland is one of the most disadvantaged regions in the UK, with persistently high levels of unemployment and in rates of long term unemployment (NISRA, 1997; NICEM, 1998).

In March 2002, the Northern Ireland executive launched its public health strategy - *Investing for Health* - central to which is the commitment to ensuring equality of opportunity and tackling social disadvantage. This strategy contains a framework for action to improve health and well-being and reduce health inequalities, which is based on partnership working amongst Departments, public bodies, local communities, voluntary bodies, District Councils and social partners. Until this point health policy had tended to concentrate on the treatment of ill health. *Investing for Health* aims to shift this emphasis by focussing on the prevention if ill health. At regional level, the inter-Departmental Ministerial Group on Public Health has the role of managing cross-Departmental action and monitoring progress in other areas. At local level, *Investing for Health* Partnerships have been established in each of the four Health and Social Services Board areas. These Partnerships comprise the key statutory, community and voluntary interests in the area together with the social partners with a role to play. The broad purpose of the *Investing for Health* Partnerships is to identify opportunities for improving the health of the people in their area by addressing the social, cultural, economic and environmental determinants of health. To achieve this all four Partnerships have produced Health Improvement Plans setting out how they plan to address the identified health and well-being needs of their local populations to meet the strategic aims and objectives of *Investing for Health*. Funding is made available to the Partnerships from DHSSPS to support the implementation of the Health Improvement Plans.

Currently, NI has a relatively younger population but the proportion and number of older people will increase, in line with other regions in the UK. Falling birth-rates as well as people living longer will lead to the number of people aged 65-and-over doubling in Northern Ireland by 2036. Women make up a much greater proportion of older people, with almost twice as many women as men in the 75-and-over age group (Northern Ireland Ageing Population Panel, 2001).

Table 16.1 - Annual totals (CDSC (NI) website) for laboratory confirmed reports of select climate-sensitive notifiable diseases in Northern Ireland (passive surveillance)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
S. typhimurium DT 104	56	121	134	142	66	37	20	16	10	95
S enteritidis	261	171	169	272	462	235	179	98	94	89
All salmonella	452	413	432	534	689	425	367	240	214	451
Campylobacter	557	653	778	775	862	1001	885	817	743	849
Cryptosporidium	81	98	82	180	181	417	360	126	140	137

The incidence of notifiable infectious diseases is comparable with other regions in the UK. Surveillance of infectious diseases is undertaken by the CDSC. Table 16.1 lists reports of notifiable diseases in Northern Ireland, that are also climate or weather sensitive. It should be noted that some important food borne diseases, such as salmonellosis, are declining due to successful control measures (such as vaccination of chickens). These trends are expected to continue although new pathogens may emerge (see below).

Cryptosporidium is the most important infectious disease transmitted through the water supply. CDSC (NI) receives approximately 150 reports of Cryptosporidiosis annually. It is the third most frequently reported microbiological cause of gastrointestinal disease in Northern Ireland. The epidemiology of this disease is particularly important in Northern Ireland considering the waterborne outbreaks of Cryptosporidiosis in 2000 and 2001, the large livestock population and exposure to farm animals and their environments (Glaberman et al., 2002).

In this assessment, disease does not mean only infectious disease, but also includes non-communicable diseases that may be sensitive to climate factors (e.g. asthma), as well as injuries. Road traffic accidents are the leading cause of death in adults in Northern Ireland.

16.4 How Climate Change May Affect the Future

Climate change will affect a range of health outcomes through a variety of mechanisms. There has been no formal assessment of the potential impacts of climate change on health in Northern Ireland. The 2002 SNIFFER report addressed a range of health issues, some of which are updated in the review below.

Climate change may bring both benefits and threats to the health of the people of Northern Ireland, and the balance of harmful and beneficial, in the near term, is currently unknown. The 2002 report concluded that issues of particular concern were “the entry of new diseases into Northern Ireland” (since increased rain and relative humidity favour the transmission of infection), and a possible increase in rodent-borne diseases.

In the UK, the 2002 Department of Health assessment of the potential health effects concluded that climate change would increase heat-related deaths, decrease cold–related deaths and cause an additional burden of disease due to increased flooding (Department of Health, 2002). This assessment is now in the process of being updated.

Table 16.2 - Summary of known effects of weather and climate on human health

Health outcome	Known effects of weather
Heat stress, cold stress	♦ Deaths from cardiopulmonary disease increase with high and low temperatures ♦ Heat-related illness and death increase during heat waves
Air pollution-related mortality and morbidity	♦ Weather affects air pollutant concentrations ♦ Weather affects distribution, seasonality and production of aeroallergens
Health impacts of weather disasters	♦ Floods, landslides and windstorms cause direct effects (deaths and injuries) and indirect effects (infectious disease, long term psychological morbidity).
Mosquito-borne diseases, tick	♦ Higher temperatures shorten the development time of pathogen in vectors and increase potential transmission to humans.

borne diseases (e.g. Lyme disease, West Nile fever)	♦ Vector species have specific climate conditions (temperature, humidity) necessary to be sufficiently abundant to maintain transmission.
Water-/ food-borne diseases	♦ Survival of important bacterial pathogens is related to temperature ♦ Water-borne diseases are most likely to occur in communities with poor water supply and sanitation ♦ Increases in drought conditions may affect water availability and water quality (chemical and microbiological load) due to extreme low flows ♦ Extreme rainfall can affect transport of disease organisms into water supply

From Kovats *et al*. (2005).

16.4.1 Heatwave planning

The South of England experienced heatwaves in 2003 and 2006, and heatwaves are likely to increase in frequency and intensity with climate change. The burden of heat attributable mortality is primarily in those aged over 75 years. The 10 day heat wave in August 2003 caused approximately 2000 excess deaths in England and Wales, which is a 17% increase in deaths expected for that time of year (Johnson et al., 2005). The greatest impacts were in SouthEast England. The effect on mortality in Northern Ireland has not been reported in the literature but the region did not experience particularly high temperatures. The impact on mortality of the July 2006 heat wave is unavailable at the time of writing.

A number of measures can be implemented to prevent heatwave mortality. Most countries in Europe, however, have focussed efforts on warning systems (Kovats and Ebi, 2006). A heat health warning system (HHWS) is here defined as a system that uses meteorological forecasts to initiate acute public health interventions designed to reduce heat-related impacts on human health during atypically hot weather. An effective heat health warning system requires:

- reliable meteorological forecasts for the population or region of interest
- robust understanding of the cause-and-effect relationships between the thermal environment and health outcomes at the population level, including the evidence-based identification of “high risk” meteorological conditions to activate and deactivate response activities.
- effective response measures to implement within the window of lead-time provided by the warning (1-3 days approximately)
- the involvement of institutions and civil society that have sufficient resources, capacity, knowledge and political will to undertake the specific response measures.

The Heatwave plan for England was launched in 2004 and revised in 2005 (Department of Health, 2005). It has four levels of warning, linked to meteorological forecasts. The highest level of warning (when very extreme temperatures are imminent) is to initiate the emergency planning response. The heatwave plan was triggered (Level 3) in July 2006 for the first time.

Deaths attributable to heat occur during hot weather and not just during a heat wave. There should be a strong commitment to preparedness and support for strategies to

reduce heat-related mortality that are not just linked to acute events. Such strategies include:

- Including heat illness prevention in the training of care staff and nurses (for both hospitals and residential homes).
- Given the high risk of mortality in residents of residential and nursing care homes, there should be greater provision for creating cool rooms (as per the French plan).
- The high risk of mortality in elderly hospital inpatients should be evaluated and response measures formulated.

Effects in France showed that government was totally unprepared for "heat" as a threat to health. Key lessons that have been learned (in France) are improved communication between agencies, and measures for early detection of heatwave impacts on health. In 2003, there was no way of detecting the increase in mortality in the elderly and it was only when all funeral homes and morgues were full that an official response was initiated. In England, NHS Direct now monitors calls for heat and sun stroke.
The Heatwave Plan for England does not cover Northern Ireland (or Scotland or Wales). Heat related surveillance (NHS Direct bulletins, Qresearch bulletins) are routinely sent to all Consultants for Communicable Diseases throughout the UK. The Heatwave Bulletin, issued throughout the summer (1 May to 1 September) is also sent to all UK regional epidemiologists, including those in NI.

16.4.2 Emergency preparedness

Climate change presents risks for both coastal and riverine floods in Northern Ireland (as discussed in chapter 9 of this report). The health implications of these events are essentially the same. The most important feature for casualties is the speed of onset of the flooding, and the presence/absence of a warning. Two reviews of the epidemiological literature have described the range of health effects: drowning, injuries, mental illness, chemical pollution, and infectious diseases (Hajat et al., 2003; Ahern et al., 2005). A study following the flooding Lewes in 2002 has confirmed that there is large burden of self reported illness (Reacher et al., 2004). However, important knowledge gaps remain concerning the long term impacts on anxiety and depression, and indirect effects on mortality and use of health services in the months and years following a flood event.

The HPA has reviewed the implication of flooding for chemical hazards (Euripidou and Murray, 2004). There are risks to health from the contamination of flood waters with chemical waste, oil, diesel, fertilisers, etc. Flooding may lead to mobilization of dangerous chemicals from storage or remobilization of chemicals already in the environment, e.g. pesticides.

Cities in Northern Ireland will have some form of emergency planning which can also be deployed for extreme heat wave events (as per Level 4 of the Heatwave Plan for England). However, as discussed above, emergency preparedness in Northern Ireland has been assessed as relatively weak.

16.4.3 Health Services

Flood events may affect health service delivery by causing damage to hospitals, clinics and general practices. The siting of hospitals, care homes, schools, nurseries, and clinics in flood risk areas should be assessed. In Lewes, one general practitioners office was flooded, and most of the patients' notes (on paper) were destroyed.

In England, there has been concern about temperatures inside hospitals. Inpatients were shown to be at risk during previous heat waves in the 70s and 80s (Lye and Kamal, 1977; Ellis et al., 1980). Many hospital buildings, including the newly built PFI hospitals do not have space cooling (Kovats and West, 2005).

16.4.4 Social Services

Emerging results from France in 2003 indicate that levels of care of older and vulnerable people, both in institutions and in the community, were important causes of heatwave mortality. Deaths increased by 200% in maison de retraite (retirement homes) during the heatwave. Information is limited about the high risk groups in the UK. However, a recent study has shown excess mortality in nursing homes in both the elderly, and the non-elderly population (Kovats et al., 2006). The care of elderly people in their own homes, and in institutions during episodes of hot weather is essential to prevent heat-related deaths. Long term strategies, such as training of staff, and regular inspections in hot weather are important.

Mental health is now recognised as an important health consequence of flooding (Ohl and Tapsell, 2000). A systematic review of the epidemiological literature found that studies, mostly the US, did provide good evidence of long term (> 6 months post flood) mental health complications (Ahern et al., 2005). A recent case-control study from the UK, found a four-fold increase in psychological distress among adults whose homes were flooded compared to those whose homes were not flooded (Reacher et al., 2004). Post-flood support for affected individuals is a potential response from Social Services, as well as Primary Care providers.

16.4.5 Food safety

Food safety is an important public health problem as well as an economic concern. Higher temperatures are associated with increases of bacterial enteric infections such as salmonellosis, a common form of food poisoning. Several studies have confirmed and quantified the effects of temperature on Salmonella types, especially those transmitted via poultry and eggs (D'Souza et al., 2004; Kovats et al., 2004). High temperatures contributed to an estimated 30% of cases of salmonellosis in Europe. It is reasonable to assume that temperatures have similar effects on E coli transmission, which is a much rarer pathogen.

The evidence is less convincing for an effect of temperature on transmission of Campylobacter infection, which is now the most important cause of food borne disease in the UK (Kovats et al., 2005). Cases of Campylobacter peak in the early spring, and the cause of this peak is unknown. Cases then decline during the summer, which confirm that temperature is unlikely to be a major factor in transmission. The main reservoir and / or route of transmission remains unknown.

Contact between food and pests, especially flies, rodents and cockroaches, is also temperature-sensitive. House and blow fly activity is largely driven by weather (temperature) rather than by biotic factors. In temperate countries, such a Northern Ireland, warmer weather and milder winters are likely to increase the abundance of flies and other pest species during summer months, and the pests will appear earlier in the spring.

Food hygiene is the most important factor for prevention of food borne diseases. Studies have shown that it is the temperature the week before illness (i.e. when food is prepared and stored) that most increases the risk of transmission. The WHO expert group on food

borne disease surveillance also reports that “temperature misuse” is a significant factor in food borne disease outbreaks (Tirado, 2005). It was reported that many food refrigeration systems failed in France during the exceptionally hot summer of 2003.

The Food Standards Agency was formed in April 2000 and assumed responsibility for food safety throughout the UK. The Agency has a target to reduce food borne disease by 20% by 2006 (the organisms that are specifically targeted are Salmonella sp, Campylobacter sp, Clostridium perfringens, Escherichia coli O157 and Listeria sp).

16.4.6 Occupational Health

Outdoor workers are at risk from heat stroke, and the risk of exposures to hot weather may increase with climate change. The occupations most at risk of heat stroke (mortality and morbidity), based on US data, are construction and agriculture/forestry/fishing (Adelakun et al., 1999). Research on ergonomics and physiology has shown a range of health problems associated with working in high temperatures. In July 2006 heat wave in France, 12 deaths in workers were reported.

16.4.7 Communicable Disease Surveillance

The surveillance of infectious disease is essential in order to detect changes in incidence, changes in seasonality, and changes in distribution.

Several food borne infections are notifiable diseases (see above). Lyme disease is the only vector-borne disease present in Northern Ireland. The tick vector is widely distributed throughout Ireland, England and Scotland. At the moment there is insufficient evidence to assess the implications of climate change for this disease. The risk of the (re)introduction of other vector borne diseases is considered to be very low in the near term and they are not considered further in this assessment.

The most important rodent borne disease is leptospirosis (Weil’s disease). Transmission in Northern Ireland, is primarily via contact with surface waters contaminated by rodents. The effect of weather and climate on this disease in NI is not known. Heavy rainfall or flood events are sometimes associated with increases in leptospirosis, due to increased contacts between human and rats.

It is important that adequate health surveillance is maintained so that the introduction of a new infectious disease or disease vector is detected in a timely manner. (Department of Health, 2002). In particular, GPs and health professionals should be encouraged to report infectious diseases as well as bits and stings from insects which may be new to the UK. A central database could then monitor changes in the distribution of diseases and vector species. As some changes are already apparent on the continent, careful attention should be paid to travel-acquired diseases and potential changes in their distribution.

16.4.8 Health Promotion

The Health Promotion Agency is responsible for health promotion campaigns including for example, campaigns relating to sun protection. Observed health effects (such as increases in skin cancer) reflect changes in personal exposure to solar radiation due to changes in patterns of recreation, clothing and occupation, rather than increases in background UVR. Climate change may change recreation patterns so that sunbathing is increased. Health promotion campaigns to reduce UV exposures should therefore be continued and strengthened.

Solar radiation has been consistently implicated in the causation of non-melanocytic skin cancers (NMSC) in fair-skinned humans. Although solar radiation is substantially involved in melanoma causation, the relationship is less straightforward than for NMSC; exposure in early life appears to be a major source of increased risk. The effect of UV on bone malignancy is speculative.

16.4.9 Town planning

Temperatures, especially minimum temperatures, are often higher in urban environments because of the urban heat island effect. For example, Greater London has a significant heat island, and this will exacerbate the increase in temperatures due to climate change (Wilby, 2003). These effects are discussed in more detail in Chapter 10.

16.4.10 Summary

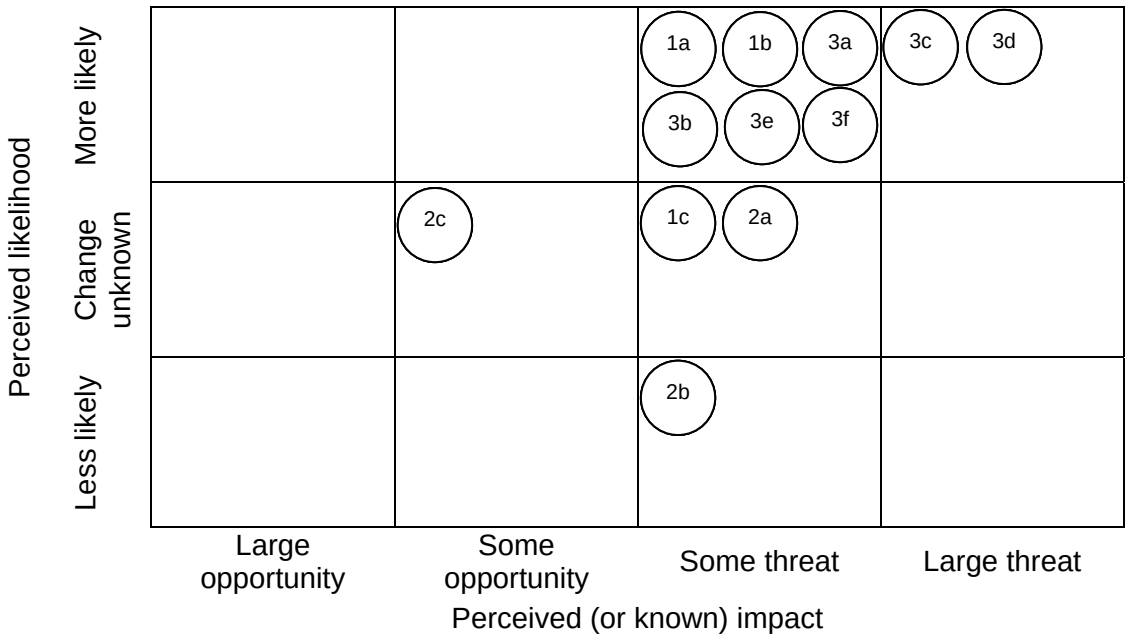
The impacts of climate change on health are summarised in Table 16.3.

Table 16.3 - Climate Change Impacts: Health

Climate change	**Impact**		
	Public Health	**Emergency Planning**	**Social services (care homes, care in the community)**
Wetter winters	Heavy rainfall may trigger flood events that have direct and indirect effects on health (drowning, mental illness, infectious disease, respiratory illness due to damp)	Emergency planning to be deployed during flood events.	Building may be flooded, patients may need to be evacuated. Post-flood care.
Warmer winters	Generally, benefits to health from reductions in cold related mortality and morbidity. Milder winters may lead to increased pest activity.		
Hotter summers	Heat-related mortality and morbidity Occupational heat stress Increases in hospital admissions due to heat waves.	Extreme heat wave could overwhelm public services.	Heat-related mortality and morbidity of residents of care homes

Climate change	Impact		
	Public Health	**Emergency Planning**	**Social services (care homes, care in the community)**
Sea level rise	May contribute to coastal flood events that have direct and indirect effects on health (drowning, mental illness, infectious disease, respiratory illness due to damp)	Emergency planning to be deployed during flood events.	Building may be flooded, patients may need to be evacuated. Post-flood care.
Other (*stated)*	***Flood risk:*** Floods have important impacts on health: deaths, injuries, communicable disease, common mental disorders (anxiety and depression).	***Flood risk:*** Incorporate health into emergency plans.	***Flood risk:*** Impacts on floods on elderly, and mental health.

Figure 16.1 - Risk Assessment: Health



Note 1: For key to numbers see the first column of the Impacts and Adaptation Summary (Table 16.4).

Note 2: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

16.5 Actions Undertaken or Underway and Key Gaps

No climate change specific actions for health protection are underway in Northern Ireland. However, the public health infrastructure is able to address at least some of the potential range of risks to health from climate hazards, at least in the near term, provided that the infrastructure is adequately supported (see section 1 above).

Northern Ireland is not covered by a Heatwave Plan similar to that in place for England. Accordingly, no heatwave prevention activities have been implemented within the public health sub-sector in Northern Ireland (as far as the author is aware).

16.6 Adaptation Strategies

There are two important dynamics driving the design of public health interventions, including the management of environmental risks: 1) scientific and technical knowledge, including the level of confidence in that knowledge; and 2) public values and popular opinion.

Environmental risk management is the process by which assessment results are integrated with other information to make decisions about the need for, approaches to, and extent of risk reduction. It is the role of policymakers to decide what interventions to implement, if any, to address current vulnerabilities, including those due to climate variability and change, even as research continues to provide additional information. Policymakers should consider the concerns and priorities of stakeholders, including the scientific community and the general public.

We have sufficient evidence to develop appropriate public health measures for climate change at present in relation to health protection for heat wave and flood events, however, there is little political will for environmental risks in general, and climate change in particular. There is a need to develop health protection capacity to contribute to responses to extreme events, as well as document impacts of individual events with formal risk assessment, and enhanced surveillance in critical periods or specific surveys. The appropriate agencies should also contribute to the study of the impact of climate change in Northern Ireland, and the development of good practice with respect to the public health responses to extreme weather throughout the UK.

16.6.1 Infectious disease surveillance

Infectious disease surveillance should be strengthened. It should be noted that new pathogens may be introduced. Surveillance and mapping of disease vectors (mosquitoes, ticks) should be undertaken.

Recommendations with regards to food borne disease and climate change (from WHO workshop report 2003) include:

- Monitor pathogens in animals as well as humans. (Currently data to determine seasonality or temperature-sensitivity to pathogens in animals is lacking).
- Improve surveillance systems; relate reported cases to real levels of disease (quantify under-ascertainment and selective ascertainment in different age and social groups). Explore the feasibility of denominators.
- Include sentinel sites of enhanced ascertainment and how the results compare with routine surveillance.

- Standardise and harmonise data collection between countries as far as possible with differences in health systems in European countries.
- Food hygiene and production should be under one authority.
- Vector-borne disease surveillance recommendations:
- Monitor changing risks as they are happening, both within the UK and to holiday makers.
- Examine the impact of multivariable environments on the spatial and temporal patterns of disease distribution and intensity for both temperate and tropical vector-borne disease systems.

16.6.2 Built environment

It is difficult to predict how many buildings may be affected by a rise in temperature without carrying out a detailed study, but it should be noted that retrofitting air-conditioning in existing buildings is seldom a viable proposition because of the practical difficulties. In the context of reducing energy demand, air-conditioning is to be avoided if possible through better building design, though obviously this only applies to new buildings. CIBSE in collaboration with UKCIP are revising their standard climate data for housing design, so that climate change will be taken into account in the future. However, less than 1% of housing stock is renewed per year, and there will still be many houses in future that will have high indoor temperatures (ODPM, 2003).

Climate change is likely to reduce winter related mortality. Winter is seen as the main problem due to the large number of deaths. However, designing for heat as well as cold is yet to be mainstreamed and will become a problem as climate warming accelerates.

16.6.3 Emergency Planning

Recommendations from the Review of Public Health Document are also applicable to emergency planning. It is also recommended that registries are set up after an extreme event, in order to monitor population health, and reassure the public.

16.7 Conclusions and Recommendations

There are large inequalities in the health of the citizens of Northern Ireland. Poverty, social inequality and deprivation mean that the burden of ill health and early mortality tends to impact on certain social groups with members of the poorest sections of society impacted the greatest.

Northern Ireland also has a relatively young population in relation to other parts of the United Kingdom. However, the proportion and number of older people will increase in line with other regions of the UK – the number of people aged 65 and over will have doubled by 2036.

A changing climate will have a number of impacts on the health of the people of Northern Ireland – both positive and negative, though the proportion to which these will occur is unclear at present. There are though a number of recommendations that can be made as follows:

- Consideration should be given to developing a Heatwave Plan for Northern Ireland similar to that in place for England – this should be specific to Northern Ireland and the predicted extreme heat events for NI.

- Consideration should be given by policy makers to the likely impacts of climate change in light of the research which has been undertaken and which is planned. A decision on priorities will need to be taken by the relevant authorities in light of the likely impact of climate change and the timeframe over which it will occur against the other competing considerations affecting the health sector in Northern Ireland.
- Infectious disease surveillance should be strengthened.
- Registries of extreme events and their impact on the public health should be set up for monitoring purposes.

Table 16.4 - Impacts and Adaptation Summary: Health

Ref.	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
1	Coastal and riverine floods, contributing to:						
1a	Physical impacts e.g. injury, drowning	Health advice & promotion; Healthcare	Disruption, loss of infrastructure, damage to building. Will need to provide extra services to those flooded.	Minor threat	Additional requirement for emergency planning and response	*Preparedness, proper health risk assessment, including chemical hazards, population at risk, health advice.*	DHSSPS, HPA
1b	Mental impacts e.g. anxiety, depression	Health advice & promotion; Healthcare	Increased demand for health care services	Minor threat	Additional post-flood staff time		
1c	Spread of infectious diseases	Health advice & promotion; Healthcare	Increased demand for health care and health promotion	Minor unknown risk	Additional post-flood staff time		
2	Milder winters (and warmer seasons):						
2a	Increased risk of infectious disease introduced into NI or increasing in incidence, due to lengthened transmission season.	Health advice & promotion; Healthcare	Increased demand for health care and health promotion	Minor unknown risk	Increase in costs	Improved surveillance, including active surveillance. [Lyme disease vaccine not available yet]	NI CDSC
2b	Reduced cold weather-related mortality and morbidity	Health advice & promotion; Healthcare	Reduced demand for health care and health promotion	Minor benefit	Resources can be spent elsewhere	No active strategy required	n/a
2c	Benefits relating to increased opportunities for recreation, potentially offset by accident risk	Health advice & promotion; Healthcare; Leisure; Transport planning	Increased demand for decent outdoor recreation facilities. Potential long-term benefit to in public health.	Minor unknown risk	Increased need for safe, secure recreational facilities.	*Construct safe*, secure recreational facilities	Local councils
3	Hotter summers with increased "heatwave" events, leading to:						
3a	Increase in heat-related mortality and morbidity	Health advice & promotion; Healthcare; Planning; Building control	Acute increase in demand for health and social service	Minor threat	Some costs for development and deployment- but interventions are generally cost-effective . Cost of retro-fitting air conditioners is high.	Development and implementation of heat wave system or plan. Implement space cooling measures. Urban planning to reduce heat islands	DHSSPS, Health Promotion Agency HSSBs, Health Trusts, Planning Service, District Councils

Ref.	Impact on receptor	Public Service Area*	Effect on public services	Risk	Resource implications	Adaptation strategy^	Responsible public sector body
3b	Increase in occupational heat stress	Health advice & promotion; Healthcare; Business support; Building control.	Increased demand for health care; potential effect on productivity	Minor threat	Increase in costs	Health advice; better building design; tax breaks for building retro-fits	HSSBs, Health Trusts Health Promotion Agency; District Councils; DFP
3c	Increase in hospital admissions	Health advice & promotion; Healthcare	Increased demand for acute health care	Major threat	Increased summer demand for staff and beds	See 3a. Contingency planning e.g. cancellation of routine procedures during heatwaves to free beds.	DHSSPS, HSSBs, Health Trusts Health Promotion Agency
3d	Increase in respiratory problems	Health advice & promotion; Healthcare	Increased demand for acute health care	Major threat	Increase in demand for facilities to assist respiratory problems	See 3a. Contingency planning e.g. increased provision of staff and equipment during heatwave, or temporary pollution control measures.	DHSSPS, HSSBs, Health Trusts Health Promotion Agency
3e	Hotter summers (and milder winters) leading to increased bacterial growth, and activity of pests (flies, rodents)	Health advice & promotion; Healthcare; Waste	May increase incidence of food borne disease	Minor threat	Costs to business and individuals. Outbreaks can cause losses to tourism and hospitality industries.	Strengthen food hygiene measures and regulations, advice. *Review waste management and pest control strategies.*	FSA, DARD, DoE, EHS Health Promotion Agency, District Councils
3f	Longer summers leading to increased exposure to UV- and its consequent health effects	Health advice & promotion; Healthcare	None	Minor threat	Increased need for health promotion and occupational health messages.	Health promotion and health and safety at work strategies	Health Promotion Agency, HSE (NI), District Councils

* Public Services Areas from Table 2 of EHS (2005a). ^ *Building adaptive capacity*; delivering adaptive actions.

17 CONCLUSIONS AND RECOMMENDATIONS

17.1 Scope

This report provides an up to date assessment of the impacts of climate change in Northern Ireland. There has been an emphasis on the consequences for public services, which have been examined on an impact by impact basis. A risk assessment has been undertaken for each sub-sector, which identifies the most significant threats, benefits and opportunities, along with areas for further monitoring or research. Finally, an adaptation strategy has been identified for each impact, with a proposed public body responsible for delivery. The study has drawn on the UKCIP02 climate change scenarios, latest research into impacts and adaptation, a telephone survey and workshop. Novel techniques for risk assessment have been applied successfully.

This final section draws together conclusions and recommendations from the study. It also provides a cross sectoral analysis across the four sector-based themes of Economic Infrastructure, Built Environment, Natural Environment and Social Wellbeing. In addition, it examines the effect on public services, specifically on the key outcomes related to the Government's three priority themes of Economic Competitiveness, Equality and Community Cohesion and Better Public Services. Findings in the context of Sustainable Development are also assessed.

17.2 Methodology

The development and assessment of socio-economic scenarios was not part of this study. Inclusion of such scenarios, alongside climate change scenarios, would be beneficial as both impacts and adaptive responses are conditioned by the socio-economic setting. **It is therefore recommended that the Government of Northern Ireland develop a set of socio-economic scenarios.** This should build on the work being undertaken as part of BESEECH study.

The use of risk assessment has proved to be highly valuable in describing impacts and as a guide to adaptation**. It is recommended that a risk-based approach is adopted in more detailed qualitative and quantitative impact assessments** that follow this study.

This study provides recommended options for adaptations. **Option appraisal and selection, and development of associated indicators and targets should now be undertaken**. This may require more detailed quantitative assessment of impacts, which may be guided by the risk assessments completed in this study. This will require a move towards a more stakeholder based engagement and development of impacts, risks and responses. **It is recommended that a Northern Ireland climate change adaptation partnership is established** to facilitate such studies and coordinate stakeholder engagement within and between sectors.

17.3 Climate Change

Meteorological observations suggest that **the climate is already changing in Northern Ireland and although it remains relatively benign, more significant changes are projected over the coming century.** In particular:

- Winters will become much wetter, with more intense rainfall days
- Summers will become much drier and hotter
- Sea level is likely to rise

The study found that the **current climate, in particular extreme weather, can present difficulties** and the examples documented provide some indication of the sensitivity to climate change. For this reason, **it is recommended that information on sensitivity to current weather is collated by public sector organisations**. Data should include the weather variable, a description of the event and the effects e.g. financial loss, staff time involved etc. This information will prove invaluable in detailed climate change impact assessments and will help improve resilience to current weather.

The UKCIP08 climate change scenarios, due in 2008, are not likely to alter the strategic findings of this report. Significantly more detail will be provided, including probabilistic projections, and this will be particularly useful for detailed technical assessments, for example related to water resource planning**. It is recommended that a brief assessment of the UKCIP08 scenarios is made on their publication**, reviewing any changes in scenarios and highlighting the enhanced data available for stakeholders in Northern Ireland. **It is also recommended that outputs of EPA research are reviewed with respect to application in Northern Ireland**; this may include more detailed comparison of EPA and UKCIP scenarios.

There are significant uncertainties associated with climate change scenarios and impact assessment, and these become more relevant for detailed studies and investment decisions. A significant amount of research is currently underway regarding uncertainty and approaches to quantification and **it is recommended that further sector specific or detailed assessments take due account of the findings of this work.**

Rapid climate change, for example leading to a decline in the North Atlantic Drift, is considered unlikely over the next 100 years. UKCIP will clearly play an important role in assessing the potential risks given the potential scale of impact and in advising the UK Government and its agencies. **It is recommended that a watching brief is kept on current research in this area** and subject to advice from UKCIP, assessment of alternative 'side-swipe' scenarios may be required to test resilience.

17.4 Climate Change Risks

The risk assessment process classified impacts into threats, opportunities, lost opportunities and benefits (in addition to unknown risks, which are discussed in the adaptation section below). Table 17.1 presents the threats identified under each sector. Table 17.2 presents the opportunities and benefits identified for each sector. No major lost opportunities (current opportunities likely to decline) were identified. Further detail related to each impact is provided within each chapter and in particular the *Impacts and Adaptation Summary* tables.

Key cross-sectoral impacts are related to an increase in flood risk, with particular implications for the built environment and economic infrastructure and drier summers, with impacts affecting the natural environment. Hotter summers will affect the built environment, economic infrastructure, the natural environment and social wellbeing.

Table 17.1 - Climate Change Threats in Northern Ireland

Sub-Sector	Threat
Conservation, Biodiversity and Habitats	o Distribution and species composition of habitats will change in response to warmer winters. o Increase in range of some invasive and exotic terrestrial, freshwater and marine animal and plant species which threaten native ecosystems, in response to warmer temperatures. o Inter-tidal habitats, salt marshes and mudflats threatened through flooding and erosion. o Loss of coastal grazing marsh. o Estuarine and river ecology threatened by tidal flooding. o Warmer sea temperatures causing changes to the phytoplankton communities resulting in a decline in sand eel populations which adversely affect a wide range of seabirds.
Fisheries	o Increased frequency flooding could lead to decreased fish egg survival and washing away of juvenile salmonids. o Lower flows, lower water quality and increased temperatures leads to fish kills. o Increased temperatures in rivers lead to poor freshwater quality leading to fish kills. o Increased temperatures can become lethal for some fish such as salmonids. o The melting of the polar ice pack has cooled the northern Atlantic, reducing the extent of thermally attractive habitat for Salmonids. o Angling affected by disturbance of breeding season of fish. o Reduced stream flow could have negative impact on salmonid migration triggers. o Loss of fly life and alteration of / to macroinvertebrate ecology resulting from low flows may lead to less available fish food.
Agriculture	o Field drainage issues in wetter winters. o Physical damage to crops in wetter winters. o Increased need for irrigation in dry summers. o Increased need to keep livestock cool in hotter summers. o Loss of coastal areas of agricultural land.
Forestry	o Hotter, drier summers will increase the water use of woodlands potentially restricting their planting in areas with limited water availability. o Increased frequency of forest fires: in isolation, predicted climate change will increase the fire risk; however, the species make-up and age structure influences the fire risk making the overall effect on fire risk less certain. o Changing incidence of insect pest and disease outbreaks. o Extended summer droughts leading to widespread tree mortality. o Changing climatic conditions will alter site suitability of tree species that are currently planted: much is known about the changes to the suitability of individual species, some of which will lose out.

Sub-Sector	Threat
Water Resources	o Lower flows cause problems for users relating to abstraction, ability to dilute effluent, aquatic ecology and recreation. o Increased temperatures may cause problems with river and reservoir water quality e.g. Dissolved Oxygen depletion, algal blooms, physiological impact on fish. o Storms may cause more Combined Sewer Overflows, damaging aquatic life. o Increased rainfall causing erosion of soil and leaching of agrochemical and agricultural wastes with problems for aquatic life, abstractions and river users. o Reduction in volume of sewer base flow may result in blockages, leading to environmental health and flooding problems. o Drier, hotter summers will increase demand for water and water-related products and activities affecting ability of abstractors to meet requirements. o Lower summer runoff leading to reduced flushing of estuaries and lakes with implications for shell fisheries, lake ecology and abstractors. o Higher evaporation and lower inflows leading to reduction in open water storage e.g. Lake Neagh, which may affect marginal habitats and abstraction. o Increase in pests and change in life cycle of aquatic and land-based organisms. o Summer storms, following dry periods, may lead to high pollutant loads, damaging aquatic habitats.
Coastal & Flood Risk Management	o Increase in winter fluvial flooding, with impacts on: settlements; farms and agricultural land; natural heritage; transport infrastructure; the economy; and health. o Increase in pluvial flooding, with impacts on: urban infrastructure: buildings (including built heritage), utilities and transport; businesses; the economy; and health. o Increase in flooding and erosion at the coast, with impacts on: coastal habitats; coastal settlements; coastal transport infrastructure; and agricultural land.
Buildings, Construction and Planning	o Increase in winter flooding, fluvial and pluvial, with impacts on: settlements; buildings and built heritage; transport infrastructure; water infrastructure (supply and drainage); the economy; health and comfort; urban green spaces; and construction. o Increase in summer temperatures and drought, with impacts on: buildings and settlements; infrastructure; green spaces and soil moisture; construction; urban heat island; and waste management. o Sea level rise leading to an increase in flooding and erosion at the coast, with impacts on: settlements and buildings; infrastructure (transport, water, communications, waste); and coastal urban green spaces.
Business	o Wetter winters leading to damage of stock and premises, supply chain problems, loss or reputation and insurance and investment issues. o Problems of exposure to outdoor workers in hotter summers. o Decline or shift in demand for certain seasonal goods.
Insurance	o Increase in inland and potentially coastal flooding under wetter winter and rise in sea level, leading to an increase in flood-related property claims and business continuity claims. o Increase in subsidence claims in hotter, drier summers.

Sub-Sector	Threat
Transport	o Wetter winters and inland flooding, leading to: infrastructure damage; problems for emergency services; delays to users; and road safety issues. o Wetter winters with increased flooding and scour, leading to destabilisation of bridge / embankment foundations. o Drier summers with drier soils and vegetation, leading to increased risk of fire and increased risk of subsidence (on clay soils). o Hotter summers with more extreme temperatures, leading to: increased discomfort / exposure for travellers; economic cost of infrastructure damage e.g. road rutting; and respiratory problems associated with deterioration in air quality.
Energy	o Heightened risk of subsidence and heave, leaving structures vulnerable to damage or collapse. o Greater demand for air conditioning in summer, altered demand profile and operational variations by power suppliers. Health implications for those without access to cool buildings. o Reduced soil moisture content and heightened risk of subsidence in vulnerable areas. o Greater levels of damage to power supply infrastructure (e.g. trees coming into contact with power lines).
Tourism	o Wetter winters will affect outdoor tourism activities. o Flooding due to wetter weather especially in coastal tourism resorts. o Increased risk from water shortages due to dry weather and increased demand. o Dry weather may be detrimental to natural environment which is a vital resource for tourism o Increased demand on tourism infrastructure. o Coastal flooding and erosion will degrade beaches. o Coastal squeeze will reduce beach size. o Damage to tourism infrastructure and sea side resorts. o Increased risk from storm surges. o Increase in storm intensity and frequency damage tourism facilities and property. o Increased storm intensity and frequency will affect coastal zones with an increased risk from storm surges and flooding.
Sport & Recreation	o Wetter winters will affect outdoor sport and recreation o Dry weather may be detrimental to local habitats and species which are vital for nature based recreation o Will reduce soil moisture which will affect pitches and sports grounds. o Increase in storm intensity and frequency may cause the cancellation of outdoor activities. o Damage to sporting and recreation facilities.
Health	o Coastal and riverine floods, contributing to physical and mental impacts o Hotter summers with increased “heatwave” events, leading to increase in: hospital admissions; respiratory problems; heat-related mortality and morbidity; and occupational heat stress. o Hotter summers (and milder winters) leading to increased bacterial growth, and activity of pests (flies, rodents). o Longer summers leading to increased exposure to UV- and its consequent health effects.

Table 17.2 - Climate Change Opportunities and Benefits for Northern Ireland

Sub-Sector	Opportunity or Benefit
Conservation, Biodiversity and Habitats	No opportunities or benefits overall, as opportunities (e.g. expansion of one species) and benefits (e.g. wetter winters for some habitats) tend to be offset by threats (e.g. loss of another species and drier summers respectively).
Fisheries	o Warmer waters providing benefits to aquaculture include higher growth rates and new species.
Agriculture	o Opportunities related to longer growing season and warmer summers e.g. new crops and products. o Benefits of reduced cold weather problems including frost damage and a decrease in time that animals need to be kept indoors.
Forestry	o Higher potential productivity resulting from increased warmth and higher CO_2 levels. o Changing climatic conditions will alter site suitability of tree species that are currently planted: much is known about the changes to the suitability of individual species, some of which will benefit. o Expansion of woodland, including riparian woodland, may be required to offset soil erosion and fluvial flooding, to provide shade for fish and amenity for leisure activities.
Water Resources	o Increased winter rainfall provides opportunity for water storage by Water Service and farmers. o Drier, hotter summers will increase demand for water efficient products.
Coastal & Flood Risk Management	No opportunities or benefits have been identified; however, there may be opportunities in related areas e.g. new habitat creation projects.
Buildings, Construction and Planning	o Increase in summer temperatures will bring opportunities for business.
Business	o Drier Summers – Boost to sales of seasonal goods, water retention products, drought tolerant plants o Driers Summers – Opportunity for business growth in outdoor activities and al-fresco retail o Hotter Summers – Boost in sales of seasonal goods o Hotter Summers – Increased demand for cooling products
Insurance	No opportunities or benefits identified for the sector overall, although there will be opportunities for new products and a reduction in certain claims (e.g. cold-weather related accidents).
Transport	o Greater demand for walking and cycling.
Energy	o Reduction in winter heating needs and winter fuel poverty.
Tourism	o Drier summers will allow increased tourism opportunities in the summer. o Increase in outdoor tourism activities. o Warmer winters will allow more year round tourism. o Hotter summers will encourage more international and domestic tourism. o More outdoor and water based activities due to hotter weather.
Sport & Recreation	o Drier, hotter summers will allow increased outdoor sport and recreation. o Increase in water based recreation and sports. o Warmer winter weather will allow more year round outdoor sport and recreation.
Health	o Reduction in cold weather-related mortality and morbidity (including reduced fuel poverty). o Potential improvement in public health related to increased opportunities for physical recreation.

17.5 Cross-Sectoral Analysis

This section describes key impacts that affect several sectors and impacts with knock-on consequences for other sectors and considers adaptation in this context. The main cross-sectoral impacts are associated with:

- An increase in flood risk, with implications for sectors including coastal and flood risk management; buildings, construction and planning; insurance; transport; and health.
- A significant reduction in summer rainfall (and potential reduction in annual rainfall), with consequences for conservation, biodiversity and habitats; fisheries; agriculture; forestry; and water resources.
- Warmer summers (with more extreme hot days), causing a mixture of threats and opportunities in different geographical settings.

There is currently uncertainty about the projections of sea level change and windstorms, both of which would have consequences across sectors.

An increase in flood risk can be expected due to wetter winters and more intense rainfall events. This has particular consequences for the Built Environment, Economic Infrastructure and Social Wellbeing, although the Natural Environment is not immune e.g. flooding of farmland. Urban areas are likely to be worse affected, either where they are located on floodplains or due to pluvial flooding – the local overwhelming of storm drains. Flooding has a direct effect on buildings, transport infrastructure and built heritage, and the health of those affected. It also can effect the continued provision of insurance, with knock-on implications for business and the wider economy. The planning and construction sectors, along with flood defence, have a lead role in managing flood risk. Adaptation to a change in flood risk will require a multi-sector approach. This may start with further, quantified, research to determine flood risk and then may involve modification of policies and standards as well as implementation of actions to physically flood risk, suitable to the specific local or catchment setting. In a large urban setting such as Belfast this may involve:

- A strategic flood risk assessment, including the impacts of climate change.
- Revision of floodplain protection and culverting policies to zone development and ensure adequate drainage capacity.
- Flood risk reduction measures including:
    - Catchment source control, involving the agricultural and conservation sectors.
    - Urban source control, involving the building, construction and transport sectors.
    - Increased drainage capacity, involving the construction and transport sectors.
    - Flood defences, involving the planning and flood defence sectors.
    - Flood proofing and individual property protection, involving the buildings, construction, business and insurance sectors.
    - Flood warning and emergency response, involving the flood defence, planning and health sectors.

A significant reduction in summer rainfall will have particular consequences for the Natural Environment sector, although public water supplies may also be affected. Impacts include species and habitat loss, increased fire risk, freshwater eutrophication, increased irrigation needs, oxidation of peatlands and increased susceptibility of trees to disease. These

impacts are highly inter-connected, not least because of the competition for water between habitats, species and human uses. Adaptive responses need to take the whole rural environment into account to ensure that actions to reduce impacts in one area do not affect another. Carefully planned actions may have multiple benefits e.g. winter storage reservoirs could be used to benefit agriculture as well as local habitat. In a rural catchment adaptation may involve:

- A strategic review of water availability and demand (human and natural) under climate change.
- Risk assessment to prioritise impacts associated with any change in the water balance.
- Supply-side measures including water transfer, increase catchment retention (e.g. groundwater replenishment, winter storage), change in irrigation technology and practice.
- Demand-side measures including change in habitat or land-use and water efficiency.

Warmer summers and more extreme hot weather will provide a mixture of opportunities and threats and these will require different responses, depending on the particular geographical setting. In urban areas, warmer weather provides the opportunity to adopt a more outdoor lifestyle, with benefits to tourism, sport and recreation, and health. However, these opportunities need to be realised e.g. through the provision of open space and themselves must be adapted to avoid negative impacts e.g. shade will be required to prevent heat-stroke and longer-term issues associated with skin cancer. Buildings and transport may also become more uncomfortable and may require adaptation, without adding to climate change (e.g. through air conditioning). In coastal areas, warmer summers are likely to benefit tourism and recreation, but this raises issues associated with transport infrastructure, business (e.g. provision of accommodation) and health (e.g. in relation to capacity of Coastguard and other emergency services). Sea level rise may also be an (long-term) issue in certain locations. Therefore, adaptation will need to involve several sectors, particularly to ensure that opportunities are realised in the most sustainable manner.

17.6 Impact on Public Services and Priority Themes

The impact on public services has been summarised within each chapter in the Impacts to Adaptation Summary. For each impact identified, the summary tables record the Public Sector Area involved, the effect on public services and the public bodies responsible for adaptation. These tend to be specific to the sector involved; however, for most impacts there is more than one area of the public sector involved and at least one responsible public body. This re-enforces the **need for a cross-sector and multi-agency approach to adaptation. Planning (and therefore the Planning Service) has a role in several sectors and will be particularly useful in development elements relating to building adaptive capacity.** Although the DOE was not often identified as the responsible body for adaptation, **there is a need for a department to continue a co-ordinating role and lead on raising awareness, monitoring and managing implementation; DOE is the most appropriate (and current) lead**, although strong links will be required with the OFMDFM, the lead office on Sustainable Development.

There are three overarching and interlinked themes associated with the Government's priorities and spending plans, set out in the Priorities and Budget 2005-2008. These are Economic Competitiveness; Equality and Community Cohesion; and Better Public Services. The Invitation to Tender identified a number of key outcomes with the potential

to be affected by climate change. An analysis of these outcomes, in terms of how climate change may help or hinder their achievement, is provided in Table 17.3. **In general climate change will make it more difficult to meet the outcomes**, but adaptation, or flexibility for later adaptation, which is built in at the planning stage will be more efficient than later retro-fitting. **There are also a number of benefits and opportunities presented by climate change** which will help achieve the outcomes if realised appropriately.

Table 17.3 - Impacts of Climate Change on Climate-Sensitive Outcomes related to Government Priority Themes

Theme	Climate-sensitive outcome[1]	Effect of climate change {further reading}
Economic Competitiveness	A modern infrastructure to support economic development.	Infrastructure directly affected by flooding and hot weather in particular; adaptation built in now / at routine upgrade will be more cost effective. {Sections 9, 10, 13, 14}
	Achievement of a competitive, sustainable and reliable energy market.	New infrastructure must take into account future climate. Seasonal and peak demand will be influenced by future climate. {Section 14}
	Higher productivity and engaging in higher value-added activities with emphasis on creativity, innovation and export.	Opportunities for innovation include development of renewables, new crops and food products, water efficient fixtures and fittings, traffic management systems and new financial products. Tourism could become a more significant earner. {Sections 6, 8, 13, 15}
	Developing the agri-food industry.	Threats associated with wetter winters and drier, hotter summers. Benefit of longer growing season; opportunities for new crops and food products. {Section 6}
Building Equality & Community Cohesion	Provision of affordable, energy efficient and fit housing.	Housing should be robust to future climate, including higher peak rainfall intensities and extreme hot weather, and a reduction in water availability. {Sections 8, 9, 10, 12}
Better Public Services	Achieving sustainable and long-term improvements in people's health.	Climate change may provide opportunities to improve health e.g. exercise in warmer conditions and there will be a reduction in cold weather mortality and morbidity. Hot weather impacts e.g. fatalities among the elderly will require adaptation. {Section 16}
	Enhancement of water, roads and transport infrastructure to improve quality of life and contribute to sustainable regional growth.	Infrastructure directly affected by flooding and hot weather in particular; adaptation built in now / at routine upgrade will be more cost effective. {Sections 9, 10, 13}
	To respond to increasing demand for water, and comply with water quality standards.	Demand from humans and the environment will increase, but supplies may reduce. Adaptation should include demand management and supply development. Lower summer flows are likely to reduce compliance; flow augmentation or more stringent discharge consents (and effluent treatment) will be required. {Section 8}

[1]This analysis considers only those climate sensitive outcomes identified in the original project specification.

A more wide ranging analysis could now be undertaken, as is recommended with respect to key targets in the Sustainable Development Strategy (see below).

17.7 Sustainable Development

In May 2006 the Northern Ireland Sustainable Development Strategy First Steps Towards Sustainability was published. Climate change and energy has been identified as one of the six priority areas for action and the third strategic action under this area is to plan and prepare for climate change impacts in Northern Ireland. Key targets are to:

- Prepare a Northern Ireland specific Climate Change Impacts report by February 2007 and update every five years.
- Develop and implement changes to Government policies and strategies to address adaptation issues.

This study will provide the initial element under the first target and will provide the evidence required to support the second target.

To achieve successful adaptation to climate change, it will be necessary to embed climate change adaptation in all sectors and across all priority areas for action within the Sustainable Development Strategy. There are two principal reasons for doing this:

1. Climate change adaptation cannot be considered in isolation – impacts will affect all aspects of the environment, economy and society. Climate change may therefore hinder or help the achievement of actions in the Strategy.
2. If climate change is not considered there is a danger that other actions, e.g. delivery of sustainable communities, may contribute to climate change or compromise adaptation.

Under the first point, climate change may support the aim to achieve a modal shift in terms of how staff may travel to work, as weather may be more favourable. In contrast climate change may make it harder to achieve compliance with water quality standards, due to lower summer flows**. It is therefore recommended that the key targets contained within the Sustainable Development Strategy are reviewed with regards to climate change, to ensure that appropriate resources are applied to meet their delivery**. Climate change will not occur in isolation to other socio-economic changes and it may be prudent to 'future-proof' the Strategy, rather than simply 'climate-proof'. For short-term targets future proofing may not be necessary, but evaluation of future changes will be necessary if the commitments contained in the targets are to be maintained in the long-term. For example, there is a risk that targets for sustainable construction are set in terms of the 'here and now', instead of the changing climate, imposing more cost in the longer term.

Under the second point, it is necessary to embed climate change thinking into the delivery of all actions. For example, in delivering targets to meet housing needs, adaptation should be incorporated in the planning and design of development. This should ensure that houses are not at risk from future flooding, that they provide suitable ventilation to cope with higher temperatures and that they are water efficient**. It is therefore important that awareness of climate change is raised and that adaptation strategies are available to ensure that all actions in the Sustainable Development Strategy assist, or at least not compromise, adaptation.** In this respect Sustainable Development can be a useful tool for promoting climate change adaptation.

By considering how climate change impacts affect the Sustainable Development Strategy and how delivery of the Strategy contributes to climate change, the Sustainable

Development Strategy can be climate proofed while at the same time it can facilitate adaptation.

17.8 Adaptation

The current approach to adaptation varies between sectors and between organisations within sectors. Some organisations are moving towards adaptation, at least in certain functions or with regards to particular strategies, but many are delaying, adopting a 'wait and see' approach. This latter approach often involves building adaptive capacity, through research and networking. **It is recommended that climate change is given a higher priority across all sectors and within each of the public bodies identified as being responsible for adaptation.** This is particularly important in relation to Social Wellbeing and Economic Infrastructure sectors (especially health, sport & recreation, tourism, business and energy), where action is particularly limited at present. This report and the Sustainable Development Strategy should provide impetus and facilitate a shift in approach.

Adaptation strategies have been developed for each of the impacts identified in the study and **it is recommended that these strategies are now taken forward**. Immediate priority should be given the most significant impacts; a guide to the timescale for adaptation is provided in Figure 19.5 (see Appendix A). Therefore, **it is recommended that adaptive actions are started immediately with respect to those impacts identified as a major threat or major opportunity. It will also be necessary to re-evaluate impacts where the risk has been classified as unknown, especially where this may lead to a major threat (or opportunity)**. This will involve review of ongoing research and development of a better understanding of the sensitivity of receptors. In the medium-term, this process of building adaptive capacity will be required for other (minor) unknown risks, while adaptive actions will be needed in relation to minor opportunities and threats and with respect to major benefits (where cost savings could be realised for example). In the long-term actions should be undertaken to adapt to maximise minor benefits and to rectify lost opportunities. The prioritisation of adaptive responses is based on the current classification of risks and these risks should be reviewed periodically to check that contemporary activity relating to them remains appropriate.

A number of general themes for climate change adaptation are apparent from across the sector- and impact-specific adaptation strategies. These can be grouped under the two main elements of the UK's Adaptation Policy Framework.

Building adaptive capacity:

- Raising awareness.
- Increase training and knowledge.
- Contribute to the development and use of climate change scenarios for Northern Ireland, to include comparison of EPA and UKCIP output.
- Development of socio-economic scenarios for Northern Ireland for use alongside climate change scenarios in detailed impact assessments.
- Review of legislation, regulations, policies and procedures with respect to protection from climate change and provision of incentives for adaptation.
- Contingency / emergency planning.

Delivering adaptive actions:

- Increase resilience e.g. diversification; buffer zones.
- Accept losses where feasible e.g. coastal realignment.
- Avoid losses e.g. by altering building materials.
- Embrace change e.g. new species and maximising opportunities provided.
- Exploiting opportunities provided by mitigation (e.g. woodland / forestry management).
- Planning for risks and opportunities in new infrastructure projects (water, sewerage, flood risk, transport, construction etc).

- Improve monitoring and records of extreme weather events.
- Incorporate climate change into existing models.
- Include climate impacts and adaptation in strategies and plans, with scheme specific risk assessments.
- Consideration of cross-sector implications of responses: threats and opportunities.
- Changes to management and maintenance practices to accommodate changes in climate.
- In building design / construction: managing heat gain; energy, water and environmental efficiencies.
- Enhanced health surveillance and heat-wave response.

In many cases there are opportunities for no or low-regret solutions, particularly in relation to improving the ability to cope with current weather-related impacts. There are also win-win opportunities to adapt to several impacts with one action e.g. planting of floodplain and riparian woodland to alleviate flooding, provide shade and maintain lower water temperatures, while increasing Northern Ireland's tree coverage.

Constraints to adaptation include uncertainty about future climate conditions and a lack of funding and human resources. The future is inherently uncertain **and decision-making will need to incorporate uncertainty in climate change and socio-economic scenarios**, drawing on appropriate techniques (e.g. risk-based approaches) and new research (which may quantify or reduce uncertainty). **Flexibility and the implementation of no- and low-regret solutions will help** avoid unnecessary adaptation. A rise in the profile of climate change adaptation will need to be accompanied by **appropriate resources to undertake detailed impact assessments and implement adaptation**. In the short-term this may require funding for capacity building (e.g. research, staff training), while in the medium to long term funding may be required to deliver adaptive actions. Despite the uncertainties, planning for climate change now is likely to yield benefits in the future, by reducing the need for expensive re-active solutions.

18 REFERENCES

ABI. 2002a. London Assembly Flooding Scrutiny. London, Association of British Insurers (cited by LCCP, 2002).

ABI. 2002b. ABI Statement of Principals on the Provision of Flooding Insurance. ABI, London.

ABI. 2003. The vulnerability of UK property to windstorm damage. BRE report for ABI, London.

ABI. 2004a. A Changing Climate for Insurance. A Summary Report for Chief Executives and Policymakers. ABI, London.

ABI. 2004b. Submission to EFRA Select Committee Enquiry on Climate change, water security and flooding, October.

ABI. 2005a. Financial Risks of Climate Change. Summary Report. ABI, London.

ABI. 2005b. Revisiting the Partnership: Five Years On From Autumn 2000. ABI, London.

ABI. 2005c. Revisiting the Partnership: Five Years on from Autumn 2000. ABI, London.

Advisory Committee on Business and the Environment (ACBE). 2001. Climate change adaptation: ACBE recommendations to government. ACBE, London.

Advisory Committee on Business and the Environment (ACBE). Undated a. Have you considered how a change in the UK climate will impact your business? Commentary on UKCIP02 scenarios. ACBE, London.

Advisory Committee on Business and the Environment (ACBE). Undated b. Sector specific risk and opportunities from predicted changes to UK climate. ACBE, London.

AEA Technology. 2003. Railway Safety Implications of Weather, Climate and Climate Change: Final Report. Rail Safety and Standards Board, London. www.rssb.co.uk/pdf/reports/research/safety%20implications%20of%20weather,%20climate%20and%20climate%20change.pdf

AEAT. 2005. Objective Setting for Climate Change Adaptation Policy. Report by AEA Technology Environment, Stockholm Environment Institute and Metroeconomica for Defra. December 2005.

Ahern, M.J., Kovats, R.S., Wilkinson, P., Few, R. and Matthies, F. 2005. Global Health impacts of floods: epidemiological evidence, Epidemiological Reviews, 27, 36-46.

Albering, H.J., van Leusen, S.M., Hoogewerff, J.A. and Kleinjans, J.C.S. 1999. Human health risk assessment: a case study involving heavy metal soil contamination after the flooding of the river Meuse during the winter of 1993-1994, Environmental Health Perspectives, 107, 37-43.

Amelung B. and Viner D. 2006. The sustainability of tourism in the Mediterranean: Exploring the future with the Tourism Comfort Index, Journal of Sustainable Tourism, Vol 14 Nos. 4.

Anderson, R. & Bealey, C. E. (2003) Ground beetle assemblages within the ECN network and climate change. British Ecological Society Annual Meeting, Manchester, September 2003.

Anderson, R. (2005) Warm enough for aliens. Horticulturist 14: 2-5.

Arkell, B. and Darch, G. 2005. Climate change and London's transport systems. Technical Report for the Greater London Authority and London Climate Change Partnership.

Arkell, B., Darch, G., Wilson, E. and Piper, J. 2004. South East Threats and Opportunities Research Study (SECTORS). Technical Report for the South East England Development Agency, Guildford.

Arnell, N.W. 2003. Effects of climate change on river flows and groundwater recharge: UKCIP02 scenarios. Report 03/CL/04/2. UK Water Industry Research, London.

ASCCUE (Adaptation Strategies for Climate Change in the Urban Environment) report to EPSRC (in preparation).

Atkins. 2004. ICZM in the UK: A Stocktake. Final Report for Defra, March 2004. HMSO, Norwich. www.defra.gov.uk/environment/water/marine/uk/iczm/stocktake/index

Atkins. 2005. Climate change and London's transport systems. Report for the Mayor of London. London Climate Change Partnership.

Baxter, P.J., Lee, B.E., Wyatt, T.A., and Spence, R.J. 2002. Windstorms and climate change, in Health effects of climate change, Department of Health.

Berkhout, F., Hertin, J. and Arnell, N. 2004. Business and Climate Change: Measuring and Enhancing Adaptive Capacity. The ADAPT project, Final Report. Tyndall Centre for Climate Change Research, Technical Report No. 11.

Bernard, S. M., and K. L. Ebi, 2001, Comments on the process and product of the health impacts assessment componant of the National Assessment of the Potential Consequences of Climate Variability and Change for the United States: Environmental Health Perspectives, v. 109, no. Supplement 2, p. 177-184.

Berry, P.M., Masters, G.J., Hossell, J.E., Butt, N., Freeman, S., Harrison, P.A. and Ward, N. 2005. Climate change and nature conservation in Britain and Ireland. Modelling Natural Resource Responses to Climate Change - Monarch 2 Report.

Bisgrove, R. and Hadley, P. 2002. Gardening in the Global Greenhouse: The Impacts of Climate Change on Gardens in the UK. Technical Report. UKCIP, Oxford. www.ukcip.org.uk

BKCC (2005) BKCC (Building knowledge for a changing climate) Update 2005, www.ukcip.org

Boyd, S.W 2000. Heritage tourism in Northern Ireland – Opportunities under peace, Current Issues in Tourism, 3(2), 150-174.

Brauner, C. 2002. Opportunities and risks of climate change. Swiss Reinsurance Company, Zurich.

BRE (Building Research Establishment) (in preparation) Study of green roofs.

Budeanu, A. 2005. Impacts and responsibilities for sustainable tourism: a tour operator's perspective, Journal of Cleaner Production, 13, 89-97.

Cassar M et al. 2005. Climate change and the historic environment. UCL Centre for Sustainable Heritage, London.

CEH (Centre for Ecology and Hydrology), British Trust for Ornithology and Oxford Brookes University (in preparation) England Biodiversity Review - towards adaptation for climate change. Report for Defra.

CII. 2001. Climate change and insurance. Research report. The Chartered Insurance Institute, London.

CIRIA. 2005. Climate change risks in building - an introduction. Technical Report (C638) prepared by S Vivian, N Williams and W Rogers. CIRIA, London.

Conrad, K. F. et al. (2002) Long-term decline in abundance and distribution of the garden tiger moth (Arctia caja) in Great Britain. Biological Conservation 106: 329-337.

Crichton, D. 2003. Flood risk and insurance in England and Wales: are there lessons to be learned from Scotland? Benfield Greig Hazard Research Centre, Technical Papers 1. UCL, London.

Crozier, W.W. and Kennedy, G.J.A. (2003). Freshwater influences on marine survival of Atlantic salmon (Salmo salar L.): Evidence from the River Bush, Northern Ireland. Pp. 124-126. In: Potter, E. C. E., Ó Maoiléidigh, N. and Chaput, G. (Eds.) 2003. Marine mortality of Atlantic salmon, Salmo salar L: Methods and measures. Proceedings of a SALMODEL Workshop, Moncton, Canada, 10-12 August 2001. Department of Fisheries and Oceans, Canada, Res. Doc. 2003/101.

Cugnoni, H. L., and I. Whitworth, 2002, Injuries related to wind speed: Ann R Coll Surg Engl., v. 74, no. 4, p. 294-296.

Cunjak, R; Caissie, D; El-Jabi, N; Hardie, P; Conlon, J; Pollock, T; Giberson, D; Komadia-Douthwright, S. 1993. The Catamarran Brook (NB) habitat research project: biological, physical and chemical conditions (1990-1992). Can Tech. Rep. Of Fish. And Aq. Sciences 118 pp 43-51.

CURE & Tyndall Centre (2003). Spatial Implications of Climate Change for the North West. Main Report, Consultation Draft.

Defra. 2005. Adaptation Policy Framework. A consultation by the Department for Environment, Food and Rural Affairs. October 2005. Defra, London.

Department of Health. 2002. Health Effects of Climate Change in the UK. Department of Health, London.

Department of Health. 2005. Heatwave: Plan for England - protecting health and reducing harm from extreme heat and heatwaves. Department of Health, London.

Dessai, S. R. 2003. Heat stress mortality in Lisbon. Part II: An assessment of the impacts of climate change, International Journal of Biometeorology, 48, 1, 37-44.

Devine, A., Devine, F (2004) The politics of sports tourism in Northern Ireland Journal of sport tourism 9(2): 171-182

DfT. 2004a. The Impacts of Climate Change – Report back from Roads Workshop 22/11/04. Department for Transport, London.

DfT. 2004b. The Impacts of Climate Change – Report back from Rail Workshop 26/11/04. Department for Transport, London.

Downing, T.E., Butterfield, R.E., Edmonds, B., Knox, J.W., Moss, S., Piper, B.S. and Weatherhead, E.K. (and the CCDeW project team). 2003. Climate Change and Demand for Water. Research Report. Stockholm Environment Institute Oxford Office, Oxford.

DRDNI (Department of Regional Development NI) (2001)Shaping the future: the Regional Development Strategy for Northern Ireland 2025, DRDNI.

DRDNI, 2001. Shaping our Future. Regional Development Strategy for Northern Ireland 2025. Department for Regional Development, Belfast.

D'Souza, R. M., Becker, N., Hall, G. and Moodie, K. B. 2004. Does ambient temperature affect foodborne disease? Epidemiology, 15, 1, 86-92.

EA. 2004. Our Nations Fisheries. Environment Agency of England and Wales.

EA. 2005. Effect of climate change on salmon fisheries. Science Report. Environment Agency of England and Wales.

EHS. 2002. Northern Ireland Biodiversity Strategy.

EHS. 2004. Climate Change Indicators for Northern Ireland. Environment and Heritage Service, Belfast.

EHS. 2005a. Guidance for Public Bodies on Climate Change Impacts in Northern Ireland. Environment and Heritage Service, Belfast. www.ehsni.gov.uk/pubs/publications/guidanceweb.pdf

EHS. 2005b. All Ireland Species Action Plan for Pollan Coregonus autumnalis. Draft for consultation, Feb 2005. www.ehsni.gov.uk/pubs/publications/Pollan.pdf

EHS. 2005c. Public Service Areas. Air – Climate Change.

EHS. 2005d. Northern Ireland Habitat and Species Action Plans www.ehsni.gov.uk/natural/biodiversity/hap_uk.shtml

Ellis, F.P., Prince, H.P., Lovatt, G. and Whittington, R.M. 1980. Mortality and morbidity in Birmingham during the 1976 heatwave, Q J Med, 49, 193, 1-8

Elwood, J; Waters, T. 1969. Effects of flood on food consumption and production rates of a stream brook trout population. Trans. Of the Amer. Fish. Soc. 98 pp 253-263.

Entec et al. 2003. The Potential Impacts of Climate Change in the West Midlands. Entec, for Sustainability West Midlands, Birmingham.

Entec. 2003. Potential Impacts of Climate Change on Waste Management. R&D Project X1-042. Environment Agency, Bristol.

EPSRC and UKCIP. 2005. Building knowledge for a changing climate: the impacts of climate change on the built environment. Mid-project update. UKCIP, Oxford.

ERM. 2000. Potential UK adaptation strategies for climate change. Technical report. DETR, London.

Euripidou, E., and Murray, V. 2004, Public health impacts of floods and chemical contamination, Journal of Public Health, 26, 4, 376-383.

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A. 2004a. Foresight. Future Flooding. Scientific Summary: Volume I Future risks and their drivers. Office of Science and Technology, London.

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Sayers, P., Thorne, C. and Watkinson, A. 2004b. Foresight. Future Flooding. Scientific Summary: Volume II Managing future risks. Office of Science and Technology, London.

Garvin, S., Phillipson, M., Sanders, C., Hayles, C. and Dow, G. 1998. Impact of climate change on building, Building Research Establishment, Scottish Laboratory.

Gill, S. 2004. Literature Review: Impacts of climate change on urban environments (draft report for ASCCUE project) Manchester: University of Manchester (CURE) see www.manchester.ac.uk/planning/cure (accessed 10 01 06).

Ginexi, E. M., Weihs, K., Simmens, S.J. and Hoyt, D.R. 2000. Natural disaster and depression: a prospective investigation of reactions to the 1993 midwest floods, Am J Community Psychol, 28, 4, 495-518.

Glaberman S, Moore JE, Lowery CL, Chalmers R et al. (2002) Three drinking water associated cryptosporidiosis outbreaks, Northern Ireland. Emerging Infectious Diseases, 8(6): 631633.

Gooroochurn, N. and Hanley, A. 2005. Spillover effects in long-haul visitors between two regions Regional Studies, 39, 6, 727-738.

Goulson,D, Derwent, L.C., Hanley, M., Dunn, D.W. and Abolins, S.R. 2005. Predicting calyptrate fly populations from the weather, and the likely consequences of climate change. Univ of Sussex.

Graves H. and Phillipson M. 2000. Potential implications of climate change in the built environment. BRE Report 2, BRE.

Greer, J. 2001. Developing trans-jurisdictional tourism partnerships – Insights from the island of Ireland, Tourism Management, 23, 12, 355-366.

Guest, C., Willson, K., Woodward, A., Hennessy, K., Kalkstein, L. S., Skinner, C. and McMichael, A.J. 1999. Climate and mortality in Australia: retrospective study, 1970-1990, and predicted impacts in five major cities, Climate Research, 13, 1-15.

Hacker, J. and Holmes, M. 2005 Climate change and the indoor environment: impacts and adaptation. CIBSE and RIBA, London.

Hacker, J.N., Belcher, S.E. and Connell, R.K. 2005. Beating the Heat: keeping UK buildings cool in a warming climate. UKCIP Briefing Report. UKCIP, Oxford.

Hajat, S., Ebi, K.L., Kovats, R.S., Menne, B., Edwards, S. and Haines, A. 2003. The human health consequences of flooding in Europe and the implications for public health: a review of the evidence, Applied Environmental Science and Public Health, 1, 1, 13-21.

Hanson, C.E., Holt, T. and Palutikof, J.P. 2004. An Integrated Assessment of the Potential for Change in Storm Activity over Europe: Implications for Insurance and Forestry in the UK. Technical Report 12. Tyndall Centre for Climate Change Research, University of East Anglia, Norwich.

Harrison, P.A., Berry, P.M. and Dawson, T.E. (Eds). 2001. Climate change and Nature Conservation in Britain and Ireland: Modelling natural resource responses to climate change (the MONARCH project). UKCIP Technical Report, Oxford.

HPA. 2005. Health protection in the 21st century. HPA, London.

Hendry, K. and Cragg-Hine, D. 2003. Ecology of the Atlantic Salmon. Conserving Natura 2000 Rivers Ecology Series No. 7. English Nature, Peterborough.

HoC. 2004. Climate Change, Water Security and Flooding. House of Commons Environment, Flood and Rural Affairs Committee. Sixteenth Report of Session 2003-2004.

Holman I.P., Loveland, P.J., Nicholls, R.J., Shackley, S., Berry, P.M., Rounsevell, M.D.A., Audsley, E., Harrison, P.A. and Wood, R.. 2002. REGIS - Regional Climate Change Impact Response Studies in East Anglia and North West England. Summary Report. Defra, London.

HRW and Atkins. 2002. UK Climate Impacts Programme 2002 Climate Change Scenarios: Implementation for Flood and Coastal Defence: Guidance for Users. R&D Technical Report W5B-029/TR. Environment Agency, Bristol.

Hulme, M. and Jenkins, G. 1998. Climate Change Scenarios for the UK: Scientific Report. UKCIP Technical Report No. 1. Climatic Research Unit, UEA, Norwich.

Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R. and Hill, S.. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich. www.ukcip.org.uk/resources/publications/pub_dets.asp?ID=14

Hutchinson, W.G., Scarpa, R., Chilton, S.M., McCallion, T. (2001) Parametric and non-parametric estimates of willingness to pay for forest recreation in Northern Ireland: A discrete choice contingent valuation study with follow-ups, Journal of agricultural economics, 52, 1, 104-122.

IPCC. 2000. Special Report on Emission Scenarios. Summary for Policymakers. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change.

IPCC. 2001. Summary for Policymakers. A Report of Working Group I of the Intergovernmental Panel on Climate Change. www.ipcc.ch/pub/spm22-01.pdf

Johnson, H., Kovats, R.S., McGregor, G.R., Stedman, J.R., Gibbs, M., Walton, H., Cook, L. and Black, E. 2005, The impact of the 2003 heatwave on mortality and hospital admissions in England, Health Statistics Quarterly, 25, 6-11.

Kalkstein, L.S. and Greene, J.S. 1997. An evaluation of climate/mortality relationships in large US cities and the possible impacts of climate change, Environmental Health Perspectives, 105, 1, 84-93.

Kerr, A. and McLeod, A. 2001. Potential Adaptation Strategies for Climate Change in Scotland. Scottish Executive Central Research Unit, Edinburgh.

Kilbourne, E.M., Choi, K., Jones, T.S. and Thacker, S.B. 1982. Risk factors for heatstroke. A case-control study, JAMA, 247, 3332-3336.

Kovats, R. S. et al., 2005. Climate variability and Campylobacter infection: an international study, Int J Biometeorol., 49, 4, 207-214.

Kovats RS and Ebi KL 2006. Heatwaves and public health in Europe, European Journal of Public Health, in press.

Kovats, R.S., and West, C. 2005. Heat waves: health impacts and acute responses, Chemical Hazards and Poisons Report, May, 20-22.

Kovats, R.S., Edwards, S. Hajat, S., Armstrong, B., Ebi, K.L. and Menne, B. 2004. The effect of temperature on food poisoning: time series analysis in 10 European countries, Epidemiology and Infection, 132, 3, 443-453.

Kovats,RS, Johnson, H, and Griffiths, C. 2006 Mortality in southern England during the 2003 heatwave by place of death, Health Statistics Quarterly, in press.

Laffoley, D.d'A and others. 2005. The MarClim Project. Key messages for decision makers and policy advisors and recommendations for future administrative arrangements and management measures. English Nature Research Report, No. 671.

LCCP (London Climate Change Partnership) 2002. London's Warming, Technical Report, LCCP.

LUC. 2005. Countryside and the Rural Economy. Climate Change Impacts and Adaptation: Cross Regional Research Programme Project D. Draft Final Report, September 2005. Prepared for Defra by Land Use Consultants, University of Edinburgh and CAG Consultants.

Lye, M., and Kamal, A. 1977. Effects of a heatwave on mortality-rates in elderly inpatients: Lancet, 1, 529-531.

Maitland, P.S. 2004. Evaluating the ecological and conservation status of freshwater fish communities in the United Kingdom. Scottish Natural Heritage Commissioned Report No. 001 (ROAME No. F01AC6).

Maitland, P.S. and Hatton-Ellis, T.W. 2003. Ecology of the Allis and Twaite Shad. Conserving Natura 2000 Rivers Ecology Series No. 3. English Nature, Peterborough.

Mather S. and Viner D. 2005 Climate and Policy Changes: Their Implications for International Tourism Flows. In: Tourism, Recreation and Climate Change, Eds Hall M. and Higham J. Publ. Channel View Publications 309pp.

McEvoy, D., Handley, J.F., Cavan, G., Aylen, J., Lindley, S., McMorrow, J. and Glynn, S. 2006. Climate Change and the Visitor Economy: the challenges and opportunities for England's Northwest. Sustainability Northwest, Manchester and UKCIP, Oxford.

McGrath, R., Nishimura, E., Nolan, P., Semmler, T., Sweeney, C. and Wang, S. 2005. Climate Change: Regional Climate Model Predictions for Ireland. Report 2001-CD-C4-M2. Prepared for the Environmental Protection Agency by Community Climate Change Consortium for Ireland. EPA, Wexford.

McMichael, A. J. et al. 2004, Climate change, in M Ezzati, AD Lopez, A Rodgers, and CJ Murray eds., Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors. Vol.2: Geneva, World Health Organization, p. 1543-1649.

McMichael, A.J., Campbell-Lendrum, D., Corvalan, C., Githeko, A.K., Ebi, K.L., Scheraga, J.S. and Woodward, A. (eds) 2003. Climate change and health: Risks and Responses. WHO, Geneva.

Met Office. 2003. Climate change: Observations and predictions. Recent research on climate change science from the Hadley Centre. December 2003. Met Office, Exeter.

Met Office. 2006 A Scoping Study on the examination of climate change on the UK Energy Industry May 2006. Met Office, Exeter.

Metcalf, G. and Jenkinson, K. (eds) 2005. A changing climate for business: business planning for the impacts of climate change. UKCIP, Oxford.

Meusel, D., and Kirch, W. 2005. Lessons to be learned from the 2002 floods in Dresden, Germany, in W Kirch, B Menne, and R Bertollini eds., Extreme weather events and Public Health Responses: Springer-Verlag, p. 175-184.

Meusel, D., Menne, B., Kirch, W. Bertollini, R. and Bratislava Collaborating Group, 2004, Public health response to extreme weather and climate events: a brief summary of the WHO meeting on this topic in Bratislava on 9-10 February 2004: Journal of Public Health.
Moss. 1988. Ecology of Freshwaters. Man & Medium.

National Trust. 2005. Forecast? - Changeable! Some examples of climate change impacts around the National Trust. National Trust, Swindon.

Naughton, M.P., Henderson, A., Mirabelli, M., Kaiser, R., Wilhelm, J.L., Kieszak, S.M., Rubin, C.H. and McGeehin, M.A. 2002. Heat related mortality during a 1999 heatwave in Chicago, Am.J.Prev.Med., 22, 4, 221-227.

NERC. 2006. Rapid Climate Change Science Plan. www.noc.soton.ac.uk/rapid/sci/Scienceplan.php

NICEM. 1998. Inequalities in Health Report. Belfast.

Northern Ireland Ageing Population Panel 2001 http://www.ageconcernni.org/

Northern Ireland Office (2005) www.nio.gov.uk Statistics and Research. 29th December 2005.

Northern Ireland Sports Council, 2005. www.sportni.net/facts/ff_nisffs.htm Northern Ireland Sports - The figures. 29th December 2005.

Northern Ireland Statistics and Research Agency (NISRA). 1997.

Northern Ireland Tourist Board (2005) www.nitb.com/research.aspx?ID=15250 Intelligence. 29th December 2005.

O'Hagan, A.M. 2003. Characterisation Report for Northern Ireland: The Character of the Coast. Unpublished report for Atkins to support ICZM Stocktake for Defra.

Ohl, C.A., and Tapsell, S. 2000. Flooding and Human Health, British Medical Journal, 321, 11, Nov, 1167-1168.

ODPM. 2003. Housing health & safety rating system. Office of the Deputy Prime Minister, London.

Orford, J., Murdy, J. and Friel, R. 2003. 20th Century sea level changes around the North of Ireland. Research Contract GPA 308-CON 466. Environment and Heritage Service and Queens University Belfast.

OST. 1999. Environmental Futures. Office of Science and Technology, Department of Trade and Industry, London.

OST. 2002. Foresight Futures 2020: Revised scenarios and guidance. Office of Science and Technology, Department of Trade and Industry, London.

Palutikof, J., Subak, S., and Agenew, M. (eds.) 1997. Economic impacts of the hot summer and unusually warm year of 1995. CRU, Norwich.

Pattenden, S., Nikiforov, B. and Armstrong, B. 2003. Mortality and temperature in Sofia and London, Journal of Epidemiology and Community Health, 57, 628-633.

Piper, J.M.; Wilson, E.B.; Weston, J.; Thompson, S. and Glasson, J. 2006. Spatial planning for biodiversity under our changing climate. English Nature Research Reports no. 677. English Nature, Peterborough.

Reacher, M. et al., 2004, Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other illness and mental health in flooded and non flooded households, Communicable Disease and Public Health, 7, 1, 1-8.

Reynard, N.S. 2003. Impact of climate change on flood flows in river catchments - interim report. R&D Technical Report W5-032/TR. Environment Agency, Bristol.

Risk Solutions. 2005. Climate Change and Adaptation: Business Impacts and Adaptation. A report for Defra, November 2005.

Rivers Agency and RPS Consulting Engineers, June 2006. Flood Management Policy Review – Consultation Document.

RSPB. 2004. The State of the UK's Birds 2004.

Samuels, P., Woods-Ballard, B., Hutchings, C., Felgate, J., Mobbs, P., Elliott, C. Brook, D. 2005. Sustainable water management in land-use planning Report for CIRIA C 630, London: CIRIA.

Semenza, J.C., Rubin, C.H., Falter, K.H., Selanikio, J.D., Flanders, W.D., Howe, H.L. and Wilhelm, J.L. 1996. Heat-related deaths during the July 1995 heat wave in Chicago, N.Engl.J Med, 335, 2, 84-90.

Shackley S. et al (1998) Everybody has an impact – Climate change impacts in the North West Region, UKCIP.

Shackley, S., Wood, R., Hornung, M., Hulme, M., Handley, J., Davies, E. and Walsh, M. 1998. Changing by degrees - the impacts of climate change in the north west of England. Technical overview. UKCIP, Oxford.

Shennan, I. 1989. Holocene crustal movements and sea-level changes in Great Britain. Journal of Quaternary Science, 4, 77-89.

Shennan, I. and Horton, B. 2002. Holocene land- and sea-level changes in Great Britain. Journal of Quaternary Science, 17, 511-526.

Smoyer, K. E., 1998a, A comparative analysis of heat waves and associated mortality in St Louis, Missouri - 1980 and 1995, Int J Biometeorol., 42, 44-50.

Smoyer, K. E., 1998b, Putting risk in its place: methodological considerations for investigating extreme event health risks, Soc.Sci.Med., 47, 1809-1824.

Smyth A. et al. 2002 Impacts of climate change for Northern Ireland: informing strategy development, SNIFFER.

Sneesby R. 2001. Conference proceedings: Building Design and Construction Cheltenham Climate Change forum www2.glos.ac.uk/cccf/report/workshop/building.htm
SNIFFER. 2002. Implications of Climate Change for Northern Ireland: Informing Strategy Development. Stationery Office, Belfast.

Solomon, D & Sambrook, H. 2004 Effects of hot, dry summers on the loss of Atlantic salmon to estuaries in South West England. Fish. Man. and Ecology 11 pp 353-363.

Stokes, K. O'Neill, K. & McDonald, R. (2006) Invasive species in Ireland. Draft MS prepared for Environment & Heritage Service, NI and National Parks & Wildlife Service, RoI. Quercus, Queen's University. Pages 1-152.

Svenssen, M.K. and Eliasson, I. 2002. Diurnal air temperatures in built-up areas in relation to urban planning Landscape and Urban Planning, 61, 37-54.

Swansburg, E; Chaput, G; Moore, D; Caissie, D; El-Jabi, N. 2002. Size variability of juvenile Atlantic salmon: links to environmental conditions. J. of Fish Biol. 61 pp 661-683

Sweeney, J., Brereton, T., Byrne, C., Charlton, R., Emblow, C., Fealy, R., Holden, N., Jones, M., Donnelly, A., Moore, S., Purser, P., Byrne, K., Farrell, E., Mayes, E., Minchin, D., Wilson, J. and Wilson, J. 2003. Climate Change Scenarios and Impacts for Ireland. Report 2000-LS-5.2.1-M1. Prepared for the Environmental Protection Agency by Department of Geography, National University of Ireland, Maynooth. EPA, Wexford.

Thornes, J.E. 1997. Transport. In: Palutikof, J.P. et al. (Eds.) Economic Impacts of the Hot Summer and Unusually Warm Year of 1995. Department of the Environment, London.

Tirado, C. 2005. WHO Surveillance Programme for control of Foodborne Diseases in Europe: Trends on foodborne diseases during the last 25 years. Copenhagen, WHO.

TRL. 2001. Climate change and the Highways Agency. Unpublished report.

UKCIP. 2001. Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme. UKCIP, Oxford.

UKWIR. 2002. Effect of climate change on river flows and groundwater recharge, UKWIR.

UKWIR. 2004. Climate Change and the Hydraulic Design of Sewerage Systems: Summary Report. Report 03/CL/10/0. UK Water Industry Research, London.

Viner D. 2006. Tourism and its Interactions with Climate Change, Journal of Sustainable Tourism, Vol 14, Nos. 4.

Viner D., Sayer M., Uyarra M., and Hodgson N. 2006. Climate Change and the European Countryside: Impacts on Land Management and Response Strategies. Report Prepared for the Country Land and Business Association., UK. Publ., CLA, UK 180 pages.

Vivian, S. Williams, N. and Roberts, W. 2005. Climate change risks in building – an introduction, Report for CIRIA, C638, London: CIRIA.

Wade, T.J., Sandu, S.K., Levy, D., Lee, S., LeChevallier, M.W., Katz, L. and Colford, J.M. 2004. Did a severe flood in the midwest cause an increase in the incidence of gastro-intestingal symptoms?: Am.J Epidemiol., 159, 4, 398-405.

West, C.C. and Gawith, M.J. (eds.) 2005. Measuring progress: Preparing for climate change through the UK Climate Impacts Programme. UKCIP Technical Report. UKCIP, Oxford.

WHO and EEA. 2004. Report of the meeting "Extreme weather and climate events and public health responses" Bratislava, Slovakia, 9-10 February 2004. World Health Organization, Copenhagen.

Wilby, R. 2003. Past and projected trends in London's urban heat island, Weather, 58, 251-260.

Willows, R.I. and Connell, R.K. (Eds.) 2003. Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.

Wilson, L.A. 2004. Visitor attractions in Northern Ireland: The relationship between visitor number performance and ownership type 1990-2002, Current Issues in Tourism, 7, 2, 146-180.

Wilson, M.I. and Burtwell, M.H. 2002. Prioritising Future Construction Research and Adapting to Climate Change: Infrastructure (Transport and Utilities). TRL Project Report PR/IS/13/02. Construction Research Innovation Strategy Panel (CRISP), London.

Wooller, S. 2004. The Changing Climate: Impact on the Department for Transport. Report of the In-House Policy Consultancy, Department for Transport. DfT, London. www.dft.gov.uk/stellent/groups/dft_science/documents/page/dft_science_027568.hcsp

WS Atkins. 2002. Warming up the region: The impacts of climate change in the Yorkshire and Humber Region. WS Atkins report no: AK2970.068.dg.013, Epsom.

19 APPENDICES

Appendix A Detailed Methodology

Stages of Study

The study was split into six consecutive sector-specific tasks:

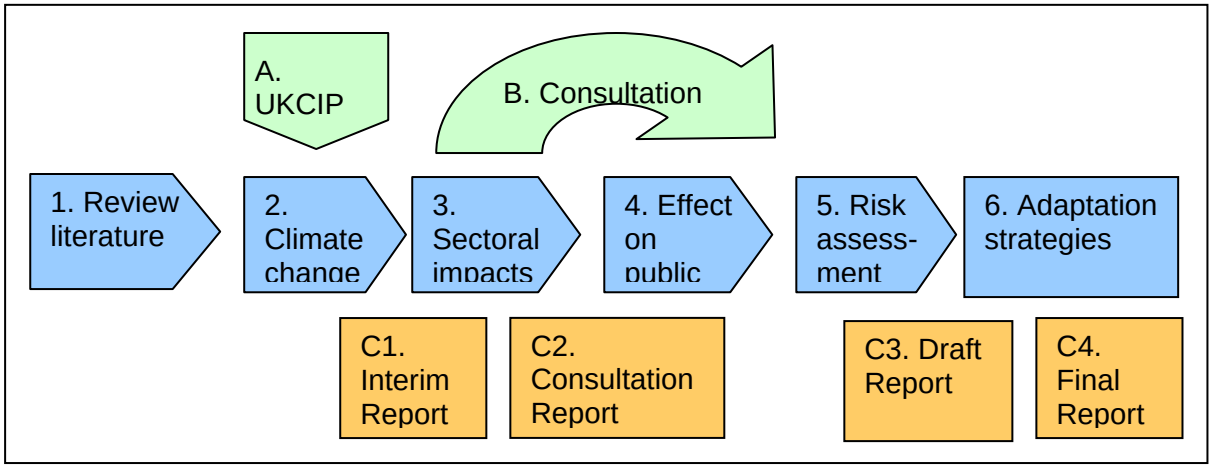
1. Review literature.
2. Examine climate change scenarios.
3. Describe impacts.
4. Assess effect on public services.
5. Undertake risk assessment.
6. Produce adaptation strategies.

Concurrent with these, there were three cross-cutting tasks:

A. Description of climate change.
B. Consultation.
C. Reporting.

The project programme is illustrated in the flow chart below:

Figure 19.1 - Task Flow Chart



The main elements of the methodology are described in detail in the following sections.

Review of Literature and Scenarios

Literature

The first stage of the project provided a review of relevant literature; in particular drawing on current climate change research in Northern Ireland (e.g. SNIFFER, 2002; EHS, 2004; EHS, 2005), as well as research specific to sectors. The literature review provided the background to each sector and assisted in the identification of current weather-related issues, impacts of climate change and current or proposed responses.

Climate Change Scenarios

This study principally draws on the UKCIP02 climate change scenarios (Hulme et al., 2002). An overview of the main changes in climate for Northern Ireland is presented, along with a review of recent climate and weather-related events. The scenarios have been used in the process of identifying impacts for each sector.

Socio-Economic Scenarios

Assessment of the impact of future scenarios of climate change should be couched in the contemporary socio-economic setting. Therefore, some climate change impact assessments have adopted socio-economic scenarios. In 2001 UKCIP published a set of socio-economic scenarios for use in climate change impact assessment (UKCIP, 2001). These scenarios provide qualitative storylines under four different futures – world markets, national enterprise, local stewardship and global sustainability. These futures are the product of two basic dimensions of change: social values and governance systems (OST, 1999, 2002). The storylines are supplemented by quantitative information, largely for the 2020s. Climate change impact assessments utilising socio-economic scenarios in some form include the regional scoping studies for East Midlands and London (Entec, 2003; LCCP, 2002), the REGIS project (Holman et al., 2002), the Foresight Future Flooding study (Evans et al., 2004), water resource studies (e.g. Downing et al., 2003), Climate Change and the Visitor Economy (McEvoy et al., 2006) and a study investigating impacts on the Countryside and the Rural Economy (LUC et al., 2005), which includes Co. Fermanagh as a case study area. Not all of these studies have adopted four scenarios and in most cases scenarios have been tailored for the specific study, especially with regards to geographical scale.

Socio-economic scenarios have proved to be a useful tool in climate change impact assessment. In those studies where they have been adopted, they have had a major effect on the results (West and Gawith, 2005). Consideration of non-climate futures is also useful for highlighting obstacles to adaptation. For example, the South East Climate Threats and Opportunities Research Study (Arkell et al., 2004) examined the timescales over which different sectors and stakeholders plan, finding that for many tourism SMEs, this was in the order of 1-2 years – too short to consider climate change. This highlights the need for other actors to facilitate adaptation, particular in developing adaptive capacity. For example, Visit Scotland has a Scenario Planning Group, which considers climate change and socio-economic futures.

The project has not been able to identify any socio-economic scenarios specific to Northern Ireland. However, the BESEECH project is currently developing socio-economic scenarios at the regional level, as part of the UKCIP / EPSRC Building Knowledge for a Changing Climate (BKCC) programme. Although focussed on the built environment, the study is enhancing the UKCIP socio-economic scenarios with new generic qualitative and quantitative information. This data, along with the factors that influence adaptive capacity, including society's economic, technological, institutional, demographic, human capital and equity characteristics (BKCC, 2005), will be published in the near future.

Development of bespoke socio-economic scenarios is not part of the project brief. Nonetheless, it will be important to consider potential socio-economic settings when identifying climate change impacts and devising adaptation strategies. Impacts will be conditioned by socio-economic factors (which define the sensitivity of the receptor) and the same socio-economic factors will influence the approach to and success of adaptation (defining the adaptive capacity of the system). For example, under a climate change scenario of sea level rise, the coastal zone would be more sensitive if there was a high level of development. However, if this development was adapted to the future climate (e.g. built on stilts) then the actual impact may be low. This study has therefore considered potential socio-economic development when assessing sensitivity and evaluating adaptive capacity. It is recommended that the government of Northern Ireland develop a set of socio-economic scenarios, building on the work being undertaken as part of BESEECH study.

Identification of Impacts

This task drew on the literature review and climate change scenario information to identify impacts for each sub-sector. Impacts were identified along with the receptors that they affect; a receptor is defined as "the entity that may be harmed by a particular set of hazardous events" (Willows and Connell, 2003). The receptor (e.g. building, person, economy) is downstream of sources (climate variables e.g. rainfall) and pathways (the link between sources and receptors e.g. rivers) in the Source-Pathway-Receptor model. Where possible, the potential impacts were quantified, but in general this information was not available.

Two matrices were produced to summarise impacts and adaptation for each sub-sector. The first (Table 2.1) describes the impacts in relation to the main changes in climate. The second (Table 2.2) was populated during subsequent tasks, starting with the list of impacts identified.

Table 19.1 - Template Climate Change Impact Tables

Climate change	Impact on receptor
Wetter winters	Impact 1
Drier summers	Impact 2 Impact 3
Warmer winters	Impact 4
Hotter summers	Impact 5
Sea level rise	Impact 6 Impact 7
Reduced soil moisture	Impact 8
Change in storminess	Impact 9

Table 19.2 - Template Impacts and Adaptation Tables

Impact on receptor	Public Service Area	Effect on public services	Risk	Resource implications	Adaptation strategy	Responsible public sector body
Impact 1						
Impact 2						
Impact 3						
…etc						

Consultation

Following the literature review, examination of climate change scenarios and initial identification of impacts (presented in the Consultation Report), a consultation exercise was undertaken. This commenced with a telephone questionnaire survey. The survey focussed on developing a better understanding of impacts, their effect on public services, key risks, resource implications and responses. Questions were based around five themes:

- Organisation Priorities and Planning, which examined decision-making processes and outcomes and identified non-climate issues.
- Today's Climate and Weather-Related Impacts, which assessed if and how current weather affects organisations, current responses to weather and the relative importance of climate and non-climate factors.

- Climate Change Impacts, which examined how climate change may affect organisations, objectives and Government priorities; discussed risks and resource implications; and compared future climate and non-climate issues.
- Adaptation Strategies for Climate Change, which assessed approaches to adaptation, strategies that may employed, maladaptation and dependencies on other organisations.
- Resources and Information, which examined constraints to adaptation, availability of information and further research requirements.

In total 38 interviews were conducted, covering all sub-sectors except Business. The information has not been analysed separately given that, statistically, the sample size is small and potentially un-representative. Instead, the information has been successfully applied within each chapter, along with outputs from the Workshop (see below).

The telephone consultation was followed by a workshop, at which consultees were presented with the initial findings. The workshop was then used to explore key issues further, with a particular focus on risk and adaptation. The Workshop Report is included in Appendix B.

Effect on Public Services

The study has focussed on the implications of the identified impacts for public service provision. For each impact, the relevant Public Service Area (as defined in Table 2 of EHS, 2005a) has been recorded, along with a description of the effect on public service provision, in the second matrix (Table 2.2). Chapter 18, Integration across Sectors, gives particular attention to the climate-sensitive outcomes identified by the Steering Group in the Invitation to Tender (ITT). These outcomes represent some of the Government's key priorities for the future and it is therefore important to understand how climate change may affect their delivery within key strategies and plans. Vulnerabilities are focused on:

- Infrastructure
- Energy provision
- Agri-food industry
- Housing
- Health
- Water resources

Risk Assessment

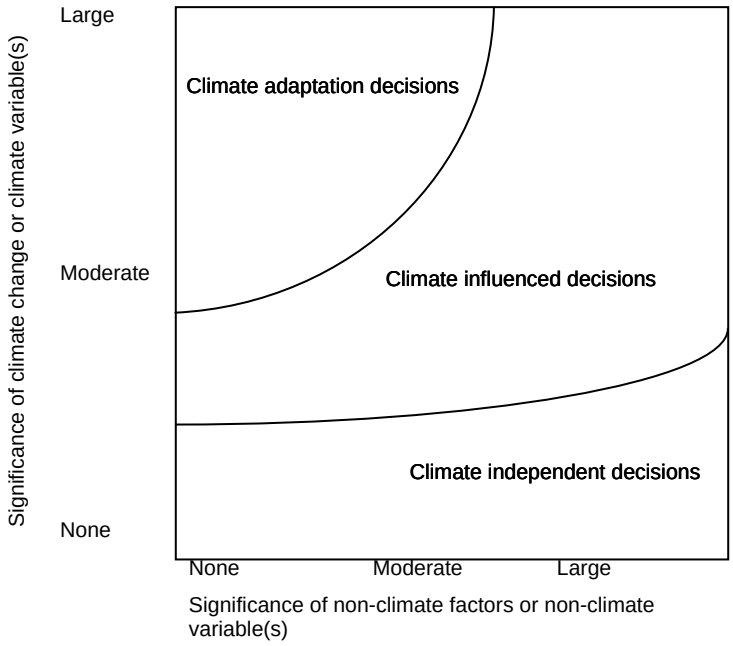
Risk assessment is a key objective of the project. There are two essential elements:

1. Identification of the resulting implications of generic impacts i.e. to consider impact on the ultimate receptor e.g. to assess where / who an increase in flooding may affect.
2. Establishment of the level of risk – the product of impact and likelihood.

The concept of risk is most easily applied in a quantitative setting. For example, the annual average damage of flooding can be calculated based on the impact of different levels of flooding and the likelihood of these levels occurring in any year. However, present scenarios of climate change have no level of probability attached to them. Although techniques exist to derive likelihood, these are complex and not suited to a strategic level study. Furthermore, for this type of study, impacts are not described in full detail or quantified (unless information is readily available). Therefore, an alternative technique is required for the assessment of risk.

This study has used a qualitative assessment of risk, based on risk screening, to provide a preliminary climate change risk assessment (Willows and Connell, 2003). This is the highest tier of risk assessment and will establish a platform from which more detailed risk assessments can be undertaken. According to Willows and Connell (2003) a preliminary risk assessment is the most appropriate method for application at the policy decision level. It should be used where climate change may influence decision-making, but where there is some uncertainty about whether it will affect decisions and how influential climate is. Prior to the assessment, the balance of climate and non-climate risk factors is largely unknown and therefore the type of decision needed with regards to adaptation is also unknown (see Figure 2.2).

Figure 19.2 - The relationship between significant climate and non-climate risk factors and the definition of climate adaptation and climate-influenced decision types



From Willows and Connell (2003). Note the boundaries are not precisely defined.

The purpose of the preliminary risk assessment (from Willows and Connell, 2003) is to:

- Identify potential factors that might represent a present or future climate hazard within the exposure unit (associated level of confidence might be low, medium, high).
- Exclude potential factors that do not represent a present or future climate hazard (associated level of confidence should be high).
- Identify potential receptors at risk within the exposure unit (associated level of confidence might be low, medium, high).
- Exclude potential receptors not at significant risk (associated level of confidence should be high).
- Help to identify, in broad terms, potential climate risk management options [dealt with under adaptation].

In this study, the exposure unit is the whole of Northern Ireland; receptors will be particular elements of the province's environment, society and economy. Each of the climate variables identified will be considered with regards to their potential effect and both threats

and opportunities will be identified. These are recorded in the climate change impact matrices within each chapter and further examined in the impacts to adaptation matrices . A potentially large number of receptors could be identified (even on a sector basis) and it is therefore some sort of screening of variable-receptors will be required to make the process and interpretation of the risk assessment manageable. This has been achieved by ignoring marginal impacts or receptors which are less sensitive to projected changes, and by grouping risks where appropriate.

The approach described above meets the first essential element discussed above and provides the 'impact' half of the risk assessment. The second element – the actual assessment of risk, including 'likelihood' – is discussed below.

The risk assessment could be based on climate factors (see first bullet point above) e.g. the risk associated with hotter summer days. Alternatively, it could be based on receptors (see third bullet point above) e.g. the risk to a building. In practice, it is hard to frame decisions on adaptation without consideration of both climate factor and receptor. This is because climate factors could represent different levels of threat and opportunity for different receptors. For example, it would be misleading to characterise the risk of hotter summer days on the exposure unit (the whole of Northern Ireland) because for some economic sectors, social groups and environments, this may represent a big opportunity, while for others (those who are more vulnerable and with limited adaptive capacity) it will represent a threat. Similarly, characterising the general effect of climate change on buildings would be misleading without consideration of the climate variables. Therefore a hybrid approach is required – one which couples climate factors and receptors – before determining risk. This involves elements of a more detailed qualitative risk assessment, including risk characterisation and prioritisation.

The likelihood of a particular climate variable occurring and causing a specified impact on the identified receptor (i.e. assuming a direct climatic cause) is only dependent on the likelihood of the particular climate variable occurring. The UKCIP02 climate change scenarios are not probabilistic and therefore no likelihood can be attached to them or any consequential impact. At present, and for strategic level assessments, an alternative approach is necessary.

Two potential approaches were explored for this study. The first would be to consider perceived likelihood, where stakeholders or experts classify likelihood based on weather-related experience or previous work with impact assessments (Figure 2.3). For example, if a town X is currently prone to flooding 'heavy rainfall and flooding in X town' would be plotted as a large threat, which is more likely under climate change. The most significant risks will be to the top right (threats) and top left (opportunities); those requiring more research will appear in the middle; while those at the bottom would represent benefits or lost opportunities (Figure 2.4). This approach is useful because it provides a conventional assessment of risk, from which priorities for adaptation are easily identified (see Section 2.7). However, the method is subjective and can be subject to bias e.g. to those impacts known, or more highly researched and understood.

Another approach would be to move away from evaluating the likelihood of a particular climate variable occurring to consider the confidence in the assessment of the link between the climate variable and the impact. Under this approach coupled climate variables and receptors are plotted according to the sensitivity of the receptor to the projected change and the confidence in the assessment of the link between climate variable and receptor. This approach has the advantage of being able to consider the influence of other (non-climate) factors on receptors and because it is based on sensitivity, is more resilient to changes in scenarios. However, the approach is also

subjective, is perhaps conceptually more challenging than the first approach and does not provide an assessment of climate change related risk, only climate related sensitivity. On this basis, the first approach has been adopted for use in this study. It has been applied assuming no planned adaptation, no fixed timescale (with any differences between time periods noted) and no geographical variations (although the definition of receptors provides some indication of location).

Figure 19.3 - Risk Matrix incorporating Stakeholder or Expert Perception on Likelihood (and Impact)

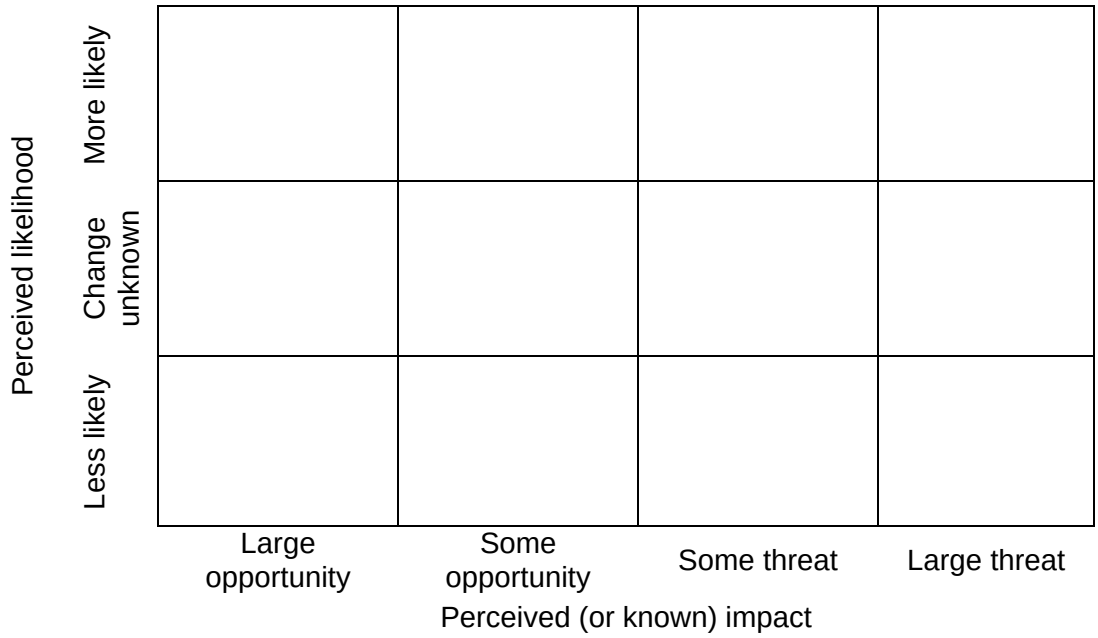


Figure 19.4 - Risk Category

Resource implications (such as effect on time or costs) will be considered in relation to the impacts identified. For example, hotter summers may increase the cost of irrigation, while outdoor workers may have to avoid the heat of the middle of the day.

The risks and resource implications will be recorded in the matrix (Table 2.2) in relation to the impacts for each sub-sector.

Adaptation Strategies

Adaptation can be defined as:

"The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits, associated with climate variability and climate change" (Willows and Connell, 2003).

The key elements in adaptation are: it is an iterative, circular process, with different tools used at different levels of decision: policy, programme and project; it leads to a reduction in risk or realisation of benefits.

Adaptation strategies will be produced for each of the impacts identified. The strategies will include practical measures, policy advice and recommendations for further research. Public sector bodies with responsibility for implementation will be suggested. These impact-specific adaptation strategies will be used to fill in the final two columns of the impacts to adaptation matrix (Table 2.2). In addition, cross-cutting adaptation advice will be provided, along with summaries for public sector bodies.

Work on adaptation strategies is at an early stage, but a number of recent publications will be used in the development of responses for Northern Ireland. The UK Government has recently launched an Adaptation Policy Framework (APF). The first stage aims to capture the national picture of adaptation, and a period of consultation closed in January 2006. The second stage analyse activities and assess why some sectors are adapting more successfully than others. The third stage will consider why adaptation is not occurring in some sectors and how this can be changed (Defra, 2005). The APF considers adaptation under two categories: building adaptive capacity and delivering adaptation actions. Building adaptive capacity covers activities such as research, data collection, change to regulations and awareness raising, while delivering adaptation actions involves activities that accept impacts, share impacts, avoid negative impacts or exploit opportunities.

This study will consider adaptation under the two APF categories. The study is also consistent with the APF in two other ways: both adopt a sector-based approach (with similar divisions) and both seek to identify the role and responsibilities of organisations.

In addition to the APF, the UK Government has also commissioned research on Objective Setting for Climate Change Adaptation Policy (AEAT, 2005). This study proposes a new method for setting adaptation policy, based around iterative cycles centred on an adaptation policy vision and sectoral policy development. The adaptation policy vision sets the policy aims and objectives and determines priority sectors for action; subsequently it integrates the policy framework at the national level. In between these steps, sectoral policy development characterises priority risks and opportunities, proposes adaptation objectives, defines targets, selects indicators, identifies adaptation options and finally appraises potential options. A number of tasks are described for objective setting (see AEAT, 2005: 10), including:

- Articulating a desired adaptation outcome in response to impacts identified.

- Proposing extreme objectives to represent a range of possible approaches.
- Evaluate objectives according to existing sectoral policies and issues.
- Evaluate objectives with respect to cross-sectoral conflicts and synergies.
- Identify regional variations.
- Condense the initial suggestions to one or more objective to be used.

These tasks will be a useful guide in developing adaptation strategies for Northern Ireland.

Once objectives have been set, the next step in sectoral policy development is conversion into targets. The aim of a target is to break down the objective into tangible goals which are temporal and may also be quantitative or categorical (AEAT, 2005). This is likely to involve stakeholder engagement and review of existing sectoral and geographical policies, plans and issues. Indicators are then used to monitor progress in target achievement.

This study will propose adaptation options, but will not produce targets or indicators or appraise options for adaptation. These tasks should be conducted by the relevant stakeholders in Northern Ireland once specific adaptation options are agreed upon. Furthermore, it is essential that the overarching vision for adaptation is set first (AEAT, 2005).

UKCIP has published a technical report addressing Climate adaptation: Risk, uncertainty and decision making (Willows and Connell, 2003). This provides an eight-stage decision-making framework, which aims to identify good adaptation options. The framework covers the entire decision making process (see Willows and Connell, 2003: 6):

Stage 1: Identify problem and objectives.
Stage 2: Establish decision-making criteria, receptors, exposure units and risk assessment end-points.
Stage 3: Assess risk.
Stage 4: I dentify options.
Stage 5: Appraise options.
Stage 6: Make decision.
Stage 7: Implement decision.
Stage 8: Monitor, evaluate and review.

The framework is particularly useful when a specific problem is identified. In this study, there are numerous ‘problems’, under the generic objective of analysing the impact of climate change upon Northern Ireland. The key stages of relevance are 3 and 4: assessment of risk and identification of adaptation options. This study will undertake a risk assessment (see Section 2.6) and this will be used to guide the type of response (see Figure 2.5). The study will also identify adaptation options. Key aspects for consideration include the type of option (e.g. do something, do nothing, delay), selection of options that are no or low regret, flexibility with regards to uncertainty, and the effect on other systems (avoidance of maladaptation).

Figure 19.5 - Potential Adaptive Responses to Risk Categorisation

Perceived likelihood	Large opportunity	Some opportunity	Some threat	Large threat
More likely	Short-term adaptive action	Medium-term adaptive action	Medium-term adaptive action	Short-term adaptive action
Change unknown	Short-term capacity building	Medium-term capacity building	Medium-term capacity building	Short-term capacity building
Less likely	Long-term adaptive action	Delay	Long-term adaptive action	Medium-term adaptive action

Perceived (or known) impact

N.B. Short-term refers to starting immediately, rather than meaning a quick fix.

In addition to the methodological frameworks described above, specific adaptation strategies have been devised for various sectors. At the forefront have been the water sector and insurance industry, with other sectors now engaged, including nature conservation, construction and buildings, transport, business and local authorities. In addition potential adaptation strategies have been set out for the UK (ERM, 2000) and Scotland (Kerr and McLeod, 2001), with a recent overview of adaptation progress provided in the UKCIP report Measuring Progress (West and Gawith, 2005). All of this material will be considered in developing adaptation strategies for Northern Ireland.

Adaptation strategies have been devised using outputs from the literature review, review of scenarios and the consultation, including the workshop. Potential strategies and responsible public sector organisations have been recorded in the final two columns of the matrix (Table 2.2) in relation to the impacts for each sub-sector. Constraints to adaptation have also been identified. These include:

- Lack of awareness
- Uncertainty about further climate conditions
- Lack of funding
- Lack of human resources
- Conflicts within or between organisations

Appendix B Climate Change Scenario Maps

All three sets of maps included in this Appendix are from the UKCIP website (http://www.ukcip.org.uk/climate_change/by_location.asp). The maps are slightly different to those which appear in the UKCIP02 Technical Report (Hulme et al., 2002), and also therefore the figures quoted in Table 3.1, because a spatial smoothing process has been employed. The UKCIP02 high and low emissions scenarios are provided to illustrate the uncertainty in future greenhouse gas emissions. Three future timeslices are presented, centred around the 2020s, 2050s and 2080s. The temperature scenarios illustrate the change in annual average daily temperature. The rainfall scenarios provide the percentage change for summer (the average of June, July and August) and winter (the average of December, January and February).

Figure 19.6 - Annual Average Daily Temperature Climate Change Scenarios

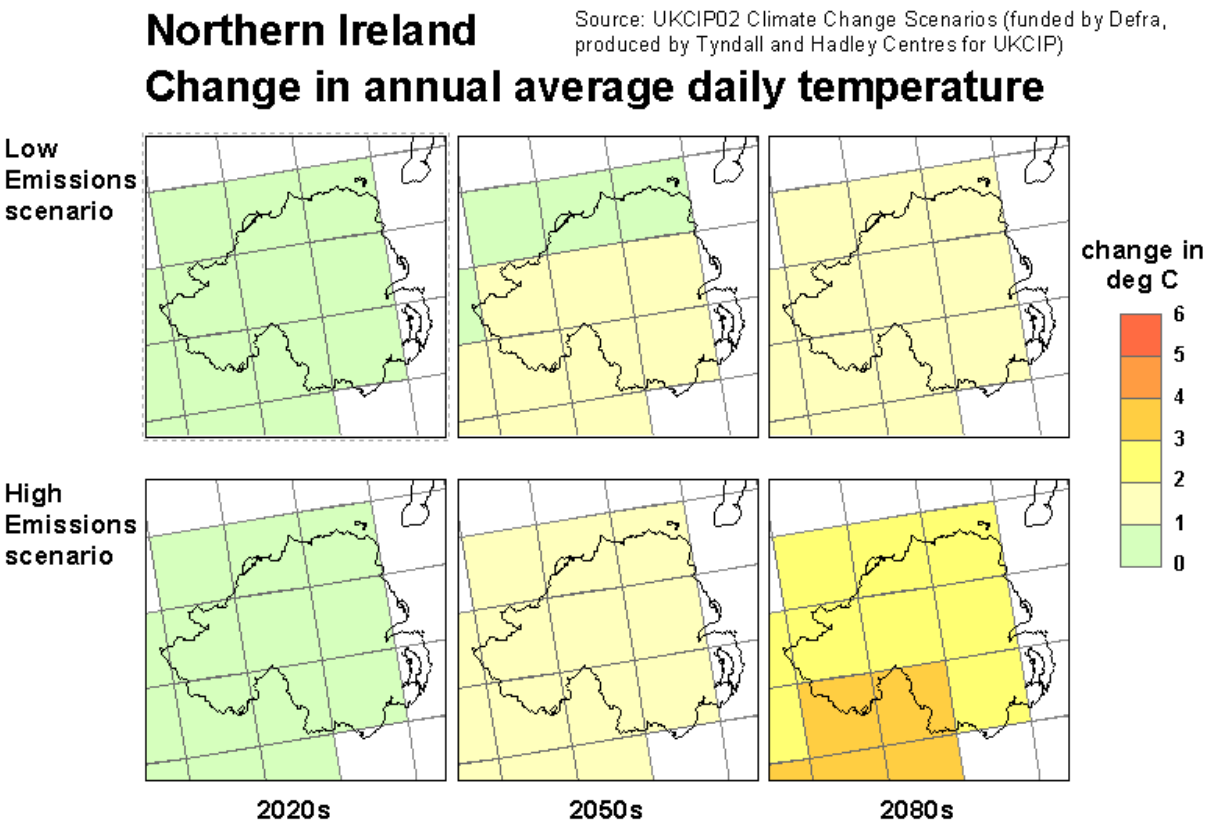


Figure 19.7 - Summer Precipitation Climate Change Scenarios

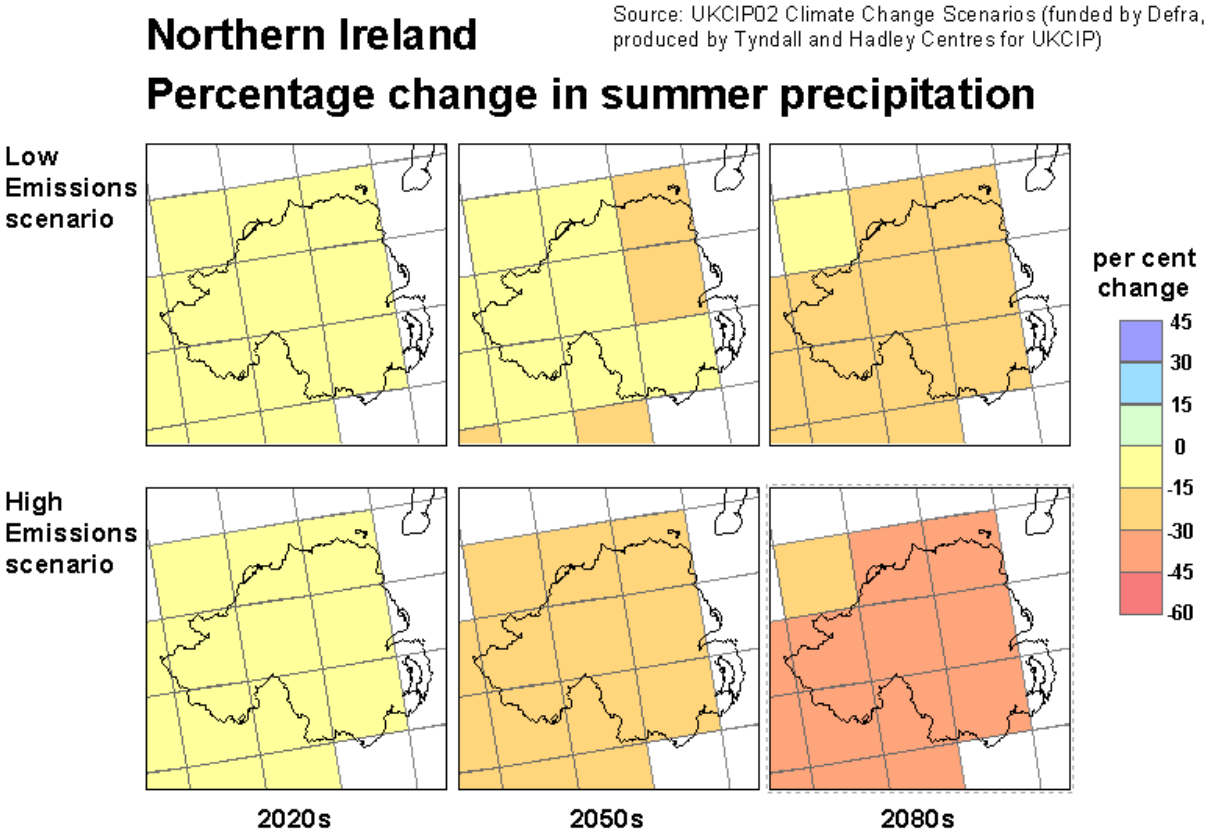
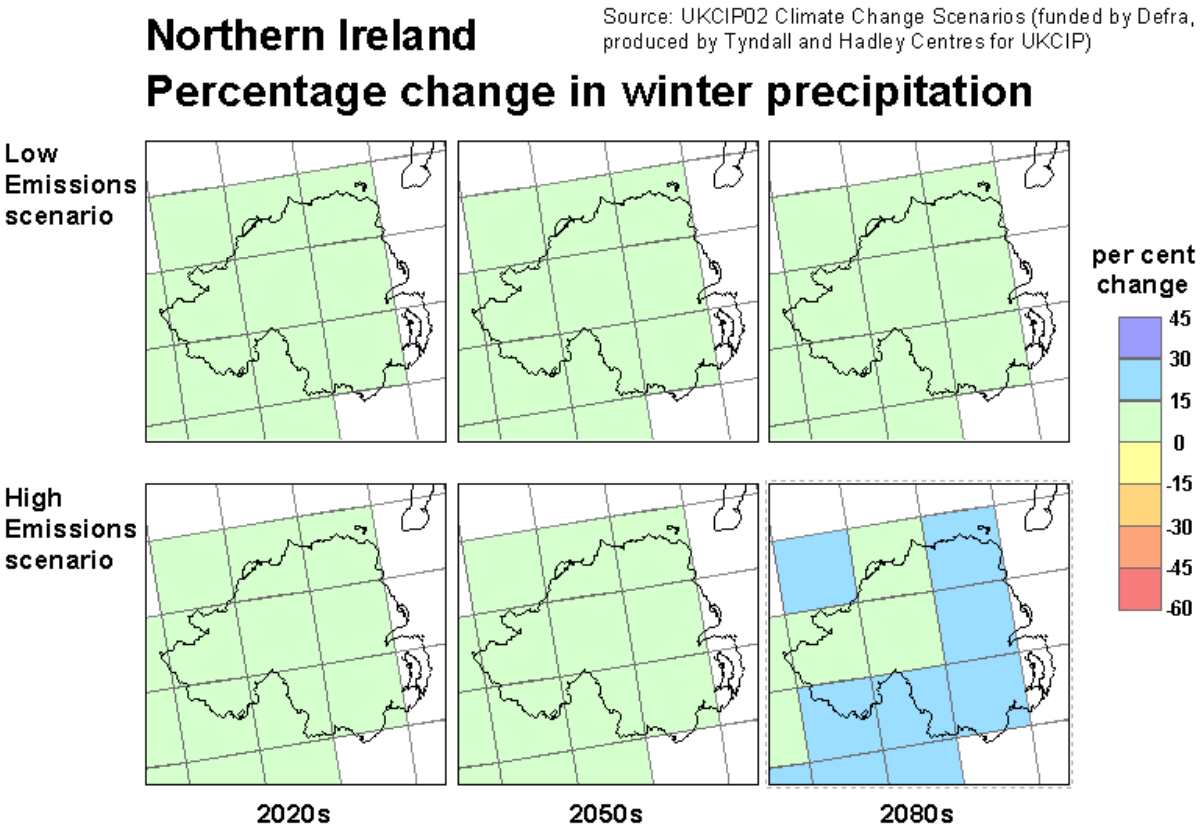


Figure 19.8 - Winter Precipitation Climate Change Scenarios



Appendix C Workshop Report

Preparing for a Changing Climate in Northern Ireland

Stakeholder Workshop, Belfast, 23 June 2006

Report on Approach and Findings

Introduction

The workshop was held to consult government stakeholders on specific aspects of impacts, risk and adaptation to climate change. The workshop also tested some novel tools, in particular for communicating and exploring risk. The workshop forms part of the consultation for the study and had the additional benefit of acting as an information, training and networking day for those addressing climate change in Northern Ireland.

The day started with introductory presentations from the research team on:

- Context, Climate Change Scenarios and Study Objectives.
- Overview of Impacts and Consultation Summary.

These presentations set the background to climate change and to the study and updated delegates on progress to date, including initial findings from the telephone consultation. Gerry Metcalf (chair, UKCIP) encouraged delegates to fully participate in the workshop, in the spirit of the UKCIP stakeholder-led approach.

Three breakout sessions followed, which explored:

- Recent Weather, Climate and Non-Climate Impacts.
- Risks and Climate Change.
- How might we Adapt to a Changing Climate: Options, Constraints and Responsibilities.

The delegates (Annex 1) were divided into 3 groups, broadly reflecting the natural environment, built environment and socio-economic sectors (see Annex 2). The findings of these sessions and evaluation of the approaches used is set out in the subsequent sections of this report.

Session 1: Recent Weather, Climate and Non-Climate Impacts

The plenary introduction to the session described the relevance of considering current weather effects, the brainstorming of potential climate impacts and the need to evaluate non-climate issues.

Current weather-related effects are useful in assessing sensitivity to weather and climate. Weather is what is experienced on a day to day basis and by considering current weather-related effects we can understand the sensitivity to weather and climate. We can also evaluate the impacts associated with different types of weather events, which is particularly useful in assessing extremes.

Climate change impacts were identified along with the receptors that they affect; a receptor is defined as “the entity that may be harmed by a particular set of hazardous events” (Willows and Connell, 2003). The receptor (e.g. building, person, economy) is

downstream of sources (climate variables e.g. rainfall) and pathways (the link between sources and receptors e.g. rivers) in the Source-Pathway-Receptor model.

Finally, **non-climate risks** were introduced. For many decisions, climate change is not the biggest risk. Furthermore, it is important to consider the future setting in which climate change impacts will occur. Socio-economic scenarios are available to aid this process (e.g. UKCIP, 2001). By defining future non-climate risks, it is possible to better understand the type of decision that is required. If climate change is unimportant, then the decision is climate independent. If climate change is important, then the decision is either climate influenced, or where non-climate risks are insignificant, the decision is purely related to climate change and termed a climate adaptation decision (Willows and Connell, 2003).

The findings of each breakout group are summarised in the following sections.

Current Weather-Related Effects

Several weather types were considered and a good variety of current impacts on receptors were identified under each theme (see Tables 1-1, 1-2 and 1-3). These demonstrate that weather events do cause problems in Northern Ireland at present e.g. storms, flooding, at least in some sectors. Hot weather was not considered to be particularly problematic at present.

Table 19.3 - Current Weather-Related Effects: Natural Environment

Weather type	Impact on receptor
Heavy rainfall	• Natural environment is generally resilient to heavy rain. • Plant communities – adaptation to severe weather unknown. • Animals – more mobile , first to respond.
Storms (variation in frequency & intensity)	• Change in tree population profile (big trees fall therefore age profile changes. There was a lack of planting 100yrs ago therefore gap in population). • Associated impact on fauna e.g. Herons look for larger trees. • Time of year is important for trees – Summer gales are worse in terms of tree fall. • Seasonal shift – temperatures rise earlier in the year & vegetation begins to grow. But cold snaps mean that this can be killed off and there are associated impacts on insects etc. e.g. Spittle Bug. • Associated impact on food chain where predator / prey relationships can be disrupted. • Possible re-adaptation may occur.

Table 19.4 - Current Weather-Related Effects: Built Environment

Weather type	Impact on receptor
Heavy rain	• Flooding: buildings; infrastructure; damage to built and natural heritage; flood defences. • Direct rain damage to structures and materials. • Effect on wellbeing and health. • Erosion.
High temperatures	• Human comfort. • Water use.

It was noted that high temperatures do not cause problems in Northern Ireland at present, although people commented on colleagues who had found it difficult to sleep in the recent warm spell. It was also noted that there had been some preparation for a drought a few years ago. In Session 2, it was noted that dry conditions had led to forest fires, while the Westlink highway had melted 3-4 years ago during a heatwave.

Table 19.5 - Current Weather-Related Effects: Socio-Economics

Weather type	Impact on receptor

High Winds
(Frequent,
In Summer
Tornadoes,
Tail ends of US hurricane)
	• Power Supply disrupted:
	  o Loss of goods e.g. if refrigerators fail.
	  o Cold.
	  o Increased dependency on standby.
	  o Emergency responses especially to vulnerable groups e.g. if water system is disrupted.
	• Wind turbines shut down:
	  o Implications for domestic micro-generation.

Flooding	• Health Impacts.
	• Sewer overflow as a result of exception rainfall.
	• Road closures.
	• Economic impact:
	  o Insurance – risk to uninsured.
	  o Compensation delay.
	  o Loss of stock.
	• Life disruption.
	• Structural damage.

High Temperatures	• Loughs:
	  o Algae.
	  o Bacterial infection.
	  o Higher treatment requirements.
	• Opportunity:
	  o Tourism.
	  o Domestic gardens.

	o Leisure. o Some crops benefit (some suffer): ▪ Move to uplands. ▪ New species.

Climate Change Impacts

A large number of climate change impacts on receptors were identified under each of the themes (see Tables 1-4, 1-5 and 1-6). These suggest that climate change may cause or contribute to a variety of impacts on different receptors in the future. Both threats and opportunities were identified.

Table 19.6 - Climate Change Impacts: Natural Environment

Climate variable	Impact on receptor
More frequent Heavy Rainfall	• Change in habitat structure. • Unknown resilience of natural environment – sufficient time between events to recover? • High mortality of salmon – impact on eggs. But possibly more survival at a later date as less competition.
North Atlantic Oscillation	• Impact on Salmon at sea: o change in sea surface temperatures. o Population varies naturally but thought that this will develop into a continuous low population scenario. • Sea level rise leading to a decline in sand eel populations in the north sea in turn leading to a decrease in puffin populations.
Wetter Winters	• Past practices such as cutting bogs have reduced ability to deal with this. • Water temperature is critical e.g. Salmon problems at 15^{o}C and mortality at 20^{o}C. • Reservoirs should be on a natural basis – bogs / wetlands etc, not man made reservoirs. • Wetter winters not necessarily better – e.g. bog growth due to capacity problems. • Bogs drying out is problematic as this releases CO_2 – solution is to decrease drainage and keep up water levels.
Increasing Temperature	• Introduction of new / alien species. Can be seen as both a threat and an opportunity. E.g. Spanish slug, New Zealand flatworm & Zebra Mussels (Risk Assessment report by QUERCUS on Invasive Species). • Situation currently not taken seriously. • Need improved strategy that is independent from GB as some species are unique to NI e.g. Lilly Beetle (Info compiled on CeDAR database). • Prevention is better than cure.

	• Preventative measures could include inspection of ports and ID of potential pests e.g. garden centre plants. • Some species that currently migrate here may not come e.g. ducks in Lough Neagh and Brent Geese. • Increasing rate of erosion leading to habitat loss. Rock armouring seems to pass energy on elsewhere – strategy needs re-examined. • Increased tourism potential.

Table 19.7 - Climate Change Impacts: Built Environment

Climate variable	**Impact on receptor**
Sea level rise	• Tourism and economy (negative effects). • Damage to coastal buildings and archaeology. • Belfast – problems with storm water infrastructure esp. height of discharge. • Inter-tidal implications (e.g. on estuaries). • Coastal infrastructure effects – rail and road.
Drier summers	• Subsistence (clay soils). • Pressure through changing land-use patterns (e.g. as agriculture moves upslope) – impact on archaeology. • Water supply infrastructure may need to be adapted. • Increase in pollution incidents.
Hotter summers	• Tourism benefit.
Warmer winters	• Fuel poverty benefit. • Positive health impact.
Wet winters	• Changes in agricultural practice. • Building damage – flooding and direct increased condensation.

Table 19.8 - Climate Change Impacts: Socio-Economics

Climate variable	Impact on receptor
Sea level rise (more rainfall, Wind, Atmospheric pressure, Tide)	• All power stations (gas, oil & coal) are sea water cooled on coast: o All impacts of power cuts, particularly in rural areas where contingency plans are more limited. The following can infer impacts from current flood impacts • Sewage plants. • Fishing. • Coastal communities. • Belfast – new regeneration development particularly vulnerable. • Major coastal roads. • Rail in Co. Down (already disrupted). • Tourism: o Beaches. o Camping / caravans.
Drought (Higher temperatures, Drier summers, Greater demand)	• Depleted reservoirs: o Shortage. o Poorer quality & treatment. • Existing EU legislation on boreholes. • Can we adapt to higher winter rain by building more means to capture this.
Decline in no. of cold days	• Malaria. • Fewer infectious organisms killed off – general feeling that cold snaps are good for killing off bugs. • Opportunities: o Costs saved on heating. o Reduced fuel poverty – although rising fuel costs may offset benefit. o Fewer cold related deaths.
• Be aware that regional issues that mean that NI impacts may be distinct from headline UK averages. • BUT current awareness of risk is relatively low. • Some mitigation measures meet adaptation needs.	

Non-Climate Risks

Non-climate risks were identified under each of the themes (see Tables 1-7, 1-8 and 1-9), some of which were theme-specific, e.g. CAP reform, while others were common across themes e.g. development issues, political uncertainty. Such non-climate risks need to be considered alongside climate risks.

Table 19.9 - Non-Climate Risks: Natural Environment

Non-climate risks
• Political Situation: o Existence / Non existence of NI Assembly. o Peoples perception now doesn't lead to stability o Local politicians are too narrowly focused. o NIMBY attitude. o Other Issues are more important. • Development in the countryside e.g. escape of nutrients into water. • Resources are under pressure – need to make a case to get more. • Environmental governance currently in NI. Role is needed for specific climate change body which overarches over a range of government departments.

Table 19.10 - Non-Climate Risks: Built Environment

Non-climate risks
• Development pressures. • Public attitude and pressures. • Government (assembly) priorities. • Funding / budgets. • EU agenda. • Review of public administration. • Media pressure / opinion. • Political uncertainty / administration uncertainty.

Table 19.11 - Non-Climate Risks: Socio-Economics

Non-climate risks
• Immigration: o Positive economic impacts. o Housing pressures. o Highly skilled workforce. • Agriculture CAP reform: o Farm size change. o Changing land use. o Changing market values on local production: ▪ Less potato production. ▪ More livestock & fodder crops. • Ideological change: o Globalisation & reactions to it. o Protectionism. o Shift in profile of CSR as business benefit. • Scrutiny of political process. • Leadership – vision about sustainable development – especially in local government.

Session 2: Risks and Climate Change

Risk Assessment

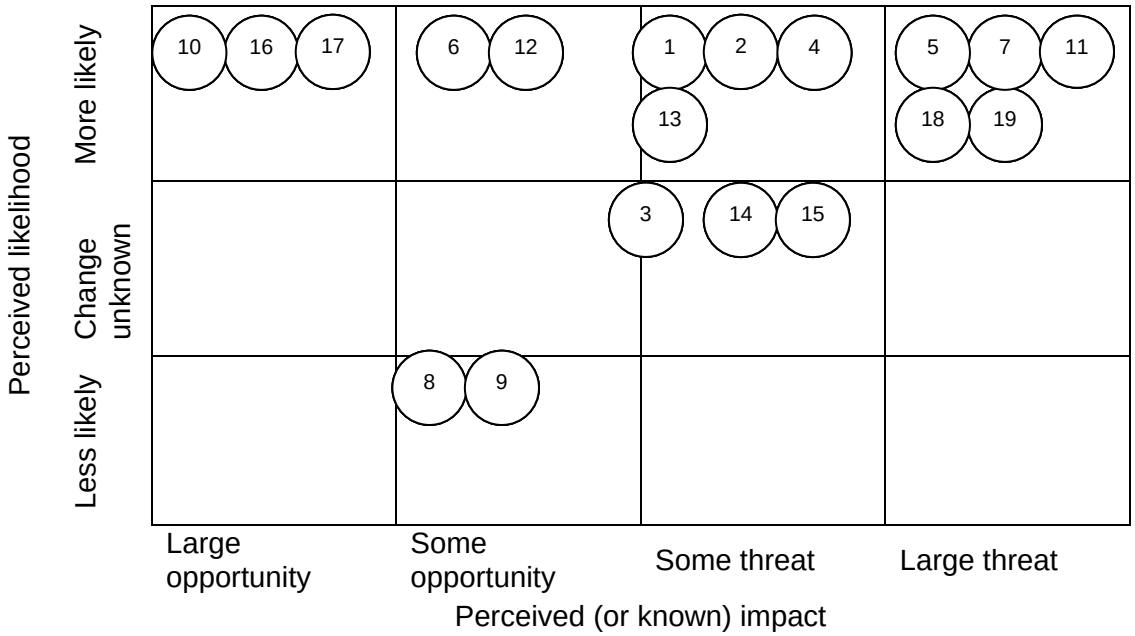
The plenary introduction to the session described the process of climate change risk assessment and introduced the risk matrix using a case study. This follows the recommended method set out in the project paper Approach to the Assessment of Risk. A comprehensive risk assessment will be undertaken as part of the study, with matrices for each sub-sector. These will define the impact significance (significant opportunity, lost opportunity, significant threat, significant benefit, significant unknowns, lesser unknowns etc) and guide responses in terms of type of action (building adaptive capacity, adaptive action) and timescale (short, medium, long-term). The workshop session used pre-defined lists of climate impacts describing the climate variable and the receptor. The process of risk assessment therefore provided a participatory learning exercise for delegates, as well as indicative outputs for the study team.

The risk assessment approach provided a useful technique for considering and prioritising impacts. The findings are presented in the following Figures (2-1, 2-2 and 2-3), supported by the keys which defined the impacts. The assessment was possible with fairly basic information on the impact and likely change in climate. Where 'perceived likelihood' was unknown, this usefully demonstrated a knowledge gap. It was recognised that there are other drivers to actions i.e. impacts are caused by non-climate factors.

In general, more explanation would improve the risk assessment exercise. Specific lessons include the need to:

- Define a timeframe (related to climate change scenarios) e.g. 2020s.
- Define or allow for geographical variation in response.
- Ensure sector relevance, whilst including an evaluation of cross-sector impacts.
- Careful wording / instruction to ensure independence of impact and likelihood. The wording of the impacts meant there was a tendency to view any change as 'more likely' e.g. 'reduction in cold-related mortality' was assigned as 'more likely' and representing 'some opportunity' suggesting that this is an opportunity needing a medium-term adaptive capacity. It would be more useful to consider 'cold-related mortality' as 'some threat' which is 'less likely' under climate change. In this case it would represent a benefit under climate change, which would happen to some extent regardless of adaptive action.
- Define whether the impact is an event or a broader change in climate.
- Define the level of any adaptation.

Figure 19.9 - Risk Matrix: Natural Environment



Note: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

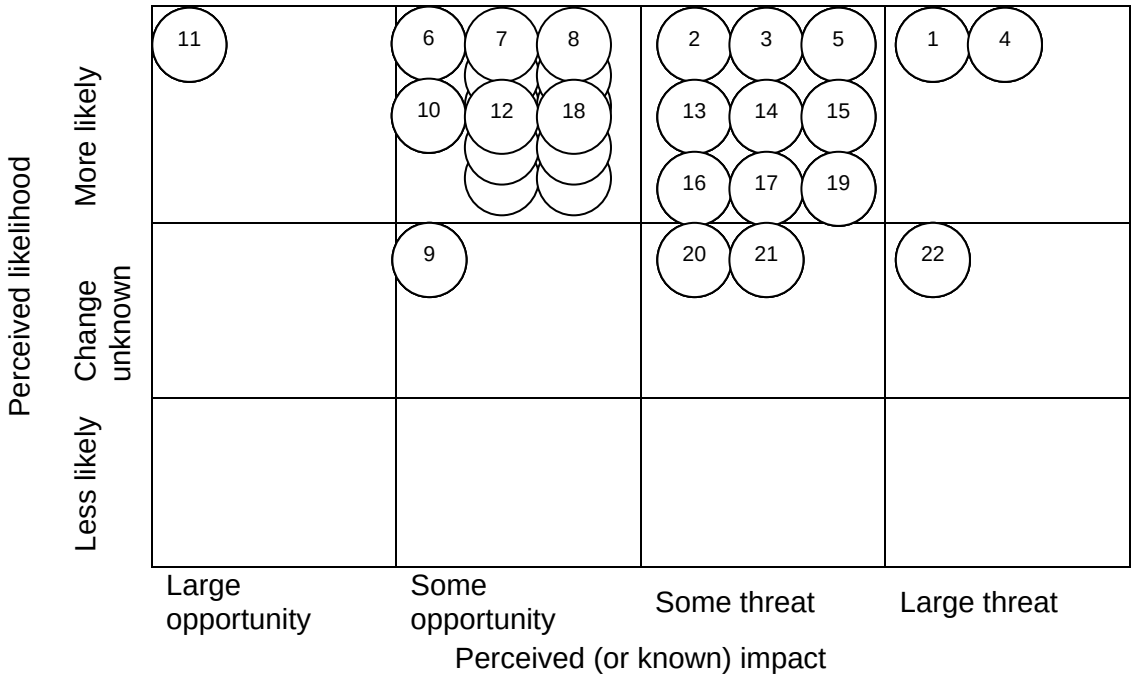
Additional Comments:

5	Depending upon Location i.e. in areas of large scale horticulture
6	E.g. Menzeproda. Combination of new technology as well as climate change e.g. sunflowers
7	Also a resource implication
8	Works if drier – varies from year to year. Seasonal shift
9	Not that many free draining soils in NI
10	By itself would increase
11	Depends e.g. problems for mushrooms
12	Apart from mushrooms and providing more water is available. Hawaiian grape is now grown in Cork
13	NI still experiencing isostatic uplift, to a point counteracting climate change
14	90% of NI is grassland. May affect some areas in Co Down
15	Buildings designed to cope
16	Economic factors will come into play. Good future opportunities for local farmers. Changes on a global scale will allow local farmers to take advantage
17	Environmental costs of food miles will come to the fore
18	Link to fossil fuel costs
19	Link to fossil fuel costs

General	• Soil compaction is a problem for drainage due to larger machinery and New Zealand flat worm that replaces our earth worm population • Has become the norm – circumstantial evidence of nutrients running off the soil • Some abandonment but this is not helping the problem

Climate change	**Impact on receptor**	**No.**
Wetter winters	Potential drop in some crop yields.	1
	Greater difficulties in accessing fields (water logging) – problematic harvesting and ground preparation.	2
	Pest & disease problems.	3
	Impact on drainage systems.	4
Drier summers	Increased need for irrigation and change in farming methodology e.g. for potatoes.	5
	Potential for new crops or crop varieties to be introduced.	6
	Increased need for greater water supply – cost implication.	7
Warmer winters	Animals can be left in fields for longer / housing period decreased.	8 9
	Increased grazing on freer draining soils	10
	Lengthening of growing season.	
Hotter summers	Increased need for shade.	11
	Heat may benefit some crops, though may damage others.	12
Sea level rise	Loss of coastal, estuary and floodplain agricultural land – major implications for polder areas at Lough Foyle.	13
Change in Storminess	Increased soil erosion.	14
	Damage to agricultural buildings / changes in building specifications.	15
Other (stated)	Potential implications for farm management – though note there are many other factors such as grant schemes, government policies, consumer patterns etc.	16
	Need to import food / supply security.	17
	Price of food – to produce.	18
	Price of food – to consumers.	19

Figure 19.10 - Risk Matrix: Built Environment

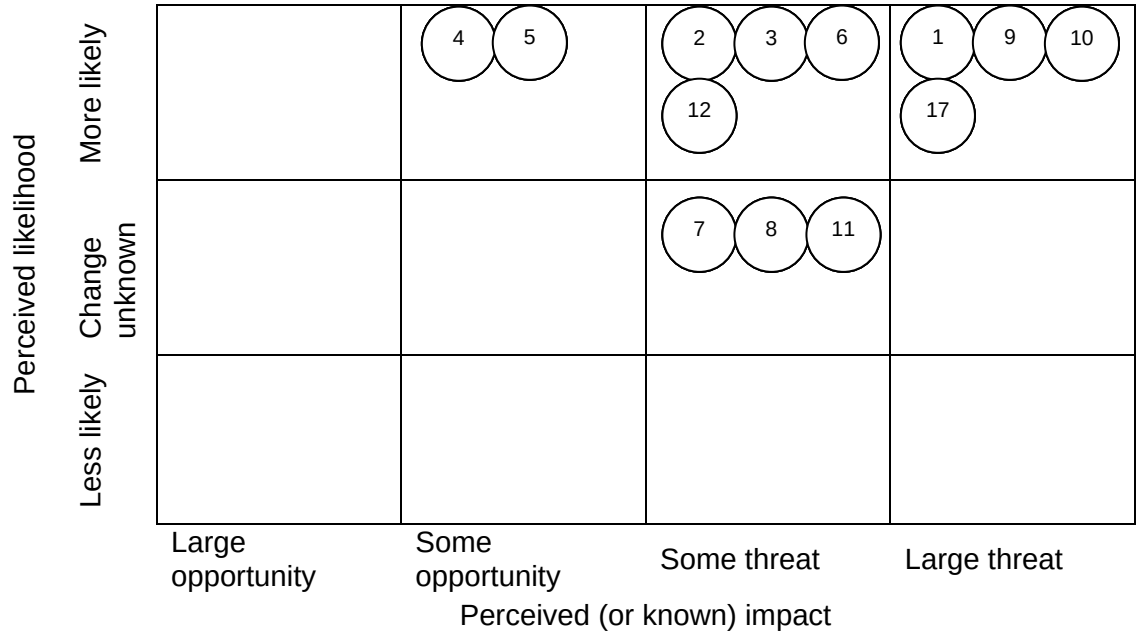


Note: Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

Climate change	**Impact**	**Impact on Receptor**	**No.**
Wetter winters	Flooding	Infrastructure damage. Delay to users. Road safety issues. Problems for emergency services.	1 2 3 4
	Scour	Destabilisation of bridge / embankment foundations.	5
Warmer winters	Reduction in snow and frost	Reduction in cold weather-related maintenance. Reduction in disruption to users. Less need for heating of trains, terminals etc. Changes in fall of autumn leaves. Safer travel? Economic benefits..	6 7 8 9 10 11
Drier summers	More amenable weather	Greater demand for walking and cycling. Health benefits?	12 13
	Drier soils and vegetation	Increased risk of fire. Increased risk of subsidence (on clay soils).	14 15
Hotter summers	Increase in surface temperatures	Increased discomfort / exposure for travellers. Economic cost of infrastructure damage e.g. road rutting.	16 17

Climate change	Impact	Impact on Receptor	No.
	More amenable weather	Economic benefit of more local and inward tourism.	18
	Ozone production	Respiratory problems associated with deterioration in air quality.	19
Sea level rise	Flooding and erosion	Economic impacts of damage. Risk to users.	20 21
Change in storminess	Windstorms	Disruption to railways, airports, road bridges and shipping.	22

Figure 19.11 - Risk Matrix: Socio-Economics



Note:
Risk matrix assumes no adaptation action
Impacts and likelihoods were assigned to discrete boxes, rather than on a continuous scale. Therefore all risks within the same box are of the same significance.

Climate change	Impact	Impact on Receptor	No.
Wetter winters	Flooding	Deaths / injuries. Anxiety and depression. Spread of disease.	1 2 3
Warmer winters	Higher winter temperatures	Reduction in cold-related mortality. Reduction in cold-related morbidity. Increase in pests (not killed).	4 5 6
Drier summers	Water quality impacts	Economic impacts associated with treatment. Health effects.	7 8

Climate change	Impact	Impact on Receptor	No.
Hotter summers	Higher extreme temperatures	Increase in heat-related mortality.	9
		Increase in heat-related morbidity.	10
		Occupational heat stress.	11
		Increase in hospital admissions.	12
		Increase in problems for residential homes.	13
		Increase in need for care in the community.	14
		Increase in food poisoning.	15
		Proliferation of pests.	16
	Exposure	Long-term health problems e.g. skin cancer	17
	Air quality effects	Increase in respiratory problems.	18
Change in storminess	Windstorms	Risk of deaths and injuries.	19

Sliding Scale Analysis

A second exercise examined impacts on sliding scales. This was very much an experimental exercise, which asked delegates to define the sensitivity of receptors or whole sectors to different levels of climate change.

The natural environment and socio-economics groups populated the matrices to some extent (see Figures 2-4 and 2-5). Several sub-sectors were plotted for the natural environment theme, while water and farming were plotted under socio-economics. In general, it proved easier to identify problematic thresholds, although opportunities were related to farming / agriculture for some indices and the water sub-sector for some levels of increases in winter rainfall. The group addressing the built environment did not complete the matrix, but discussed it, reaching the following conclusions:

- Sea level rise would be easiest to assess.
- All top level thresholds would be difficult.
- The built environment is less directly affected than sectors such as agriculture.
- Knock-on changes and indirect impacts are more important to the built environment.

General conclusions are that:

- The analysis is useful for looking at sensitivity on a sector basis.
- There are receptor and geographical differences.
- There may be a need to have more specific variables e.g. date-related

Figure 19.12 - Sliding Scale Matrix: Natural Environment

+4°C	+10°C	-50%	+30%	+1m
+3°C	+8°C	-35%	+20%	+60cm
+2°C ***Water Resources Natural Heritage Agriculture***	+6°C ***Water Resources Natural Heritage Agriculture***	-20% ***Water Resources Natural Heritage Agriculture***	+10% ***Water Resources Natural Heritage Agriculture***	+30cm ***Water Resources Natural Heritage Agriculture***
+1°C ***Water Resources*** *Natural Heritage* Agriculture	+4°C ***Water Resources*** *Natural Heritage* Agriculture	-5% ***Water Resources*** *Natural Heritage* Agriculture	No change (but annual decline) ***Water Resources*** *Natural Heritage* Agriculture	No change ***Water Resources*** *Natural Heritage* Agriculture
Average Temperature	**Peak Temperature**	**Summer Rainfall**	**Winter Rainfall**	**Relative Mean Sea Level**

Key: major problems, some problems, ok/opportunities.

Figure 19.13 - Sliding Scale Matrix: Socio-Economics

+4°C ***Water*** Farming	+10°C ***Water Farming***	-50% ***Water Farming***	+30% ***Farming*** *Water*	+1m ***Water Farming***
+3°C ***Water*** Farming	+8°C ***Water Farming***	-35% ***Water Farming***	+20% ***Farming*** Water	+60cm ***Water Farming***
+2°C *Water* Farming	+6°C ***Water Farming***	-20% ***Water Farming***	+10% *Farming* Water	+30cm *Water Farming*
+1°C *Water* Farming	+4°C *Water Farming*	-5% *Water Farming*	No change (but annual decline) *Water Farming*	No change *Water Farming*
Average Temperature	**Peak Temperature**	**Summer Rainfall**	**Winter Rainfall**	**Relative Mean Sea Level**

Key: major problems, some problems, ok/opportunities

Session 3: How might we Adapt to a Changing Climate: Options, Constraints and Responsibilities

The session commenced with a brief introduction to adaptation. Adaptation can be defined as:

"The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits, associated with climate variability and climate change" (Willows and Connell, 2003).

The key elements in adaptation are: it is an iterative, circular process, with different tools used at different levels of decision: policy, programme and project; it leads to a reduction in risk or realisation of benefits. The risk assessment process will define the type and level of risk and the adaptation response required.

Adaptation responses range from do nothing and delay to do something. The Defra Adaptation Policy Framework (Defra, 2005) divides the latter into building adaptive capacity and delivering adaptive actions (see Table 3-1).

The first activity in the session considered how current or planned actions of delegates fell into different categories of response. The second activity considered constraints to adaptation. Responsibilities for adaptation were not explicitly considered, but public sector organisations will be identified in the project report.

Table 19.12 - Actions under Defra's Adaptation Policy Framework

Building adaptive capacity	Delivering adaptive actions
Research Data collection Change to regulations Awareness raising	Accept impacts Share impacts Avoid negative impacts Exploit opportunities

Adaptation Actions

Adaptation actions were identified for each theme (see Tables 3-2, 3-3 and 3-4). The majority of current or planned actions fell under building adaptive capacity, although some adaptive actions were identified. Two of the themes had no activities under do nothing and delay, suggesting that the need for adaptation has been recognised by those present.

Table 19.13 - Adaptation Actions: Natural Environment

Do nothing	Delay
• Depends on timescale but do nothing would be considered. • Will increasingly not be an option.	• Still in data gathering stage – need guidance from science – more hard facts needed to inform response. • Nature Conservation – is UK level people working with regard to climate change. • Will to act is needed & resources. • Connectivity of habitats – corridors for plants / animals to respond. • Still need to change perceptions. • Each ASSI declared costs approx £1M to declare and maintain. • Problems if habitats increase.

Building adaptive capacity	**Delivering adaptive actions**

• Sustainable development strategy – communications plan.
• Variable communications from various bodies – need to be standardised.
• Decide who is taking the lead:
  o Met Office.
  o UKCIP.
• Biodiversity action plans – (local and national level) – role for local government especially after reorganisation of local government.
	• Resources needed.
	• Identify the risks.
	• Relevant research required.
	• Need stabilisation of the political status of NI.
	• Needs bought into at highest government levels.
	• Getting balance right between nature and e.g. protection.
	• EU directive to accommodate climate change.
	• Funding required to manage the financial constraints of monitoring.

Table 19.14 - Adaptation Actions: Built Environment

Do nothing	**Delay**
Building adaptive capacity	**Delivering adaptive actions**
• Research and networking (Flood Defence). • Liaising with partner organisations (Built Heritage). • Changes to planning policy (Planning). • Awareness raising (DOE).	• Climate proofing flood defences. • Building in design safety factors.

Table 19.15 - Adaptation Actions: Socio-Economics

Do nothing	**Delay**
Building adaptive capacity	**Delivering adaptive actions**
• Co-ordinate partnership working on adaptation e.g. Scottish climate change impacts partnership. • Run workshops on adaptation strategies. • Commission research on Climate change in NI. • Order region specific research. • Create regulations to drive adaptation. • Set up IT communication strategy. • Upgrade sewage infrastructure. • No water treatment works have been designed for climate change. • Promote importance of adaptation in policy and political work. • Help people (govt, politicians, public) recognise what they can do & why it	• Training programme for industry on threats and opportunities and possible strategies and products. • Provide grants to encourage public to micro generate. • Lead by example – have % of power used in govt buildings generated by sustainable sources. • Using green energy~8%. • Dedicated energy manager.

is important. • Use climate change impacts to promote general environmental awareness & action. • Change legislation e.g. to encourage energy suppliers to buy back electricity produced in households through micro generation. • Study countries through out the world which have the climates now that we expect to have. • Identify threats and opportunities and devise strategies and products to enable companies to adapt.	

Constraints to Adaptation

Constraints to adaptation (Figures 3-1, 3-2 and 3-3) were fairly evenly split across suggested factors. Overall, conflicts with or dependencies on other organisation was the most popular constraint, suggesting the need for a coordinated approach to adaptation, with funding also identified as important. A lack of human resources was not considered a particular issue. There were some notable differences between themes. Lack of awareness was identified as the key constraint in the socio-economic theme, which was not an issue in the natural and built environment themes. Funding problems were only identified as an issue for the built environment and socio-economic themes.

Table 19.16 - Constraints to Adaptation: Natural Environment

Lack of awareness		
Uncertainty about future climate conditions	X	• Uncertainty of scale
Lack of funding		
Lack of human resources		
Conflicts in your organisation's priorities	XX	• Conflicts of funding within agencies • Continuity of funding – fighting to establish longer term of funding – problem that work done will go 'down drain'.
Conflicts with or dependencies on other organisations	X	
Other	X	• Short term-ism among government

Table 19.17 - Constraints to Adaptation: Built Environment

Lack of awareness	
Uncertainty about future climate conditions	XX
Lack of funding	XXX

Lack of human resources	X
Conflicts in your organisation's priorities	
Conflicts with or dependencies on other organisations	XXX
Other	

Table 19.18 - Constraints to Adaptation: Socio-Economics

Lack of awareness	XXXXX	
Uncertainty about future climate conditions	XX	
Lack of funding	XXX	
Lack of human resources	X	
Conflicts in your organisation's priorities	XX	
Conflicts with or dependencies on other organisations	XXX	• EHS and Planning Regulations mean water treatment works are more energy intensive. • Lack of cross cutting working between government departments. • Lack of cohesive ownership of key relevant policies.
Other	XX	• Lack of NI political leadership. • Lack of power in local government.

References

Defra. 2005. Adaptation Policy Framework. A consultation by the Department for Environment, Food and Rural Affairs. October 2005. Defra, London.

EHS. 2005a. Guidance for Public Bodies on Climate Change Impacts in Northern Ireland. Environment and Heritage Service, Belfast.

Willows, R.I. and Connell, R.K. (Eds.) 2003. Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.

Annex 1: Delegates

Name	Organisation	Group Ref
Geoff Darch	Atkins	2
Paddy McEntee	Atkins	1
Michael McLarnon	Atkins	1
Emily Postan	SNIFFER	3
Ivan Gregg	DOE	2
Barry McAuley	DOE	2
Brendan Forde	DOE	1
Gerry Metcalf	UKCIP	3
Roy Anderson	DARD – AFBINI	1
Fiona Mulholland	EHS Natural Heritage	1
John Davison	DOE Planning Service	2
Howard Platt	EHS Conservation	1
Ken Neill	EHS Built Heritage	2
Sue Christie	NI Environmental Link	3
Roger Thompson	DARD Rivers Agency	2
John Griffin	DRD Water Service	3
Paddy Boylan	The Loughs Agency	1
David Bell	Invest NI	3
Greg McCleary	EHS Water Management Unit	1
Chris McWilliams	DOE	2
Keith Brown	DOE	3
Davina Quigley	DETI	3

Annex 2: Break-Out Groups

Group Ref	Sector Group*	Sub-Sector*	Facilitator	Support
1	Natural Environment	o Conservation o Biodiversity o Habitats o Agriculture o Forestry o Fisheries o Water resources	Paddy McEntee (Atkins)	Brendan Forde (DOE) Michael McLarnon (Atkins)
2	Built Environment	o Buildings o Construction o Planning o Coastal & flood defence o Transport o Energy	Geoff Darch (Atkins)	Ivan Gregg (DOE) Barry McAuley (DOE)
3	Socio-Economics	o Business o Insurance o Tourism o Health o Sport & recreation	Gerry Metcalf (UKCIP)	Emily Postan (SNIFFER)

*Study sectors and sub-sectors were re-aligned to reflect the delegates present.