



‘The economic impacts of natural hazards in coastal zones, taking account of the consequences of climate change’

LIFE Environment Project 2003-2006 ‘RESPONSE’ : LIFE 03 ENV/UK/000611



*Intensive use of the beaches of Regione Marche, Italy;
Courtesy of IRPI & Regione Marche*

CONTEXT

This report forms part of the 2003-2006 LIFE-Environment Project RESPONSE (LIFE/03/ENV/UK/000611), published in September 2006.

It has been prepared by the Project Leader, the Isle of Wight Centre for the Coastal Environment, Isle of Wight Council, UK, with the assistance of the Project Partners in the UK, Italy, France & Poland.

The report is part of **TASK 2 'The Costs of Natural Hazards'**, with it's stated objective as follows:

"Wider Objective: Natural hazards have significant impacts on coastal zones throughout Europe. The costs of emergency action, remediation and prevention represent a significant burden to the communities affected, often local authorities with limited resources. The full financial implications of these hazards are hard to define and are often incorporated with other natural hazards including floods, storms and forest fires. A review of the existing and predicted costs arising from natural hazards in coastal zones (in the context of climate change) will provide a basis from which decision-makers can judge and highlight the benefits of taking cost-effective preventative action now against the consequences and costs of inaction."

CONTENTS

'THE ECONOMIC IMPACTS OF NATURAL HAZARDS IN COASTAL ZONES, TAKING ACCOUNT OF THE CONSEQUENCES OF CLIMATE CHANGE'

FOREWORD –WHY SHOULD WE PLAN FOR THE ANTICIPATED EFFECTS OF CLIMATE CHANGE?

1. INTRODUCTION –WHAT ARE THE NATURE AND SCALE OF COASTAL RISKS?

1.1 Scope and Aims of the Report

1.2 Target Audience

1.3 Types of Natural Hazards

1.3.1 Coastal erosion

1.3.2 Instability

1.3.3 Flooding

1.4 Types of Costs

1.4.1 Economic

1.4.2 Social

1.4.3 Environmental

2. CURRENT COSTS OF NATURAL HAZARDS FOR COASTAL COMMUNITIES IN EU COASTAL ZONES

2.1 Introduction

2.1.1 Why is it necessary to assess the costs?

2.1.2 How can the costs be assessed?

2.1.3 How is this information used?

2.1.4 Limitations

2.2 Economic costs

2.2.1 Emergency Action and Remediation
Who Pays?

2.2.2 Coastal Management and Protection

2.2.3 Insurance

2.3 Environmental Costs

2.3.1 Cost to environment

- 2.3.2 Cost to society
- 2.3.3 Solutions?
 - Sediment balance
 - Managed realignment

2.4 Social Costs

- 2.4.1 Fatalities
- 2.4.2 Stress/depression
- 2.4.3 Time
- 2.4.4 Forced choices

3. ADDITIONAL FINANCIAL IMPACTS OF CLIMATE CHANGE FOR COASTAL COMMUNITIES IN EU COASTAL ZONES

- 3.1 What is the current climate?
- 3.2 What have the trends been?
- 3.3 What are the main factors expected to change?
- 3.4 What would be the effects of this?
 - Extreme Events
 - Rapid Climate Change?
 - Uncertainties
- 3.5 What will the financial impacts be?
- 3.6 What will the environmental impacts be?
- 3.7 What will the social impacts be?
- 3.8 How can we prepare/protect ourselves against this in the EU?
 - Insurance
 - Planning

4. DIFFICULTIES IN OBTAINING INFORMATION ON THE COSTS OF THESE PARTICULAR HAZARDS

5. COSTS OF CLIMATE CHANGE IN THE RESPONSE PROJECT STUDY AREAS: CASE STUDIES OF COSTS IN VARIED EU COASTAL ZONES

- 5.1 Costs of Coastal Risks and Climate Change in the UK
 - 5.1.1 What is at risk?
 - 5.1.2 The cost of protection
 - 5.1.3 Implications of climate change
 - The Stern Review on the economics of climate change
 - Predicted sea-level rise around the UK coast
 - 5.1.4 SCOPAC Coastal Study Area, central south-coast of England
 - The Isle of Wight
 - The Ventnor Undercliff, Isle of Wight, UK

5.1.5. North Yorkshire Coastal Study Area, north-east coast of England
Holbeck Hall Landslide, Scarborough, 1993.

5.2 Costs of Coastal Risks and Climate Change in Poland

5.3 Costs of Coastal Risks and Climate Change in Italy

5.3.1 Regione Marche Coastal Study Area, central-east coast of Italy

5.4 Costs of Coastal Risks and Climate Change in France

5.4.1 Languedoc-Roussillon and Aquitaine Coastal Study Areas, southern and south-west coasts of France

6. CONCLUSION AND KEY MESSAGE

REFERENCES

ANNEX 1 : FRENCH PROJECTS AND WORKS COSTS TABLES

ANNEX 2 : FRENCH CASE STUDIES

ANNEX 3 : DATABASE OF REFERENCES ON THE COSTS OF NATURAL HAZARDS AND CLIMATE CHANGE

Foreword

Why should we plan for the anticipated effects of climate change?

	EC Environment Commissioner Stavros Dimas Brussels, 7th July 2006; SPEECH/06/444 <i>"Winning the battle against climate change concerns us all. The time of theoretical debates about climate change is over, we need practical and effective actions."</i>
  	6th Environmental Action Programme: "Environment 2010: Our Future, Our Choice" <i>"The scientists have told us clearly that we must face up to climate change or else accept dramatic consequences."</i> (Environment Commissioner Margot Wallström) <i>'A certain degree of climate change is expected to happen and the EU needs to put in place measures to adapt'.</i> European Commission Press Release: Reference: IP/01/102 Date: 24/01/2001 Sesto programma di azione per l'ambiente: "Ambiente 2010: il nostro futuro, la nostra scelta" <i>"La comunità scientifica ci ha detto chiaramente che dobbiamo farci trovare preparati dal cambiamento di clima, altrimenti subiremo conseguenze drammatiche."</i> (il Commissario per l'ambiente Margot Wallström) <i>Frattanto non è da escludere che il cambiamento climatico si faccia sentire in certa misura, ragion per cui l'UE deve approntare opportune misure preventive.</i> European Commission Press Release: Reference: IP/01/102 Date: 24/01/2001 6ème Programme d'action en faveur de l'environnement: "Environnement 2010: notre avenir, notre choix" <i>"Les scientifiques nous ont clairement signifié que nous devons nous atteler au problème du changement climatique ou bien accepter d'en subir les conséquences graves."</i> (Mme Margot Wallström, commissaire chargée de l'environnement) <i>'Un changement climatique d'une certaine ampleur est prévu et l'UE doit prendre des mesures pour y faire face.'</i> European Commission Press Release: Reference: IP/01/102 Date: 24/01/2001
	EUrosion Project Launch, May 2004, "Living with Coastal Erosion in Europe: Sediment and Space for Sustainability", Commissioned by EC DG Environment <i>'Europe's coast is under growing threat from erosion...A fifth of the enlarged EU's coastline is already severely affected, with coastlines retreating by between</i>

	<i>0.5 and 2 metres per year, and in a few dramatic cases even by 15 metres...The estimate of the current total value of economic assets located within 500 metres of the EU's coastline, including beaches, agricultural land and industrial facilities, is €500 to €1,000 billion. Public expenditures to fight erosion are increasing. In 2001, they amounted to an estimated €3.2 billion.'</i> EuroSION Results Press Release 'European Commission puts spotlight on coastal erosion', IP/04, Brussels, 17 May 2004
	Professor Jacqueline McGlade, Executive Director, European Environment Agency; <i>"...Climate change is already happening and having widespread impacts, many of them with substantial economic costs, on people and ecosystems across Europe...Strategies are needed, at European, regional, national and local level, to adapt to climate change."</i> BBC News Online, 'Europe 'must adapt on climate'', Wednesday 18 August 2004
UNITED NATIONS 	UN Secretary-General Kofi Annan*, Senior UN official Klaus Toepfer**, United Nations: New York, 28th September 2006; SG/SM/10665/ENV/DEV/903. <i>"We need to adapt to the climate change that is inevitable because of the massive accumulation of past emissions. We are far from helpless in the face of this challenge. There are many things we can do to reduce risks and protect ourselves from the extreme weather associated with climate change. Climate change still tends to be perceived as an environmental concern. But it has profound implications for jobs, growth, health and almost all other aspects of human well-being, including security."*</i> BBC News Online '2003 climate havoc 'cost \$60bn'' Thursday 11 December 2003 <i>"Climate change is not a prognosis, it is a reality that is and will increasingly bring human suffering and economic hardship".**</i> There has been a heightened frequency of extreme weather events in recent years. "There is growing concern that this trend is likely to continue."*



"Human induced climate-change must be treated as an immediate threat to national security and prosperity, says John Ashton, the UK's climate change envoy. He argues that we must secure a stable climate whatever the cost, as failure to do so will cost far more....What this means is that we need to treat climate change not as a long-term threat to our environment but as an immediate threat to our security and prosperity."

BBC News online, Friday 8th September 2006, 'World's most wanted: climate change' <http://news.bbc.co.uk/1/hi/sci/tech/5323512.stm>



Prime Minister Rt. Hon. Tony Blair, United Kingdom:

*"Unchecked climate change has the potential to be catastrophic in both human and economic terms". "There are whole communities that are going to be affected. The time to act is now."**

*"No one nation alone can resolve it. It has no definable boundaries," "It is now that timely action can avert disaster. It is now that with foresight and will such action can be taken without disturbing the essence of our way of life, by adjusting behaviour, not altering it entirely." "If there is one message I want to leave with you it is one of urgency,"***

BBC News Online, *'Blair 'shocked' by climate change', Tuesday 14 September 2004, **'PM gives dire warning on climate', Wednesday 15 September 2004

INTERGOVERNMENTAL
PANEL ON CLIMATE CHANGE



Dr R K Pachauri, Chairman, Intergovernmental Panel on Climate Change:

"The effects of climate change on human health, eco-systems, food production, water resources, small islands and low lying coastal areas are likely to be serious."

"The Third Assessment Report, therefore, concluded that the primary economic benefits of mitigation would be in the nature of avoided costs associated with the adverse impacts of climate change."

Address to the Ninth Conference of the Parties to the United Nations Framework Convention on Climate Change, Milan, 10 December 2003



Dr Chris West, Director, UK Climate Impacts Programme:

"No matter how effectively we tackle the causes of climate change now, there will be some unavoidable climate change due to our past greenhouse gas emissions, so we need to plan for what lies ahead."

"With climate change, we expect to see extreme events, like the autumn floods of 2000 and the summer heatwave of 2003, more often. These affected many people's lives, as well as their businesses, their environment and the local and national economies."

UKCIP Press Release, 'Counting the cost of the impacts of climate change', Friday 25 June 2004



"2005 broke all negative records. Natural catastrophes have never been so expensive, either for the world's economies or for the insurance industry. It was also one of the deadliest years of recent decades."

Munich Re (2006), Annual review: Natural catastrophes 2005.

“Observed throughout the world in recent decades and clearly reflected in the claims burdens of the insurance industry, the increase in natural catastrophe losses is one of the first and strongest pieces of evidence that the impact of global environmental changes generated by human activity is growing.”

Dr. Gerhard Berz, Head of Geo Risks Research Department, Munich Re
(2006), Climate change – Modest warming, dramatic effects.

"We will have to get used to the fact that hot summers like the one we had in Europe this year [2003] must be expected more frequently in the future. It is possible that they will have become more or less the norm by the middle of the century."

“Warmer summers mean a rise in the intensity and frequency of severe weather events. A heated-up Mediterranean and a warm North Atlantic increase the risk that particularly strong low-pressure systems will form in autumn and winter with torrential rain and extreme wind speeds.” “This was confirmed by the devastating floods in southern France at the beginning of December and the intense low-pressure system called Jan over west and central Europe shortly before Christmas.”

Dr. Gerhard Berz, Head of Geo Risks Research Department, Munich Re Press Release,
'Munich Re's analysis of natural catastrophes in 2003', 29 December 2003





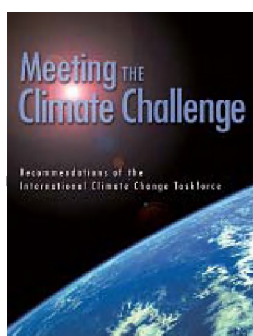
Rt Hon Margaret Beckett MP, UK,

"Recent events show that even wealthy modern societies struggle with extreme events, and developing societies are particularly vulnerable to catastrophe."
"Extreme weather events can be costly, not only in both in human lives and suffering but also in terms of sheer economics. The flooding which swept Europe in 2002 not only caused 37 deaths but cost US\$16 billion in direct costs; the European heat-wave in 2003 led to 26,000 premature deaths and US\$13.5 billion in direct costs."

1st February 2005, Ministerial Address to the Hadley Centre Symposium on 'Avoiding Dangerous Climate Change', held in Exeter 1-3 Feb 2005, published by Cambridge University Press (2006)

"We estimate that man-made climate change has already doubled the risk of such heatwaves. For an IPCC A2emissions scenario, we predict that by the 2060s such summer temperatures will be unusually cool."

Hadley Centre (2004), Uncertainty, risk and dangerous climate change



The International Climate Taskforce:

"Climate change represents one of the most serious and far-reaching challenges facing humankind in the twenty-first Century. Scientific opinion is also agreed that the threat posed will become more severe over coming decades."

"The cost of failing to mobilise in the face of this threat is likely to be extremely high. The economic costs alone will be very large: as extreme weather events such as droughts and floods become more destructive and frequent; communities, cities, and island nations are damaged or inundated as sea level rises; and agricultural output is disrupted. The social and human costs are likely to be even greater, encompassing mass loss of life, the spread or exacerbation of diseases, dislocation of populations, geopolitical instability, and a pronounced decrease in the quality of life. Impacts on ecosystems and biodiversity are also likely to be devastating."

"By contrast, the cost of taking smart, effective action to meet the challenge of climate change should be entirely manageable. Such action need not undermine standards of living. Furthermore, by taking action now and developing a long-term climate policy regime we can ensure that the benefits of climate protection are achieved at least cost."

	Meeting the Climate Challenge, Recommendations of the International Climate Taskforce. 2005. Institute for Public Policy Research, London; Center for American Progress, Washington, D.C.; the Australia Institute, Canberra.
	<i>"Of course, in coastal areas, natural disasters will take place. We can certainly warn communities against them if we have adequate and effective warning systems. But we must also understand that natural disasters are going to take place no matter what. If climate change is going to exacerbate conditions, which would enhance the severity of the impacts, then that adds another responsibility that the global community has to accept."</i> Cambridge University Press (2006), Avoiding Dangerous Climate Change.
	Association of British Insurers: <i>"In the UK, climate change could increase the annual costs of flooding by almost 15-fold by the 2080s under the high emissions scenario, leading to potential total losses from river, coastal and urban flooding of more than \$40 bn (£22 bn).....Taking account of climate change in flood management policies, including controlling development in floodplains and increasing investment in flood defences, could limit the rising costs to a possible four-fold increase (to \$9.7 bn or £5.3 bn)."</i> Association of British Insurers (2005), Financial Risks of Climate Change, Summary report, June 2005.
G8 Group	<i>"Climate change is a serious and long-term challenge that has the potential to affect every part of the globe. Adaptation to the effects of climate change due to both natural and human factors is a high-priority for all nations."</i> G8 Gleneagles Communiqué, 8th July 2005 (European Commission, United Kingdom, France, Italy, Germany, Russia, Japan, USA, Canada).

1. Introduction –What are the nature and scale of coastal risks?

1.1 Scope and Aims of the Report

Natural hazards such as coastal erosion, flooding and landsliding have significant impacts on coastal zones throughout Europe. The costs of emergency action, remediation and prevention represent a significant burden to the communities affected, often local or regional authorities with limited resources. It is widely accepted that the impacts of climate change are real, and sea level rise in particular poses serious risks to coastal communities. Sea-level rise and the predicted increase in the intensity of storms will affect patterns of coastal erosion and flooding, and increase the incidence of damaging storm events. In order to protect assets in the coastal zone it is necessary to establish the impacts of current hazards and risks and the future consequences of climate change, to implement sustainable management policies in order to reduce the risks for future generations.

In 2005, Europe suffered 648 natural catastrophe loss events (a loss event is defined as an earthquake, tsunami, volcanic eruption, windstorm, flood, temperature extreme or mass movements). These resulted in 336 fatalities, and overall losses of US\$ 16,002m (insured losses of US\$ 4,875m). In the summer of 2005 Central Europe was affected by extreme floods which hit the entire northern Alpine region, causing overall losses as follows (in US\$): Switzerland \$2,100m, Germany \$220m, Austria \$700m. All figures are from the report by Munich Re, 2006, Annual Review: Natural Catastrophes 2005. The report by Munich Re recognises that there are clear signs that there has been an increase in the number of westerly weather conditions and a significant rise in so-called Vb weather conditions, the cause of recent flood catastrophes (Odra 1997, Elbe, and the Danube 2002, northern Alps 1999 and 2005). They report that *"what was new in 2005 was that there were three instances of Vb conditions within the space of just six weeks – a clear sign that climate change is already happening in central Europe. This will result in more frequent and more severe events – and, of course, more loss and damage, to which the insurance industry and society as a whole must devise an effective response."* (Munich Re, 2006, Annual Review, Natural Catastrophes, 2005).

Munich Re are equally sure that *natural "Catastrophes will continue to increase around the world. The reasons for this include population growth, an increasing concentration of people and values as a consequence of urbanisation, the settlement and industrialisation of exposed areas such as coasts and river basins, the greater susceptibility of modern societies and technologies and – especially hazardous – changes in the climate and the environment."* (Munich Re, 2006, Annual Review, Natural Catastrophes, 2005).

The future of coastal areas is particularly vulnerable: *"Rises in sea level will threaten to displace entire coastal communities and destroy their assets with severe disruption to adjacent regions and the finance sector."* (Allianz Group and WWF, 2005)

Coastal zones are affected by a range of pressures and interests, and climate change is an additional factor of growing importance for coastal communities and governments at local, regional, and national levels. The EEA Briefing 2006-03 *"The continuous degradation of Europe's coasts threatens European living*

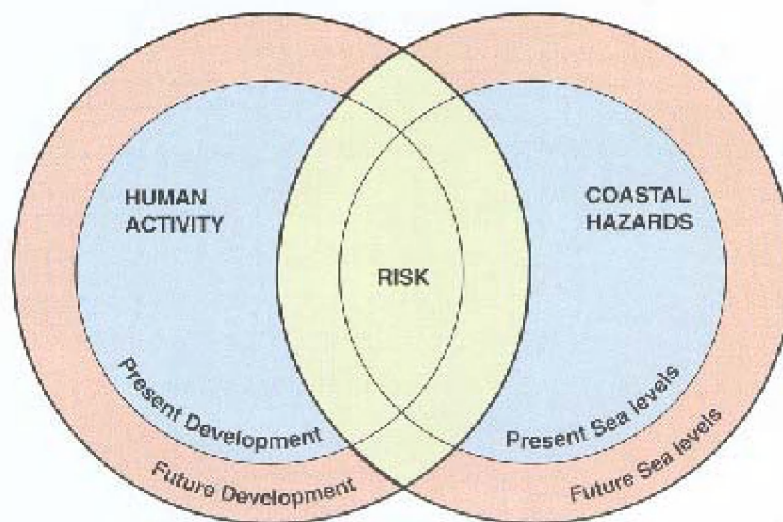
standards' states that "Living by the sea is very attractive. People picture coasts as an immutable asset, yet damaging and irreversible changes to coastal ecosystems continue unabated. Available trends show that changes in land use in coastal areas outstrip those seen elsewhere; for instance, the growth of artificial surfaces along Europe's coasts is increasing at a rate one third faster than in inland areas. These changes are widespread and driven by a range of factors — demographic changes, economic restructuring, increased living standards and leisure time and global trade patterns. In many coastal regions these factors have caused rapid changes that have drastically altered the potential long-term viability of coastal ecosystems and the services they provide. It is increasingly likely that existing impacts on coastal ecosystems will be exacerbated from now on by climate change."



Rockfall on popular tourist beach in Sirolo, Regione Marche, Italy, 2006.



Failure of the A3055 coastal road in April 2001, near the town of Ventnor, Isle of Wight, UK, at the crest of a coastal mudslide (part of the important circular 'round the island' road).



Coastal Hazards, Human activity and risk.
(Adapted from DOE)

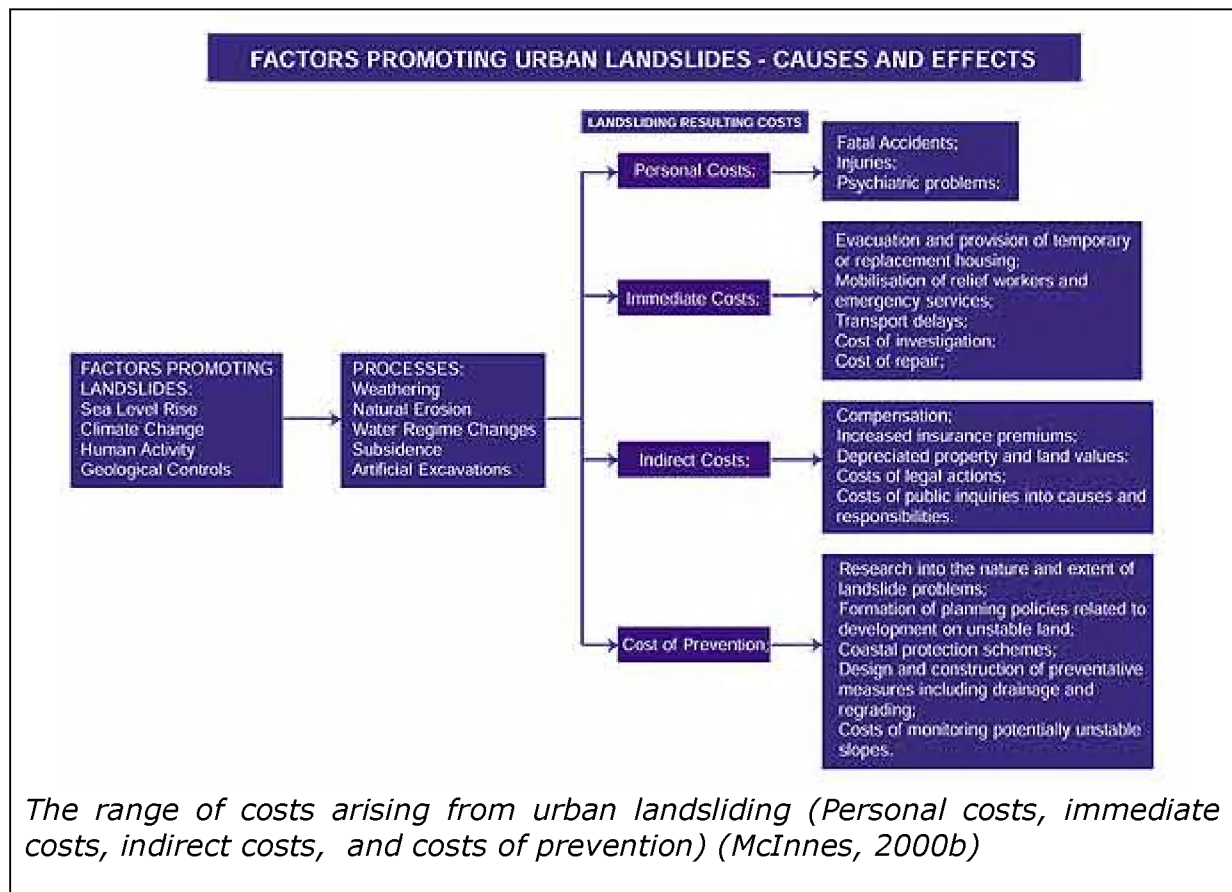
The Concept of risk as the interaction of the human environment with the physical environment is illustrated above. Only when the two systems are in conflict do hazards such as coastal erosion, landsliding and flooding become a threat to the community. Of particular importance is the fact that as urban development increases, intensifies or spreads into vulnerable areas so the potential impact of hazards also increases.

Increasing coastal risks will result from the interaction of climate change & development pressure, and wise decision-making must take account of predicted change (McInnes, 2003).

This report aims to establish the costs of natural hazards for communities in EU coastal zones as a basis from which decision-makers can judge and highlight the benefits of taking cost-effective preventative action now against the consequences and costs of inaction. The main aims are:

- To establish as accurately as possible the current annual costs of natural hazards for coastal communities in EU coastal zones
- To identify the additional financial impacts of climate change for local authorities and interest groups affected by the consequences of climate change in the next 100 years

A range of costs result from the risks arising from coastal change, climate change and natural hazards, ranging from economic to social and environmental. For example, the following diagram illustrates a range of 'costs' arising from landsliding affecting an urban area.



The following table (Table 1) provides a preliminary comparison of the costs of landsliding in a selection of countries.

COUNTRY	DAMAGE COSTS MILLION US \$ COSTS PER CAPITA	AVERAGE DAMAGE US \$ CAPITA/YEAR
Canada	50	0.40
Caribbean	15	0.78
China	500	0.41
Denmark	Up to 3	0.59
Germany	150	1.85
Italy	1140	19.95
Japan	4000	33.13
New Zealand	6	0.71
South Africa	10	0.29
Sweden	Up to 20	2.36
Switzerland	16	2.28
USA	1473	5.65
Notes 1. Calculated average damage cost per capita is estimated on the basis of total population in the year when economic costs caused by landslides were reported. 2. Economic costs are difficult to compare because of the varying recording criteria adopted. However, it allows a broad comparison of the importance of landslide damage in different parts of the world.		

Table 1: Annual damage costs caused by landslides in various countries (after Glade, 1999).

In Italy, for example, the potential significance of instability is illustrated. Over the last forty years major instability events have resulted in substantial loss of life and property in coastal and mountainous areas. In Italy alone there are several dozen deaths a year caused by landsliding.

Fatalities associated with landslides and coastal erosion events are, fortunately, rare in England. The Dorset coast has however seen a series of recent tragedies (Jones and Lee 1994, in McInnes, 2000b): In 1971, a nine year old girl was hit on the head by falling rock at Kimmeridge, and later died of her injuries. At Swanage, a schoolboy on a field course was seriously injured by a rock fall in February 1975, and a year later a young boy was killed by a falling rock. In 1977 a school party were studying the geology of Lulworth Cove, when they were buried beneath a sudden rockslide; a schoolteacher and a 2 pupils were killed. In 1979 a woman sunbathing on the beach near Durdle Door was killed when a 3m overhang collapsed. These incidents, and others, led the Chief Inspector of Wareham Police to coin the phrase "killer cliffs", highlighting the serious danger that rock falls and landslides posed to the community.

The cumulative loss of land associated with rapid cliff top retreat is also a relevant cost. England, for example, experiences some of the fastest cliff retreat rates in Europe. The Holderness coast of north-east England has retreated by around 2km over the last 1,000 years, including at least 26 villages listed in the Domesday survey of 1086. 75 million m³ of land has been eroded in the last 100 years. On parts of the north Norfolk coast there has been over 175m of recession since 1885 (McInnes, 2000b). Rapid erosion as well as cliff falls also occur along the French Channel coast, posing a serious threat to development.

The following European Environment Agency definitions have been used in this report: (<http://glossary.eea.eu.int>)

- *Hazard*
A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period and area
- *Vulnerability*
The degree to which a system is susceptible to, and unable to cope, with injury, damage or harm.
- *Risk*
Expected losses (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability.
- *Natural Disasters*
Events of natural origin that cause health, economic and environmental damage.

Please note: currency conversions into Euros in this report use the European Central Bank rates of 1st September 2006.

1.2 Target Audience

This report is applicable to coastal communities throughout the EU coastal zone, the report will be relevant to all individuals and organisations involved in decision-making including stakeholders and local authorities.

1.3 Types of Natural Hazards

The European Environment Agency (2004) states "Europe's diverse geophysical and climatic characteristics make it susceptible to a wide range of extreme natural events". Natural hazards such as coastal erosion, flooding and instability (landsliding) are a common feature of coastlines in the EU and have the potential to pose significant threat to the communities found within the coastal zone. Operating on different timescales they present a varying degree of risk, coastal erosion is a relatively gradual process whilst flooding and landsliding are more spontaneous, episodic events that are relatively more difficult to predict and are potentially more costly as a result.

1.3.1 Coastal erosion

Coastal erosion is a natural process which is responsible for shaping the great variety of landforms we see around the EU coastline and is defined by the IPCC as the process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water (IPCC, 2001a). Its importance to the coastal environment lies in the fact that it provides a major source of sediment to depositional features such as saltmarshes, sand dunes etc which not only provide us with natural defences but which usually serve as ideal habitats for a diverse flora and fauna and also as an important recreational amenity. However, erosion results in 3 different types of impacts (or risks):

- Loss of land with economic value
- Destruction of natural sea defence as a result of a single storm event, which in turn results in flooding of the hinterland.
- Undermining of artificial sea defences, potentially also leading to flood risk. (After EUrosion, 2004)

It should be noted that although a natural process, coastal erosion has been exacerbated in the past by artificial defences, which can cut off the downshore sediment supply resulting in vulnerability of the coastline elsewhere due to increased exposure at the foreshore. This essentially transfers the problem rather than solving it and relocates if not exacerbates the costs elsewhere. A move towards more sustainable strategies in the future would aim to reduce this.

A major finding of the EUrosion report (EUrosion, 2004) was that the cost of reducing the coastal erosion risks above is mainly supported by national or regional budgets, hardly ever by the local community and almost never by the owners of assets at risk or by the party responsible for coastal erosion. This is emphasised by the fact that coastal erosion risk assessment has not been incorporated in the decision-making processes at the local level and risk information to the public remains poor. Although it should be noted that the EUrosion study focused on coastal erosion specifically and a broader range of risk types is considered here, it highlights the importance of the RESPONSE project in its aim to develop sustainable strategies for managing coastal natural hazards including erosion that will inform land-use development and planning by ensuring decisions are compatible with specific local coastal conditions and also future challenges. Dissemination material outlining best-practice approaches will increase awareness in the wider community.

1.3.2 Instability

Instability is a much more spontaneous problem that faces EU coastal communities. For the purpose of this report the Intergovernmental Panel on Climate Change (IPCC, 2001a) definition of a landslide will be applied, being a mass of material that has slipped downhill by gravity, often assisted by water when the material is saturated. In Europe, most catastrophic landslides are associated with heavy storms and flooding, coupled with soil erosion on mountain slopes (European Environment Agency, 2004a). However, in the Nordic countries, landslides are attributable more to the presence of soft sediments of glacial origin that become a threat when mobilised (European Environment Agency, 2004a). Areas with steep slopes, unstable materials, high soil water content and deforestation are at risk, and the problems posed by these factors are compounded by human activities such as the construction of roads and buildings (European Environment Agency, 2004a). The risk from landsliding in

coastal locations is set to increase in the face of climate change, not least because developments, through choice or necessity, are still being situated in vulnerable areas. The European Project 'Coastal Change, Climate and Instability' (McInnes *et. al*, 2000a) notes that whilst major landslide events inevitably lead to significant loss of life and damage to property in developed areas, minor, longer term failures can also have costly implications through disturbance of structures and damage. This is particularly true for those EU coastal communities which do not have even the most basic monitoring systems and movements may go largely unnoticed, possibly leading to irreversible damage and substantial costs. This again accentuates the importance of integrating natural hazard management into land-use development and planning policies, particularly as there are few mitigation measures that can be implemented to combat large, spontaneous ground movements that occur with little or no warning.

1.3.3 Flooding

Flooding is a major concern facing coastal communities, particularly when considering predicted estimates of sea-level rise. EM-DAT, the international disaster database, suggests that floods comprised 43% of all disaster events between 1998 and 2002 (European Environment Agency, 2004). Foresight (2004) suggests that in the UK alone there are 2 million properties in coastal and fluvial locations at risk of flooding, with 80,000 urban properties threatened with heavy downpours that could overwhelm urban drains. Without suitable action it is expected that flood risk will increase to unacceptable levels for a range of groups, not just people and property but also businesses, hospitals and emergency services. Foresight estimate that if flood-management policies and expenditure remain unchanged within the UK, annual losses here would increase under every scenario by the 2080s. However, the degree of increase will depend largely on a number of factors including the amount of climate change and the extent to which assets continue to be situated in vulnerable locations. This is applicable to all EU coastal communities and the integration of flood risk into the planning and development process is one way of decreasing costs for coastal communities in terms of economic, social and environmental losses.

1.4 Types of Costs

The costs of natural hazards in coastal zones fall broadly into three categories: economic, social and environmental.

1.4.1. Economic

The economic costs of natural hazards in the coastal zone can be sub-divided into two main categories:

- the costs of emergency provision and remediation in the occurrence of a hazardous event (most applicable to landsliding and flooding)
- the costs of mitigating the effects of natural hazards

The costs listed above are the greatest in financial terms and are perhaps the most important from the perspective of local authorities and other organisations responsible for defending the coastline. There are also other, more indirect costs such as insurance costs, depreciation of property/land and legal actions amongst others that are of more immediate importance to those communities directly

impacted by natural hazards. However, for the purpose of this report we aim to establish the overall cost of natural hazards to coastal communities as a whole and since the costs above are publicly funded they are indeed the most important in financial terms.

As outlined in the 'Non-technical Guide to Coastal Defence' (McInnes, 2000c) the cost of emergency provision and remediation encompasses such things as emergency coast protection works, evacuation and provision of temporary accommodation, mobilization of emergency and relief services, cost of investigations, transport delays and other interruptions. Mitigation is also very costly and involves research into coastal evolution and risks, SMPs and Strategy Studies, formulation of planning policies relation to coastal defence, cost of coastal protection schemes (design and construction) and the cost of coastal monitoring.

1.4.2 Social

The social costs of natural hazards are largely intangible. Fatalities are the largest cost and can be measured in real terms but other health-related factors such as stress and depression, which may be related to risk, cannot be measured in the same way. The other factors that impact on the individual/society are largely related to inconvenience and are more difficult to measure. Other accidents on cliff tops due to landsliding, or those as a result of flooding, can possibly be measured in terms of suitable compensation and loss of earnings where it is considered there is cause for blame. The knowledge that one is at risk may also be a social cost to pay. In increasingly busy lifestyles, time has become somewhat of a commodity and the time taken for homeowners to effectively maintain and protect their properties (through regular inspection, clearing of drains etc) can be considered a cost. The inconvenience of property searches for mortgage purposes may also be costly, both in terms of time and finance. The potential for blight increases in areas where risk is not properly understood, and also in communities where greater emphasis is placed upon economic expansion and development as a means of competing with other European communities.

1.4.3 Environmental

Environmental costs are a significant feature of natural hazards, but are difficult to quantify as natural hazards promote natural coastal evolution, which can also be seen as a benefit. For there to be a cost, there implies vulnerability/damage to an asset of specified value. There is a wealth of ecologically valuable land along the coastline, e.g. SPAs/SACs/RAMSAR sites, and in some of these areas a change to a rare or unique habitat can be highly significant. An example of this is the phenomenon of 'coastal squeeze' affecting low-lying saltmarshes backed by hard coastal defences or rising ground. The difficulty arises when we try and quantify value and thus the cost when it is damaged. Environmental mitigation and, wherever possible, enhancement, can result in significant additional costs for coastal construction projects, a growing issue in times of increasingly rapid coastal evolution.

An additional cost is damage or loss of culturally and historically important sites, e.g. those of archaeological value. A particularly important branch of this field is the loss of irreplaceable sites in the littoral, inter-tidal and marine zones containing palaeo-environmental evidence of the nature, scale and pace of past shoreline change. These sites, often sediment archives or sequences of

preserved wooden structures, can be interrogated through pollen analysis or dendrochronology to provide reliable evidence of the rate of change over a much longer timescale than historical maps, and provide an insight into the impacts of the changes impacts on past communities living on the coast. Palaeo-environmental sites and their value for coastal management have been assessed in the Central Southern England Study Area, one of the Coastal Study Areas assessed as part of this RESPONSE Project. The fact that many of these preserved sites are now being exposed, discovered, eroded and lost implies that a significant change has occurred in the pattern of coastal processes from a long-term regime of sediment accretion to one of depletion.

Although the loss/damage to property is a significant economic cost of natural hazards, the environmental loss of the undermining of coastal dunes/natural sea defences is of greater overall cost as it has the potential to impact on several thousands of square kilometres and millions of people who are protected by these kinds of defences (EUrosion, 2004).

2. Current costs of natural hazards for coastal communities in EU coastal zones

2.1 Introduction

2.1.1 Why it necessary to assess the costs?

The costs associated with natural hazards often comprise a large proportion of local authority finance, particularly if there happens to be a major hazardous event which requires emergency response procedures to be implemented. In the event of future climate change it is expected that natural hazards will increase in frequency and intensity over time, which will further amplify the financial burden necessitated by the particular hazards experiences by individual EU communities.

Munich Re's Annual review of natural catastrophes in 2005 (Munich Re, 2006) clearly states that *"2005 broke all negative records. Natural catastrophes have never been so expensive, either for the world's economies or for the insurance industry. It was also one of the deadliest years of recent decades."* *"Overall losses exceeding US\$ 210bn set a new record (the most expensive year before that was 1995 with US\$ 175bn, in original values), although, with some 650 loss events registered, the number of natural catastrophes was in line with the average of the last ten years."*

This project aims to address the problem by advising local authorities and other stakeholders that are often responsible for bearing and reducing part of this burden about cost-effective management solutions that will not only be good value in the short-term, they will also be sustainable and adaptable during the changing conditions at the coast imposed by climate change.

2.1.2 How can the costs be assessed?

The evaluation of costs incurred at the coastal zone will be defined under the classification in Section 1.4. This is not a definitive classification and there is some overlap between these rather broad headings. However, as this report is aimed largely at providing a cost-benefit scenario for local authorities that would

deem the costs discussed above to be the most important for themselves and their communities, it is considered to be sufficient for this purpose.

2.1.3 How is this information used?

Once the costs have been assessed, it is possible to estimate the current financial expenditure relative to that which might be required in 2080 in order to develop a cost-benefit analysis in support of new management strategies.

2.1.4 Limitations

A major difficulty in assessing the costs of natural hazards is the distinct lack of available data concerning the costs of individual hazards, rather than countrywide data on multiple hazards. This is somewhat unhelpful when addressing specific communities at risk and attempting to financially justify the development of a site-specific planning framework, as we have difficulty in providing an effective cost-benefit analysis. However, the available information clearly points to the need for effective and sustainable management schemes into the future as costs are projected to continue rising and defences are in danger of not keeping-pace with predicted climate change scenarios. The need to look ahead and plan our coastal defence strategies accordingly and across the EU is supported by the information below.

2.2 Economic costs

2.2.1 Emergency Action and Remediation

Emergency response plays a key role in minimising the potential costs of a hazardous event. Early warning and preparedness are primarily a means of reducing the social costs of hazardous events, particularly those of the type considered in this report, enabling evacuation procedures to be effectively implemented and at-risk communities to seek refuge. To this end, early warning systems consist of three elements (after ISDR, 2002):

- (i) forecasting and prediction of impending events
- (ii) processing and dissemination of warnings to political authorities and the population
- (iii) undertaking appropriate reaction to warnings.

These measures enable the cost in human suffering and loss of life to be minimised but the economic losses of an inevitable event are more difficult to control, particularly in the case of property loss due to landsliding. Research has shown that flood warnings can reduce the damage to property by more than 25%, but only if properly communicated (Parker et al. (1991), cited in Crichton, 2003). With the technology available today, the ability to provide early warning has allowed structures such as the Thames Barrier in London, UK to be extremely effective at preventing millions of pounds worth of losses to people, property and businesses within the floodplain. It is estimated by the Environment Agency that the costs of a severe flood in the centre of London could possibly top the £30,000 million mark, before considering the cost to human life (Environment Agency, 2004). In comparison, the initial outlay involved with constructing the barrier and its associated defences reached approximately £535 million (valued at £1300 million in 2001 prices), whilst the cost of operating and maintaining the barrier and the associated defences is approximately £6 million per year, plus £5

million on walls and embankments (2001 costs) (Environment Agency, 2004). The Environment Agency operates many smaller flood barriers across the UK that would also be used in conjunction with emergency response procedures.

Who Pays?

In most European countries the government bears the brunt of costs associated with both emergency response and remediation. The emergency services, armed forces, local authority emergency planning departments and national flood warning services (such as the Environment Agency in the UK) can all be mobilised, along with other groups of people including search and rescue teams and the coastguard. Emergency coastal works may also be necessary in some cases. This would all require a substantial degree of expenditure from the government, and would constitute an unavoidable cost possibly reaching millions of pounds. This would be the case for governmental authorities in coastal communities throughout the EU, a significant burden on poorer communities that are already stretched financially. In the UK, the cost of an emergency response may be subsidised by Defra and also through the Local Government and Housing Act 1989, Section 155 (the 'Bellwin Scheme'). The expenditure necessary to cover damage caused particularly by the types of hazards being considered here would be reimbursed above a certain threshold, subject to specific criteria (McInnes, 2003). The media also play a vital role, disseminating important information and instruction to the public at an additional cost.

Householders pay a more personal cost as a consequence of a hazardous event. In addition to fatalities that may occur, the degree of injury and stress experienced, whilst not economic costs, are significant sacrifices to make. Flooding and landsliding can be traumatic events to those affected, particularly when the degree of warning is slight. Rising insurance excesses could be an additional cost to householders, whilst the loss of irreplaceable items is more intangible and again relates to stress and distress. The economic value of time can also be calculated, the loss of productive (working) and leisure time often a significant factor for householders in the occurrence of a severe natural hazard event (see UKCIP, 2004). This would be compounded by the disruption to the transport network and infrastructure that inevitably accompanies hazardous events, particularly flooding. Insurance companies are also dealing with the costs of natural hazards; worldwide insurance losses for natural catastrophes reached almost \$US 100 billion for the 1990s (*Munich Re, 2000*, cited in Crichton, 2003), whilst subsidence costs insurers nearly £1 million per day on average (*ABI, cited in Crichton, 2003*).

The estimated costs for a particular catastrophic event cover damages and recovery of a huge range of assets, and different hazards incur different types of losses. For example, heat waves and drought in central, southern and eastern Europe caused crop failure of an estimated \$US 12.3 billion, whilst forest fires in Portugal were responsible for a further \$US 1.6 billion in damage (Swiss Re, 2004). During 1998-2002 Europe suffered about 100 major damaging floods, causing some 700 fatalities, the displacement of about half a million people and at least €25 billion in insured economic losses (European Environment Agency, 2004). The most effective way of reducing the costs to each of the groups of people affected is to minimise the potential impact of natural hazards. Coastal protection measures are an important means of achieving this, as will be discussed below, but it has also become apparent that an integrated approach to decision-making on this matter, involving participants from all areas of the

community, is necessary to successfully reduce the financial, social and environmental impacts of natural hazards in the coastal zone.

Flooding, both fluvial and coastal, can result in very substantial destruction. To exemplify the degree of loss that can be experienced as a result of a severe natural catastrophe, the European floods of August 2002 are detailed below. Although it would have been impossible to fully protect against an event of the magnitude experienced, the losses were thought to be greater than those that would have been suffered had the planning and land use restrictions been more stringent.

The summer floods in Europe in 2002 were defined by Munich Re as a 'great' natural catastrophe (i.e. the ability of the region is overtaxed, making interregional or international assistance necessary), the 2002 Europe floods constituted one of the worst natural disasters in the region for years. Two meteorological systems moving in the direction of eastern central Europe lead to torrential rain and flooding over wide areas of Europe, including northern Germany, Slovakia, Hungary, Bulgaria, Romania, Ukraine and Moldova. The Elbe area was the region most badly affected but the losses incurred apply to the entire region affected by the flooding event. Germany suffered its greatest ever losses from a natural catastrophe, with the Czech Republic and Austria also suffering huge losses. Munich Re (2003) estimate that the economic losses for Germany stood at €9.2 billion as of the 31st December 2002, the Czech Republic and Austria losing €3 billion each. The overall loss from all flood events in central Europe (all countries affected) in August came to €18.5 billion, of which €3.1 billion was insured (Munich Re, 2003). Non-economic losses included the death of approximately 17 people and the evacuation of 220,000 in the Czech Republic alone, whilst the lower levels of several important historic buildings were inundated (RMS, 2003). The flooding closed 13 stations on the Prague underground Metro, and repairs subsequently continued for at least 6 months, at an estimated cost of €230 million (RMS, 2003). In the aftermath of the flooding, the European Commission signed an agreement to supply Germany with €444 million to 'reimburse expenditure on aid operations, immediately securing flood-protection facilities, repairing waster-water treatment plants and restoring energy supplies, welfare infrastructure such as kindergartens and hospitals, and drinking-water supplies' (EUROPA, 2002). This money was supplied through the European Union Solidarity Fund, a fund aimed at providing assistance to EU communities after major disasters.

2.2.2 Coastal Management and Protection

Coastal protection requires the allocation of a significant amount of public expenditure, costs that are increasing with the recognition that the impacts of natural hazards are set to increase both as a result of climate change and the continued pressure of development in marginal and vulnerable areas. Whilst the development issue can and must be addressed through planning policy, awareness raising of the risks associated with climate change is equally essential. There are three main cost categories for the local authorities that supply the bulk of the money: monitoring, coastal protection, and research. Whilst these are interrelated, they each perform their own function.

One of the most important ways of reducing risk of natural hazards is to continue to develop a "culture of prevention" (ISDR, 2002). Hazard mitigation measures are built to a large extent on warning technologies such as telemetry that can

monitor the accumulation of soil moisture in a watershed that could serve as a warning of sudden flooding downstream, or satellite sensors that might read telltale signs of collapsing hillsides before any incident occurs (ISDR, 2002). Whilst this cannot prevent a catastrophe occurring, it has the potential to significantly limit the impact on the vulnerable communities. Monitoring is an important means of providing a basis for early warning and preparedness. This aims to reduce the costs associated with emergency response procedures by encouraging preparation for an impending event either by protecting people and assets at risk from a particular hazard, or by evacuating those that cannot be protected. In this way we can attempt to develop a "culture of risk prevention". The gauging of floodwaters, particularly during and after heavy rainfall, can allow accurate predictions of how the river level will change based on the monitoring of previous events. As a consequence, the areas at risk from potential flooding can be predicted and suitable action taken to minimise the damage experienced. Bridge sensors can be used as an effective way of triggering warning alarms when the water levels beneath reach critical height. This allows floodgates to be closed where possible and minimises the impacts of a flooding event. In a similar way, the monitoring of ground movement and rates of coastal erosion can allow predictions on future movement in terms of timing and extent. Satellite land movements can detect minimal changes in the land and can help predict the location of possible landsliding events. Monitoring also forms the basis of policy decisions in relation to coastal protection strategy, particularly where the analysis of long-term data trends allows a good understanding of spatial coastal change. This can also assist our insight into the long-term effects of climate change and consequently the level of protection that may be appropriate in the future. It should be noted here that although monitoring goes a long way to assist managing the costs of natural hazards, it has its own costs associated with it. However, these are small compared to the expenditure that would be necessary to cope with the damage and losses associated with unexpected landslide or flooding events, and the damage caused by inappropriate and unsustainable defences constructed after poorly informed decision-making.

The Global Vulnerability Assessment estimated that the coastal protection cost for European coastal states between 1990 and 2020 would exceed €120,000 million, with an additional (indirect) cost of over €41,000 million (EUrosion, 2004). The total cost of coastal erosion for the period would thus add up to over €161,000 million, corresponding to an average of €5,400 million per year (EUrosion, 2004). In 2001, public expenditure dedicated to coastal defence in the EU (against the risks of erosion and flooding) reached an estimated €3,200 million (compared to 2,500 million in 1986). This comprised: new investments made in 2001 (53%), costs for maintaining existing protection schemes and monitoring the coastline (38%) and provision for purchasing coastal land at risk (9%). These costs would include those incurred over the 15km² of land affected by erosion per year in the EU. During 1999 – 2002, between 250 and 300 houses had to be abandoned within this area as a result of imminent coastal erosion risk and another 3,000 houses saw their market value decrease by at least 10% (EUrosion, 2004). However, the number and value of properties to which no loss occurred due to construction or continued maintenance of coastal defences is harder to quantify. Meanwhile the total value of economic assets located within 500 metres of the coastline has increased to an estimated €500-1000 billion in 2000 (EUrosion). Whilst it is unlikely that all of these assets would be at risk, the costs of coastal management strategies clearly do not even approach the damages that would be incurred should the coastline be left unprotected. This is particularly the case as the effects of climate change intensify and development

continues to be forced into marginal areas. There is evidently cause for the development of a sustainable approach to management techniques so that existing and new assets are not compromised for future generations.

A large amount of the expenditure increase seen between 1986 and 2001 (above) represents an increased awareness of the need to protect coastal developments where appropriate and the associated increases in government funding, but conversely this has been necessary due to increases in human induced coastal erosion as developments continue to arise in vulnerable areas of the coastline. This has encouraged calls for the cost of human induced coastal erosion to be controlled through better internalisation of coastal erosion concerns in planning and investment decisions. It has already been recommended (see EUrosion: Policy Recommendation 2, 2004) that "the impact, cost and risk of human induced coastal erosion should be controlled through a better internalisation of coastal erosion concerns in planning and investment decisions. Risks should be monitored and mapped, evaluated and incorporated into planning and investment policies", a recommendation that is supported and developed here.

These figures provide a good overview of how much is being spent on natural hazard protection along EU coastlines but should be treated with a certain degree of caution. It is not specified as to what constitutes coastal protection; the figures are likely to be an underestimate because they primarily reflect the costs of coastal erosion protection and will largely neglect the costs of landslide mitigation, and those of defending against the effects of flooding, figures for which are much more sparse.

Research is the third factor that assists the management of natural hazards. The coastal protection measures implemented have traditionally protected against the current level of risk in the coastal zone. However, it has become increasingly apparent that in the light of climate change the level of threat is likely to alter. As a result it is necessary to define the level of risk expected in the future and to plan accordingly. It is important to research future conditions in order to promote sustainable solutions that will adapt to those conditions so as to minimise the impacts of hazardous events and the associated costs. This will also reduce the expenditure of repairing and replacing defences that have not adapted to the future environment.

Although the loss/damage to property is a significant economic cost of natural hazards, the environmental loss of the undermining of coastal dunes/natural sea defences is of greater overall cost as it has the potential to impact on several thousands of square kilometres and millions of people who are protected by these kinds of defences. Traditionally hard engineering techniques have been implemented as a means of protecting the community. The EUrosion report (2004) found that over the past hundred years the limited knowledge of coastal sediment transport processes at the local authority level has resulted in inappropriate measures of coastal erosion mitigation. This is problematic as we are increasing costs, economic, environmental and social, to ourselves by bad practice and in effect transferring, not solving, the problem. The costs incurred must then not only cover the mitigation measures themselves but then must meet those of the coastal erosion and additional environmental problems at other locations, making the process a very inefficient way of tackling coastal management. Only recently has significant progress begun to be made towards, where possible, incorporating softer engineering solutions such as beach

nourishment and managed realignment so that less of an impact is being made on the natural environment.

2.2.3 Insurance

The insurance industry is actively assessing the growing trends and impacts of natural hazards and recognising the effects of climate change, as quoted by re-insurers Munich Re Group (Munich Re, 2006) in their article on 'Climate change – Modest warming, dramatic effects':

"Observed throughout the world in recent decades and clearly reflected in the claims burdens of the insurance industry, the increase in natural catastrophe losses is one of the first and strongest pieces of evidence that the impact of global environmental changes generated by human activity is growing."

"Changes in exposure and vulnerability do not sufficiently account for the increase in natural catastrophe losses in its entirety, as Munich Re demonstrated in its millennium report on the development of natural catastrophes in the last thousand years. On the contrary, there is mounting evidence that the frequency and intensity of weather-related natural catastrophes are increasingly being influenced by global environmental changes, and above all by climate change."

Insurance against the occurrence of natural hazards assumes acceptance of the risks associated with them and aims to spread the cost between those affected by them. Natural hazards are an ever-burgeoning sector of the insurance market. Recent decades have seen a large increase in losses associated with natural hazards not only due to the fourfold increase in the global population (many concentrated in coastal zones) but also because the number of great natural catastrophes has increased threefold (Munich Re, 2003). This will of course include a number of catastrophes that are not primarily being considered here but it should be recognised that there has been a significant increase in the number of hazardous events and their impacts in terms of losses. There are fears that loss potentials could develop in certain areas that will be 'capable of stretching the capacity of the insurance industry to its limits' (Munich Re, 2003). As a result, the insurance industry has attempted to play an increasing role in managing the impacts of natural hazards through measures such as exclusions and encouraging clients not to rely solely on mitigation loss measures but also to act in an environmentally friendly manner (Munich Re, 2003).

This level of involvement by the insurance industry is particularly evident in Switzerland. The Swiss authorities are familiar with the occurrence of natural hazards and they are responsible for an estimated annual cost amounting to 200 million Swiss francs for landsliding and flooding events (McInnes *et. al*, 2000a). The Swiss insurance industry has ensured that the wider community has also been encouraged to take responsibility for decreasing the risk of natural hazards in their locality by limiting or excluding insurance cover in areas at risk; the insurers define risk zones where they will or will not give cover, with rates of insurance related to the defined risk zones (McInnes *et. al*, 2000a). In a similar way, the Swiss have recognised that the most effective way to combat losses from this source is to incorporate natural hazards into the landuse planning framework, placing real and major constraints on development of land where there is deemed to be a high degree of risk present. All areas of land will be classified under certain hazard zones which will define whether development is possible: red zones represent areas in which development is generally prohibited

and destroyed buildings should not be reconstructed, blue zones depict medium hazard and buildings are allowed under certain restrictions, whilst yellow zones represent low risk areas where it may be appropriate to offer advice on prevention of damages (McInnes, 2000c).

2.3 Environmental costs

As discussed above, the financial implications of natural hazards both in terms of management and losses of assets along the coastline are substantial, and generally represent the most conspicuous aspect of hazard impact. However, the consequences of environmental losses within the coastal zone can be much greater.

The coastal zone forms the interface between the marine and terrestrial environments and due to its nature it therefore hosts large areas of valuable land. This value is mainly attributable to the rich habitats that it supports but certain areas also form an important flood protection function. In this way, the loss of this land incurs two types of costs: the cost to the environment of losing valuable habitat, and the cost to society of losing an invaluable flood protection zone in those areas in which it is present.

2.3.1 Cost to the environment

Coastal zones vary widely in form throughout the EU dependent on location specific prevailing conditions. However, all coastal zones have the potential to be areas of rich and environmentally valuable land. Governments and other environmental organisations have developed several different designations for protected areas within the EU. Of particular significance are heritage coasts that are 'spectacular scenic coastlines that are managed to conserve their natural beauty' (Environment Agency, 2004). Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) are commonplace along the coastline, established to protect the habitats and species of birds and non-birds respectively. RAMSAR sites are also of high ecological and environmental value, and have been the subject of the International Convention on Wetlands of International Importance (especially Waterfowl Habitat) 1971 in order to promote their conservation and protection. Unfortunately half of Europe's coastal wetlands are expected to disappear by 2020 (EUrosion, 2004). There is an additional cost of natural hazards to the environment, in the form of the protection measures themselves. In circumstances where it is necessary to undertake coastal protection works on land that is a designated area of protection, there can be significant loss of habitat and damage to valuable land. Fortunately it is required under the Habitats Directive that mitigation of this effect occurs. Developers and coastal planners must compensate for losses caused during development. In some instances, flooding can have a significant effect on pollution, particularly where it leads to the mobilisation of pollutants present in the soil and contaminates aquifers.

2.3.2 Cost to society

Part of the value of the environment bordering the coastline is that it can, in certain areas, perform a valuable flood protection role. This is particularly true for those regions of the coastline that host areas of saltmarsh and/or coastal dunes. Saltmarshes provide an extremely effective barrier between the marine and terrestrial environments, absorbing excess water, trapping pollutants,

dissipating wave energy during extreme storm events and protecting millions of people and assets across the EU coastal zone. Coastal dunes are also valuable assets performing a protective and dissipative function. Whilst these systems are unlikely to be influenced to any great extent by losses instigated by ground movement, they are threatened by flooding, a real concern in the face of predicted climate change scenarios. Not only will they be affected by inundation as a result of sea-level rise but the increased frequency and intensity of storms also expected, for example in the UK, as a consequence of climate change will promote erosion of these fragile habitats. The benefits of wetlands in terms of their protection against losses, particularly as a result of flooding, are immense and should not be underestimated. They serve the dual purpose of minimising the costs associated with urban flooding damages and engineered defences, but also provide recreational amenity, the loss of which can be considered as an additional cost to society. In an era where sustainability is increasingly cited as the manner in which we should undertake development, it is fundamental that we should avoid losing this kind of asset so that successive generations are able to experience it.

2.3.3 Solutions?

Sediment balance

Coastal erosion and landsliding are the hazards that pose the most damage to areas of high environmental value, as they will result in the permanent loss of this land. The EUrosion project (2004) relates the loss of land through coastal erosion to the sediment in the balance in the coastal zone, and suggests that the sediment balance be restored in order to conserve coastal biodiversity. Traditionally hard engineering techniques have provided benefits only in the short term and have caused longer-term problems by disrupting longshore drift of sediment further down the coast, promoting erosion in these areas (EUrosion, 2004). Softer and more sustainable solutions to coastal defence provide an opportunity to avoid this pitfall and work with the environment's natural defences.

Managed realignment

Managed realignment has received increasing attention in recent years as an effective tool for sustainable coastal management. Given the climate change predictions and the expected rise in costs for flood and coastal defences, artificial creation of wetland habitats are being increasingly considered as a long term feature of flood and coastal defence strategy (Ledoux, 2004). The implementation of managed realignment techniques provides the opportunity to challenge the costs of natural hazards both to the environment and to society within the realm of coastal flooding and erosion. Although the constraints associated with the procedure, including a lack of sufficient compensation to landowners, lack of public support, technical barriers and a lack of a strategic approach have all acted as barriers to its widespread implementation, some believe that it provides a useful alternative to the techniques traditionally in use. This is exemplified by Ledoux (2004), who considers that 'the environmental and economic benefits of managed realignment are an argument for increasing its level of implementation independently of the requirements of the Habitats Directive'.

2.4 Social Costs

2.4.1 Fatalities

In the immediate aftermath of a natural disaster, the most apparent way to measure the magnitude of the event is to assess the costs in terms of loss of human life. This is particularly the case within the media, as it is the cost that can be most widely related to. Munich Re (2003) estimates that there were 459 fatalities in Europe in 2002 as a result of natural catastrophes, the majority of which were caused by flooding. This is a small number relative to the 8,570 fatalities that occurred in Asia in 2002 (Munich Re, 2003). It should be noted that due to the nature of natural catastrophes, the number of fatalities experienced in one year can often be unrepresentative of the average losses over a number of years if a catastrophic event takes place. As a result, a figure for the average losses would give a more accurate picture of the degree of vulnerability in a certain location to natural hazards. Poorer countries/regions are often more vulnerable than those which are developed as they are less well equipped to protect and prepare themselves. They are also more likely to have developments in vulnerable areas, leading to greater costs in the event of a natural catastrophe. The capability of richer countries to protect themselves against natural hazards is exemplified by Hong Kong, which is now the world leader in landslide hazard assessment. During the 1960s and 1970s 200-300 people were killed each year by landslides, due mainly to rapid growth in construction. In response the Geotechnical Control Office (with over 1000 staff) produced a set of controls and recommendations for planning and development and cut deaths by 90% (Geological Society, 2001).

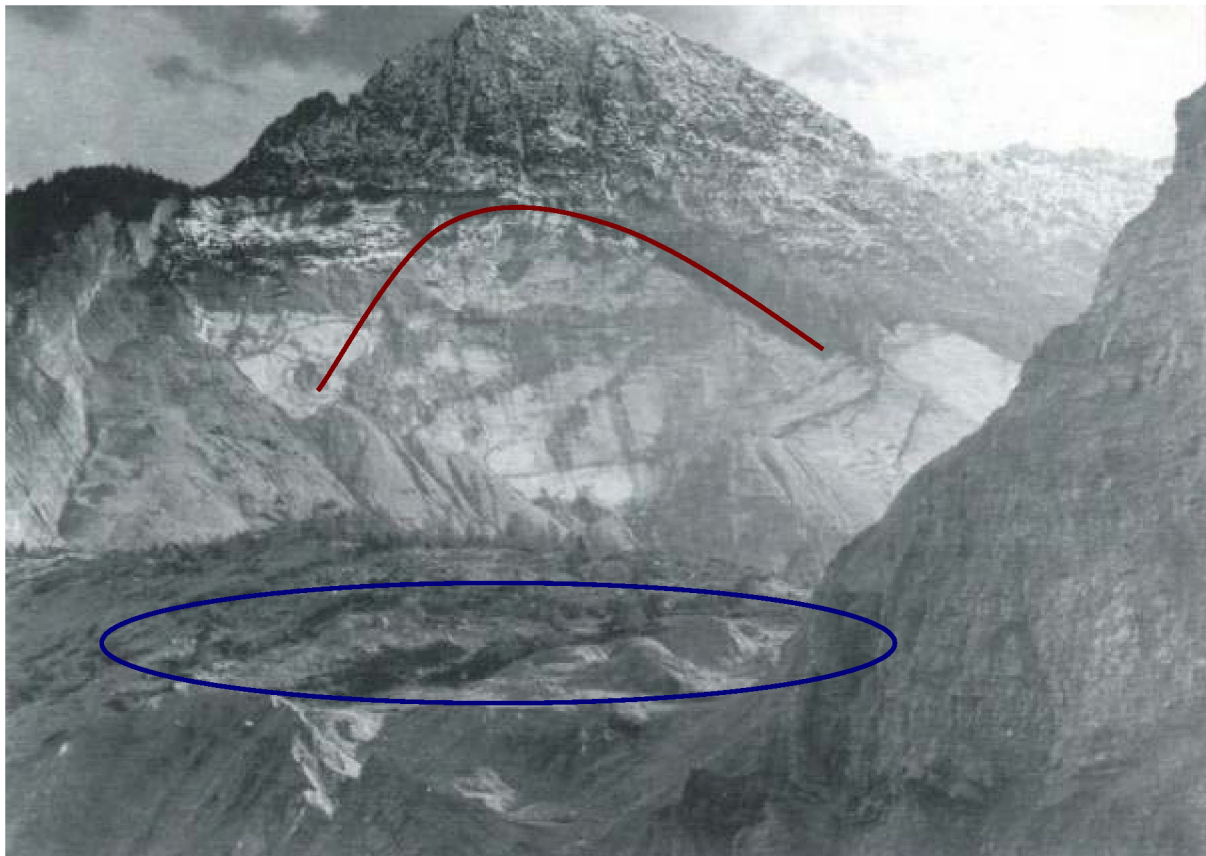
Vajont landslide catastrophe, 1963

In 1963, a massive landslide occurred in the Vajont Valley in the Dolomite Region of the Italian Alps, causing the overtopping of a dam and the death of thousands of people in the valley below. In 1960, the construction of a dam across the Vajont Valley, a deep, narrow gorge, was completed. During construction of the dam there had been some concern from the chief engineer about the stability of the left bank of the dam. Though the possibility of landslides in the valley was discussed, it was thought that a major deep-seated landslide was unlikely. However, at 22.38 GMT on October 9th, 1963, a catastrophic failure of the Mount Toc landslide occurred. As the people in the surrounding villages slept, the mass of the landslide slid into the reservoir behind the Vajont dam and caused a wave to overtop the dam by 245m. The debris flow then travelled down the narrow gorge and flooded a village 500m below, killing 2,500 people. The impact of water on the unstable slope was instrumental in triggering the landslide.

Images of Longarone and Vajont by kind permission of Longarone Commune
<http://www.vajont.net/>



Vajont dam before the landslide filled the lake behind



Vajont valley above the dam, showing part of the scar at the top of the landslide block (in red) and the approximate former location of part of the lake (in blue).



Longarone Valley the day after the landslide and flood, showing the entrance of the Vajont valley (the source of the flood waters) in blue and the approximate location of Longarone village in red (by Zanfron).



Longarone village before the disaster.



Longarone village after the disaster in 1936.



*The sea of the helpers
(by Zanfron)*

2.4.2 Health

Living within a hazard prone area and the knowledge that one is potentially at risk can contribute to a high level of stress. The Global Vulnerability Assessment (carried out for the UN-IPCC) estimated that as a result of sea level rise the annual number of victims of actual coastal erosion or flooding would reach 158,000 in 2020 (EUrosion, 2004). When considering the additional number impacted by landsliding and other hydrogeological problems this figure increases dramatically. Research carried out following serious flooding in Lewes (in Sussex, on the south coast of England) by the Health Protection Agency outlines some of the potential health issues for those at risk. Lewes experienced severe flooding in the year 2000 and it was found that people whose homes were flooded were four times as likely to suffer from psychological distress than those who weren't flooded, and that flooding was also associated with increased risk of earache and sickness and vomiting (Health Protection Agency, 2004). It was also noted that severe flooding may become more commonplace as a result of climate change and therefore it is important to understand the long-term health implications so that it is possible to inform policy for flood prevention and support of flooded individuals and communities (Health Protection Agency, 2004).

2.4.3 Time

Particularly in the case of landsliding, the awareness and action of community members, primarily residents, can go a long way towards reducing the impact of hazardous events. However, this is costly to residents in terms of time and requires that they be 'hazard conscious'. Public awareness campaigns such as flood and ground instability warnings or property protection can aid this process, advocating property inspections, investigation of unusual cracks or other signs of ground movement and carrying out prompt repairs to guttering and swimming pools in areas prone to landsliding.

2.4.4 Forced choices

As discussed previously, the insurance industry is becoming increasingly involved in the area of hazard mitigation by identifying zones in which the risk is considered to be too great to warrant insurance. Developers are also now becoming increasingly restricted by the planning system over where they can construct property. In this way, people are guided towards lower-risk areas which would result in reduced losses should a hazardous event occur. However, the implication of this is that people are unable to live in the areas that they may desire and are victims of forced choice.

3. Additional financial impacts of climate change for coastal communities in EU coastal zones

3.1 What is the current climate?

Europe experiences a fairly diverse climate in terms of regional variations. The IPCC have provided a regional view of current and predicted climate change, affording a valuable basis for estimating the potential effects in terms of coastal hazards. The western and central areas, attributable to the warming effect of the seas, enjoy a temperate climate with mild summers and winters. An important element is the interaction of three pressure centres: the Icelandic Low, the Azores High, and continental highs and lows (IPCC, 1997). Prevailing westerly winds from the North Atlantic bring precipitation throughout most of the year, although rainfall patterns vary significantly. In the Mediterranean, summer months are hot and dry with winter rainfall predominating. From Central Poland eastward, the moderating effects of the seas are reduced leading to drier conditions with greater amplitude in annual variations of temperatures (IPCC, 1997). Northwestern Europe is largely wet and mild with colder winters and generally drier conditions in Sweden and Finland.

3.2 What have the trends been?

Despite significant regional variations, most of Europe has experienced an average increase in temperature of about 0.8°C this century. This response has not been uniform however, with some areas of Greece and Eastern Europe having exhibited a cooling trend over much of the century. Temperature rise has been most marked in the winter months suggesting a greater increase in minimum temperatures compared to maximums. The most significant warming (2°C per century) has been observed in southwestern Europe (Iberian Peninsula, south and central France). Annual precipitation trends show enhanced

precipitation (by 10 to 50%) through the century in the northern half of Europe whilst the region from the Mediterranean through central Europe has experienced an overall decrease (up to 20%).

3.3 What are the main factors expected to change?

The expected climate change in Europe is uncertain. Projections developed in the Europe Acacia project (2000) suggest that annual temperatures will warm at a rate of 0.1 – 0.4°C per decade, with southern (Spain, Italy and Greece) and northeast Europe experiencing the greatest warming and the areas along the Atlantic coastline to a lesser extent. It is suggested by the IPCC (IPCC, 2001) that there may be an overall increase in winter annual temperatures, thus an increase in minimum rather than maximum temperatures accounting for the majority of the warming. Winters currently classified as cold will become much rarer by the 2020s and disappear almost entirely by the 2080s (Acacia, 2000). Most models show an increase in precipitation for Europe, particularly so in the north of the continent. However, there are expected to be seasonal anomalies within this trend, an increase in wetness during winter outbalancing a rise in dryness during the summer in southern Europe (Acacia, 2000). The impact of most potential significance to the coastal zone is sea-level rise, which is predicted to increase by about 5mm/year, two to five times the rate of increase experienced over the past century (IPCC, 2001). The Acacia project (2000) estimates a rise of between 13 and 68cm by the 2050s, noting that natural vertical land movements will induce regional variations in relative sea-level change between these figures. This is exemplified by the south east of England which has which is subject to sinking of the land due to tectonic tilt caused by post glacial rebound (Crichton, 2003).

3.4 What are the expected effects of this?

The effects of the predicted changes in climate outlined above are causing considerable concern to those responsible for coastal risk management. Without more effective and integrated coastal planning and implementation, consequences for the coastal zone could be severe. Both an increase in the intensity of precipitation and a rise in sea level will elevate the risk of coastal flooding, particularly in low-lying areas. This will have particular consequences for sensitive areas that are already close to or below mean sea level such as the Dutch and German North Sea coastlines (IPCC, 2001). Southern Europe also seems to be more vulnerable to these perturbations, but it is noted that northern Europe already has a high exposure to coastal flooding (Acacia, 2000). A rise in sea level will compound the risks already faced by coastal communities as it will likely lead to a promotion of coastal erosion and lead to the inundation and displacement of wetlands and lowlands, the erosion of shorelines, the exacerbation of coastal storm flooding and the deterioration of water quality (IPCC, 2001). Indeed, the EUrosion project (2004) states that 'the prospect of further sea level rise due to climate change and the heritage of mismanagement in the past imply that coastal erosion will be a growing concern in the future'. Coastal squeeze is a phenomenon that will, without doubt, become increasingly common, raising questions over the suitability of hard engineering defence techniques for future use in some locations. The Inter-governmental Panel on Climate Change confirms that the degree of impact felt by coastal communities will depend on their 'adaptation capacity', related to the ability of systems to move inland (IPCC, 2001). In areas where engineering measures prevent this, or

the policy is to protect the land despite the risks, the adaptation capacity is likely to be low.

The European Environment Agency's 2005 Report on Vulnerability and Adaptation to Climate Change (EEA, 2005, from Nicholls and Klein, 2003) lists the potential impacts of a 1m sea level rise in selected European countries in the table below (Table 2), taking as a basis the situation in 1990 with no adaptation or adaptation costs to protect the human population. 13 million people in five European countries could be flooded, with the highest potential impact in the Netherlands. Significant areas of Europe's coastal zones are low-lying and vulnerable to high-tide and storm-surge flooding, which will be exacerbated by climate change effects such as sea-level rise and increase in storm intensity or frequency. The EEA estimates that 9% of all European coastal zones (defined as a 10 km strip) lie below a 5m elevation and are potentially vulnerable to sea level rise (EEA, 2005), with 85% of the coast of the Netherlands and Belgium under 5m elevation, 50% in Germany and Romania, 30% in Poland and 22% under 5m elevation in Denmark, where 100% of the population lives within 50km of the coast. In the UK 75% of the population live within 50km of the coast, whereas the average for the EU is one-third of the population (EEA, 2005).

Country	Coastal floodplain population		Population flooded per year		Capital value loss		Land loss		Wetland loss	Adaptation costs	
	# (k)	% total	# (k)	% total	US\$ (10 ⁹)	% GNP	km ²	% total	km ²	US\$ (10 ⁹)	% GNP
Netherlands	10,000	67	3,600	24	186	69	2,165	6.7	642	12.3	5.5
Germany	3,120	4	257	0.3	410	30	n.a.	n.a.	2,400	30	2.2
Poland	235	0.6	196	0.5	22.0	24	1,700	0.5	n.a.	4.8+0.4/yr	14.5+1.2/yr
Estonia	47	3	n.a.	n.a.	0.22	3	>580	>1.3	225	n.a.	n.a.
Ireland	<250	<5	<100	<1.8	0.17	0.2	<250	<0.3	<150	<0.42/yr	<0.6/yr

Table 2: Potential impacts of a 1m sea level rise in selected European countries (EEA, 2005).

The EEA report also lists the direct and indirect impacts of this potential inundation (EEA, 2005): '*Direct impacts from sea level rise include inundation and displacement of wetlands, lowlands, coastal erosion, increased storm flooding and damage, increased salinity in estuaries and coastal aquifers, and rising coastal water tables and impeded drainage. Potential indirect impacts include changes in the distribution of bottom sediments, changes in the functions of coastal ecosystems and impacts on human activities.*' These direct impacts all have negative consequences and financial costs for the communities affected by these, sometimes radical, changes.

Extreme Events

The MICE Project 'Modelling the Impacts of Climate Extremes', published in 2005 (part of the EU Energy, Environment and Sustainable Development Programme), brought together a team led by the University of East Anglia, UK to examine the potential and consequences of extreme climate events, with the following conclusions for rainfall and windstorm natural hazards (MICE, 2005):

- **RAINFALL:** MICE observes that more intense rainfall has already been recorded, and predictions for the future under the warmer climate scenario of A2 for 2070-2099 include: Northern Europe becoming generally wetter with more days of high rainfall and periods of summer drought and Southern Europe becoming generally drier with prolonged droughts and a

higher proportion of rainfall falling on very wet days. They recognise that the increasing winter rainfall expected over most of Europe will lead to greater flood risk including consequences for flash flooding, urban drainage, water management, erosion, slope stability and ground water recharge. For example, a series of heavy rainfall events in August 2002 resulted in the deaths of 100 people from flooding in Germany, Austria, Russia and the Czech Republic, causing severe damage to housing and public infrastructure and forcing thousands of people out of their homes.

- **WIND:** The MICE report predicts that although fewer storms in total are expected in the future (2070-2099), the number of severe winter storms over Western Europe is expected to increase. Europe's vulnerability to storms is demonstrated by the impact of storm Lothar in France on 26th December 1999, which killed 87 people and destroyed 5000km² of forest. In Western Europe (e.g. UK, France and Germany) windstorms are expected to increase property damage losses by 15% in 2070-2099 under the A2 scenario (compared to the 1961-1990 baseline) with adaptation, or by 20% or more without adaptation. In 1999, for example, a series of three storms produced €16 billion in economic losses (at 2004 prices).

Insurers are warning that *"On the contrary, extreme weather events could become the norm. Adjustment and preventive strategies are therefore more urgently required than ever before."* (Munich Re, 2006, 'Climate change – Modest warning, dramatic effects')

Rapid Climate Change?

In 2004 the Hadley Centre report 'Uncertainty, risk and dangerous climate change' presented recent research on climate change science, with a focus on examining rapid climate change (Hadley Centre, 2004), with the following conclusions. Whilst gradual climate change over the next century is expected, there are some processes which may have a trigger point which, once exceeded, will make changes inevitable, sometimes abrupt and frequently irreversible. Although it is difficult to quantify the risk of these events and the probability of occurrence is low in the current climate, they could be very high-impact, so estimating their global and regional consequences can provide plausible worst case climate scenarios for impacts studies and adaptation planning. The following situations were considered (Hadley Centre, 2004):

- The impacts of an abrupt collapse of the ocean's Thermohaline Circulation (THC) would be large, with cooling over much of the northern hemisphere, though its probability cannot yet be reliably estimated;
- More than half of the Greenland ice sheet could be lost over the next 1,000 years, with a contribution to sea level rise of up to 4m, based on a new Hadley Centre simulation;
- Europe experienced its most intense heatwave on record in 2003, resulting in 15,000 extra deaths. The Hadley Centre predicts that such summer temperatures will be unusually cool by the 2060s (based on the IPCC A2 emissions scenario), and that man-induced climate change has already doubled the risk of such heatwaves.

In June 2005 the report 'Climate Change and the Financial Sector' produced by Allianz Group and WWF states that *"shutdown of THC could result in catastrophic*

changes in ice cover or vegetation, dramatic shifts in the water cycle, and a sharp drop in temperature for the North Atlantic and all those regions which border the Atlantic (East Coast USA and Canada, Western Europe)” resulting in disruption and conflict, with countries exceeding their carrying capacity and consequent large population movements (Allianz Group and WWF, 2005).

Uncertainties

Whilst a relatively large amount of research has been carried out into the possible effects of climate change in the coastal zone, the future remains unsure. Whilst the occurrence of sea-level rise is considered to be all but a certainty, the effects of other, more unpredictable factors such as changes in the frequency and intensity of storms and associated surges are more difficult to plan for. This is particularly so as there is a poor understanding of the manner in which climate change effects will interact within the coastal zone. Consequently these are the factors that are of most concern. Other uncertainties that must be acknowledged include the fact that the use of a number of climate change scenarios lead to several different values for the expected changes in each variable. Outputs from models are generated at a large scale and information on regional and local variability is sparse, although improving. This is a significant point for the purpose of this report, as it is very difficult for local authorities to develop sustainable solutions that will minimise the costs of natural hazards in the future if they have a poor understanding of the level of threat likely to be faced.

3.5 What will the financial impacts be?

A number of translational studies contribute to the wider picture in terms of costs, for example the Association of British Insurers has highlighted that *"Global damages from a 0.5 metre rise in sea-level have been estimated as \$24 – 42 bn per year. Adaptation – in the form of coastal defences – could bring these costs down to \$8 – 10 bn per year."* (ABI, 2005).

Sperling and Szekely produced a paper in 2005 on 'Disaster Risk Management in a Changing Climate', a discussion paper prepared for the World Conference on Disaster Reduction, on behalf of the Vulnerability and Adaptation Resource Group (VARG), which examines to cost of natural disasters globally:

Natural Hazards of hydro-meteorological (water and weather-related) or geological origin can trigger secondary hazards such as landslides, and when the magnitude of the event interacts with the socio-economic and environmental vulnerabilities of the system being impacted, to a degree where it is unable to cope, a disaster occurs. Response to this hazard is based on an understanding of the consequences of inaction and risk reduction measures can then be aimed at reducing both the exposure to the hazard and the vulnerability that may result in losses of life and assets.

3.4 billion people are highly exposed to at least one natural hazard, and on average more than 600 disasters are recorded each year globally. 160 countries have more than one fourth of their total population in areas at relatively high mortality risk from one of more natural hazards, and the majority of disasters are of hydro-meteorological origin (Sperling and Szekely, 2005).

The economic costs of disasters have been increasing for decades due to urbanization, intensification, population growth and environmental degradation. At the time, 2004 was the costliest year for natural catastrophes (a record since

exceeded), with two thirds of the economic impacts attributed to weather-related events, a clear warning in a changing climate, and an estimated global annual cost of 145 billion US dollars. Economic losses have increased by a factor of 7 over the last ten years when compared to 1960-1969 and adjusted for inflation. US\$ 2.5 billion has been spent on relief costs associated with natural disasters from 1992-2003, with World Bank emergency lending of US\$ 14.4 billion from 1980-2003 (Sperling and Szekely, 2005).

Ranked by economic losses, Europe suffered the 4th largest natural catastrophe of 2005, the winter storm Erwin/Gudrun, with 18 fatalities, 5,800m US\$ economic losses and 2,500m US\$ insured losses (Munich Re, 2006 'The five largest natural catastrophes of 2005').

According to the report 'Climate Change and the Financial Sector', produced by Allianz Group and WWF in June 2005, Europe has already sustained severe damage from climate change, and is warming 40% faster than the world as a whole. It quotes examples that *"Storms in 1999 and floods in 2002 each cost 13 billion euros, while a heat wave in 2003 cost 10 billion euros"* and suggests that the European Commission has estimated the future cost of potential cumulative global damage, if no effective action is taken, at 74 trillion euros (present day values). (Allianz Group and WWF, 2005).

The report continues (Allianz Group and WWF, 2005) *"The extraordinary heat wave in 2003 caused 27,000 deaths in Europe and disrupted agriculture, inland shipping, and electricity production. Huge swathes of forests covering a total of 5 percent of Portugal's surface area were destroyed in a loss put at one billion euros. By the end of this century such a summer could be routine. Mediterranean agriculture might be in a state of collapse. Everywhere in Europe rainfall will be more intense. The number of major floods in Europe has already risen from one per year to 15 in recent decades. In the UK, the annual cost of flooding this century will rise to as much as 30 billion euros. Businesses are increasingly reporting reduced profitability because of unusual weather. Many European Union holiday destinations will suffer – in a region where travel and tourism generate about 4 percent of GDP."* In physical terms the drier summers result in clay shrinkage both on the coast and inland. The shrinkage opens up the soils for easy ingress by autumn and winter rainfall, increasing the frequency and seriousness of coastal landslides.

It has been estimated by Gerhard Berz that annual losses in the event that atmospheric carbon dioxide concentrations reach twice pre-industrial levels would reach \$US 0.1 billion for coastal protection measures and \$US 0.3 billion for loss of coastal land (<http://www.ourplanet.com/imgversn/113/berz.html>).

The IPCC have compiled a selection of national figures to emphasize the scale of the human and ecological assets that could be affected by sea-level rise, shown in Table 3 (an extract of IPCC, 2001b): Impacts of sea-level rise in selected European countries, assuming no adaptation, plus adaptation costs.

	Sea-Level Rise Scenario	Coastal Floodplain Population		Population Flooded per Year		Capital Value Loss		Land Loss		Wetland Loss	Adaptation Costs	
Country	(m)	# 10 ³	% total	# 10 ³	% total	US\$ 10 ³	% GNP	Km ²	% total	(km ²)	US\$ 10 ⁹	% GNP
Netherlands	1.0	10,000	67	3,600	24	186	69	2,165	6.7	642	12.3	5.5
Germany	1.0	3,120	4	257	0.3	410	30	n.a.	n.a.	2,400	30	2.2
Poland	0.1	n.a.	n.a.	25	0.1	1.8	2	n.a.	n.a.	n.a.	0.7	2.1
Poland	0.3	n.a.	n.a.	58	0.1	4.7	5	845	0.25	n.a.	1.8	5.4
Poland	1.0	235	0.6	196	0.5	22.0	24	1,700	0.5	n.a.	4.8	14.5
Estonia	1.0	47	3	n.a.	n.a.	0.22	3	>580	>1.3	225	n.a.	n.a.
Turkey	1.0	2450	3.7	560	0.8	12	6	n.a.	n.a.	n.a.	20	10

Source = IPCC: Climate Change 2001: Impacts, Adaptations and Vulnerability

Note: Impacts of sea-level rise in selected European countries, assuming no adaptation, plus adaptation costs (from Nicholls and de la Vega-Leinert, 2000).

"Available national results emphasize the large human and ecological values that could be affected by sea-level rise. The table shows results of national assessments in The Netherlands (Baarse et al., 1994; Bijlsma et al., 1996), Poland (Zeidler, 1997), and Germany (Sterr and Simmering, 1996; Ebenhöf et al., 1997) for existing development and all costs adjusted to 1990 US\$. In the table, adaptation assumes protection except in areas with low population density. People at risk are the numbers of people flooded by storm surge in an average year. Adaptation/protection costs for Poland include capital and annual running costs; % GNP assumes that costs are all incurred in 1 year. Subnational and local studies from East Anglia, UK (Turner et al., 1995); South Coast, UK (Ball et al., 1991); Rochefort sur Mer, France (Auger, 1994); Estonia (Kont et al., 1997); and Ukraine (Lenhart et al., 1996), as well as regional reviews (Tooley and Jeldersma, 1992; Nicholls and Hoozemans, 1996) also support this conclusion. Many of Europe's largest cities—such as London, Hamburg, St. Petersburg, and Thessaloniki—are built on estuaries and lagoons (Frasetto, 1991). Such locations already are exposed to storm surges, and climate change is an important factor to consider for long-term planning and development."

Table 3: Impacts of sea-level rise in selected European countries, assuming no adaptation, plus adaptation costs; Extract from IPCC Report "Climate Change 2001: Working Group II: Impacts, Adaptation & Vulnerability, Chapter 13, Table 13-5" (IPCC, 2001b).

The Netherlands face the greatest potential losses of the selected countries, with a capital value loss of 69% of their GNP and a land loss of 6.7% of the total. This represents a huge loss, particularly when considering that the potential losses of the next most badly affected country of those selected (Germany) only reaches 30% of the total GNP, less than half in comparison. However, the importance of determining an accurate sea level rise scenario can be observed, with the land losses experienced varying from between 0.1 and 0.5% of the total. This variation in predictions makes it difficult for coastal managers to plan effectively for the future.

An additional concern is that climate change could well lead to an increased risk of failure of British dams, causing subsidence of the dam foundations, landslip into the reservoir, or overtopping due to heavy rainfall (Crichton, 2003). Not only of financial concern, the implications of dam failure could extend to substantial areas of society as a result of downstream flooding.

3.6 What will the environmental impacts be?

The Global Vulnerability Assessment (carried out for the UN-IPCC) has estimated that the loss of European coastal wetlands due to sea level rise would exceed 4,500 km² by 2020, which corresponds to 51% of coastal wetlands in 1990 (EuroSION, 2004). It is difficult to measure the value of these areas and has been attempted using techniques including willingness to pay (WTP) or willingness to

be compensated (WTBC) (Ledoux, 2004). However, it is clear that the benefits afforded to habitat and species diversity along with environmental function are increasingly at risk of being lost due to natural hazards, at great cost to the environment as a whole. Cluffed coastal areas, often a haven for a variety of bird species, will often be affected by more rapid coastal erosion and the additional hazard of landsliding where the toe is eroded. Lower lying areas are in danger of flooding and this is particularly the case on wetlands, for example saltmarshes, which are rather fragile environments increasingly threatened by sea-level rise and storm induced inundation. Coastal squeeze is also a serious concern, an issue of particular relevance where 'hard' engineering structures have fixed the landward boundary and erosion of the seaward margin is occurring. This is common where saltmarshes are eroding and will become increasingly prominent as sea level rise progresses.

The IPCC (IPCC, 2001b) used 1990 data on the wetland stock (saltmarsh and unvegetated intertidal areas) in three different coastal regions of the EU (the Atlantic, Baltic and Mediterranean coasts), to estimate the percentage of coastal wetland losses by 2080s assuming no adaptation, shown in Table 4 (an extract of IPCC, 2001b).

Region	Minimum Wetland Stock in 1990 (km ²)			Range of Losses by the 2080s (%)
	Saltmarsh	Unvegetated Intertidal Areas	Total	
Atlantic coast	2,306	6,272	8,578	0 to 17
Baltic coast	226	271	497	84 to 98
Mediterranean coast	347	136	483	31 to 100

Source = IPCC: Climate Change 2001: Impacts, Adaptations and Vulnerability, Note: Estimated coastal wetland losses by region in Europe by the 2080s (new runs using model described by Nicholls et al., 1990). Range of losses reflect range of SRES sea-level rise scenarios and uncertainty about wetland response to sea-level rise. Losses from other causes, such as direct human destruction, are likely. Former Soviet Union is excluded.

"Europe (excluding the FSU) is estimated to have at least 2,860 km² of saltmarshes and 6,690 km² of other unvegetated intertidal habitat, mainly composed of sites recognized in the Ramsar treaty. Based on coastal morphological type and the presence or absence of coastal flood defences, The table shows wetland losses resulting from sea-level rise. Wetland losses are most significant around the Mediterranean and Baltic. Under the A2-high scenario, wetlands in these regions could be eliminated. Any surviving wetlands may be substantially altered. Such losses could have serious consequences for biodiversity in Europe, particularly for wintering shorebird and marine fish populations."

Table 4: Estimated coastal wetland losses by region in Europe by the 2080s; Extract from IPCC Report "Climate Change 2001: Working Group II: Impacts, Adaptation & Vulnerability, Chapter 13, Table 13-4" (IPCC, 2001b).

The Acacia project (2000) states that 'losses and changes to coastal ecosystems are one problem where adaptation measures appear more limited, particularly in the most threatened areas... this shows that there is often a conflict between sustaining socio-economic activity and the ecological functioning of the coastal zone in Europe under rising sea levels which needs to be explicitly addressed by coastal management'.

3.7 What will the social impacts be?

The EEA report 'The changing faces of Europe's coastal areas' published in 2006 encourages coastal residents to be aware of the changes in the environment around them: *"People who decide to live by the coast must take into account the prevailing conditions, such as the physical processes related to sea level rise and the effects of storms, flooding and erosion. A risk assessment of potential property damage from coastal natural hazards and property damage mitigation need to be addressed when living on the coast. Living by the coast should be*

considered as a responsibility, not just a privilege. It should be coupled with the awareness that the coast is a common asset. People not living by the coast but using its resources, such as tourists, should also be involved."

Tables 2 and 3 (above) show the potential number and percentage of the population affected by flooding in selected European countries under various sea level scenarios. These figures suggest the extent of the social impact of just one type of natural hazard in the coastal zone, highlighting the importance of adapting to climate change. A secondary impact of flooding is the effect on human health. Recorded increases in leptospirosis in the Ukraine and Czech Republic in 1997 and in post-flood food poisoning after the Odra flood are examples (IPPC, 2001). The effect on mental health is also significant, as exemplified by the Easter flooding in parts of England during 1998. Tapsell and Tunstall (2000), cited in IPCC (2001a) found that the majority of flood victims interviewed cited stress as the worst aspect of their experience. In addition to this, 50 flood-related suicides were reported in the 2 months following the major floods in Poland in 1997 (IFRC, 1998, cited in IPCC, 2001a).

The IPCC (IPCC, 2001b) used 1990 data of the number of people affected by flooding in three different coastal regions of the EU (the Atlantic, Baltic and Mediterranean coasts), to estimate the percentage increase in the population affected by the 2080s assuming no adaptation.

Region	1990 Exposed Population (millions)	Flood Incidence	
		1990 Average Number of People Experiencing Flooding (thousands yr ⁻¹)	2080s Increase due to Sea- Level Rise, Assuming No Adaptation (%)
Atlantic coast	19.0	19	50 to 9,000
Baltic coast	1.4	1	0 to 3,000
Mediterranean coast	4.1	3	260 to 120,000

Source = IPCC: Climate Change 2001: Impacts, Adaptations and Vulnerability

Note: Estimates of flood exposure and incidence for Europe's coasts in 1990 and the 2080s (new run using model described by Nicholls et al. 1999). Estimates of flood incidence are highly sensitive to assumed protection standard and should be interpreted in indicative terms only. Former Soviet Union is excluded.

"A regional/global model of flood and coastal wetland losses described by Nicholls et al. (1999) considers the interacting effects of sea-level rise, population growth, and improvements in protection standards. All other climate factors are assumed to be constant. This model allows the impacts of the SRES scenarios on Europe [excluding the former Soviet Union (FSU)] to be explored. Because increases in population and protection standards in Europe are minor, the major changes are caused by sea-level rise. In 1990, about 25 million people were estimated to live beneath the 1-in-1,000 year storm surge, with the largest exposure along the Atlantic/North Sea seaboard. However, these people generally are well protected from flooding now. The changes in flooding, shown in the table indicate a significant increase in the incidence of coastal flooding by the 2080s, assuming no adaptation, particularly around the Mediterranean."

Table 5: Estimates of flood exposure and incidence for Europe's coasts in 1990 and the 2080s; Extract from IPCC Report "Climate Change 2001: Working Group II: Impacts, Adaptation & Vulnerability, Chapter 13, Table 13-3" (IPCC, 2001b).

3.8 How can we prepare/protect ourselves against this in the EU?

Insurance

The last few decades have seen increasing concern over the increase in the extent and frequency of natural disasters, with great implications for the international insurance industry. This is primarily as a result of the continuing steady growth of the world population and the increasing concentration of people and economic values in urban areas (Berz, 1999). However, there is the additional contribution of climate change, which is expected to compound the existing problems by leading to increases in storm surges, thunderstorms and

rainstorms, all of which have considerable implications for flooding, coastal erosion and instability in the future.

The insurance bill for extreme weather events and rising sea levels is set to increase tenfold, from £20bn a year to £200bn a year by 2050, making some locations uninsurable. Berz states that the increase is due mainly to 'mounting economic values and insured liabilities in heavily exposed metropolitan areas' (Berz, 1999). Climatic changes could trigger worldwide losses totalling many hundreds of billion of dollars a year, and Berz fears the losses will bankrupt parts of the industry and wants government action to halt climate change. Berz is particularly concerned about the effect on Europe where he says the pattern of insurance losses shows that climate change has already begun. Flooding on the Rhine in December 1993 and January 1995, and in England in 2000 are examples. Despite this, it is thought that costs to the insurance industry can be minimised by adaptive measures if initiatives are taken soon (Acacia, 2000). The insurance industry itself is expected to take an increasingly active role in controlling its costs; as outlined in section 3.2.4 the delineation of areas where insurance cover is refused can act as a deterrent to initial development or redevelopment in the future.

Planning

It has been noted that despite advances in climatic research, the development of climate change is, and will remain, uncertain (Swiss Re, 1998). It is with this understanding that we must address appropriate adaptation strategies, which take into account the continuing existence of risk at the coastal zone. The Acacia project (2000) suggests that 'many of the impacts of sea level rise could be avoided or managed effectively given proactive measures today'. However, this requires long term planning strategies to be developed for coastal management. Indeed, Foresight (2004) states that 'decisions taken today will have a profound impact on the size of flooding risks that future generations will need to manage. They will also strongly influence the options available for managing those risks'. Strategies across EU coastal communities will vary enormously depending on a number of factors. Clearly, an assessment of the importance of the land at risk will be carried out, comparing the assets at risk with the cost of protection. Different countries may have different criteria for land classed as 'at risk', and this will also be influenced by the degree of finance available for protection work. Klein et al. (1999), cited in IPCC (IPCC, 2001a) argue that successful adaptation requires an integrated approach, including recognising the need for 'adaptation, planning, implementation and evaluation'. The European Environment Agency (2004) states the following two reasons (of five) that summarise the need for adaptation to climate change and explain why planning should begin as soon as possible:

- 'anticipatory and precautionary adaptation is more effective and less costly than forced, last minute, emergency adaptation or retrofitting';
- 'climate change may be more rapid and more pronounced than current estimates suggest. There is a risk of under-adaptation and the potential for unexpected sudden events'.

Responsibilities for dealing with natural hazards and climate change impacts are often divided at a national level, with concerns of disaster management, prevention and relief often associated with Civil Defence or Ministries of Interior, whilst climate change policies and international co-operation are frequently

managed by Ministries of Environment and Energy (Sperling and Szekely, 2005). Active co-operation and sharing of information at the highest level are required for effective adaptation. Similarly, synergies are essential in terms of links between regions and local authorities, taking note of advice and guidance from central government.

4. Difficulties in obtaining information on the costs of these particular hazards

A difficulty in assessing and evaluating cost implications of climate change is the lack of coherent data on the costs of individual hazards within the coastal zone. It is recognised by the European Environment Agency (2004) that the exact figures for economic losses are always difficult to determine because data is available only for a proportion of all the events that occur over a given period of time. Frequently, the majority of costs are aggregated together under broad categories, a particular obstacle being the lack of data on the losses and costs associated with landsliding. A further deficiency has been the apparent absence of figures for more localised areas, the majority being for the global, European or national costs of natural catastrophes. In addition, comparisons are difficult to make between Member State costs within Europe because that there is a lack of a uniform method for data collection. Administration and/or legal frameworks may vary widely between countries leading to substantially different collection methods. Certain countries may not have coastal management as high on their national agenda than other countries, mainly reflecting the degree of funding available to different communities, and their varying levels of knowledge concerning the potential impacts of natural hazards on their respective countries or communities. Quoting losses on an EU-scale does not convey the disparities in losses for individual countries; the impact can vary significantly and can be particularly severe for those countries which have economies in transition. Also, estimates tend to vary between sources, particularly where certain publications use estimates and others provide the real cost. In this instance it is difficult to establish accuracy and what the estimates are based on in the absence of the true figure.

In this report it has been attempted to provide an overview of the position of the insurance industry in assessing the costs of natural hazards and its role in attempting to reduce the costs to itself and to society. Despite supplying a large amount of valuable information, the data that it provides should possibly be viewed with a modicum of caution. It could be argued that the industry has a vested interest in disseminating selected information whilst withholding other data as a means of presenting a justification of their premiums.

5. Costs of climate change in the RESPONSE Project Study Areas **>Case Studies of costs in varied EU Coastal Zones**

The results of the RESPONSE project have been developed in within five European coastal areas (shown in the map below) which are regional in scale, ranging in length from 100 to 500km or more. The five Study Areas each represent one of four major oceans and seas surrounding Europe, and these varied and extensive coastal frontages represent a wide range of the geomorphological features and coastal landforms found around the European coastline.

- *SCOPAC region, central south-coast of England (on the Channel/La Manche, a south-facing coastline);*
- *North Yorkshire coast of England (on the North Sea, a north-east-facing coastline);*
- *Regione Marche, central-east coast of Italy (on the Adriatic Sea in the Mediterranean region, an east-facing coastline);*
- *Aquitaine, south-west coast of France (on the Atlantic Ocean, a west-facing coastline).*
- *Languedoc-Roussillon region, southern coast of France (on the Mediterranean Sea, a south-facing coast)*

There is also great diversity within each Study Area. For example the first Study Area (the SCOPAC coast of south-central England) includes hard cliffs, soft cliffs, landslides, saltmarshes, sand dunes, barrier beach, estuaries and shingle beaches, reflecting a diversity of geology, including chalk, sandstone and limestone cliffs ranging in height up to 180m. The Study Areas were selected to ensure they included this diversity. The five Study Areas also represent a range of differing climatic regimes and encompass the spectrum of coastal development, from highly developed and vulnerable coastal towns and cities to high-quality natural environments designated of international importance for birds and habitats.

It is hoped that the diversity of experience and landscape in the Project Study Areas in the UK, France and Italy, with addition of Partner experience from Poland, will provide enhanced understanding of future coastal risks and the costs they will bring to vulnerable coastal regions around the European coastline, comparisons useful for many other communities facing similar issues and problems. The Study Areas also provide a range of national, regional and local political and administrative settings and frameworks, so a range of examples of planned policy and actual practice can be demonstrated. In this context, a range of examples of the costs of natural hazards and climate change are provided in this chapter, drawn from the RESPONSE Project partners.



RESPONSE project coastal study areas:

1. North Yorkshire coast;
2. Central-southern England coast
3. Aquitaine coast;
4. Languedoc-Roussillon coast;
5. Marche coast.

Map © European Community, 2006

5.1 Costs of Coastal Risks and Climate Change in the UK

5.1.1 What is at risk?

It has been estimated that approximately 10% of the population of England and Wales live within areas potentially at risk from flooding or coastal erosion, whilst approximately 12% of the agricultural land (including 61% of the country's Grade 1 agricultural land) is also located in these areas. The number of residential and commercial properties that are located within these areas includes 1.8 million residencies and 140,000 commercial properties. As a crude estimate, this equates to 4-5 million people who could potentially be directly affected by flooding or erosion. This situates property worth over £220 billion and agricultural land worth approximately £7 billion within areas potentially at risk. The majority of these assets are at risk from flooding, coastal erosion accounting for only 2 to 6% of the total capital value of assets at risk. The UK has 15,000 km of coastline with 106 internationally important sites for wintering waterfowl, 10 per cent of which have been identified as under threat from climate change, with a further 10 per cent vulnerable. English Nature estimate that at least 13,000 hectares of English shoreline, much of it vital wildlife habitat, will disappear in the next 20 years. Mudflats could decline by around 10,000 hectares; in the winter 3 million wading birds rely on the UK's mudflats as breeding grounds. Saltmarshes will decline by 2750 hectares by 2020, with two thirds of the loss in southeast England. Ten per cent of saline lagoons are expected to disappear, along with many rare species (all figures from DEFRA, 2001).

The figure of 10% relating to the number of the population living within at risk areas highlights the fact that a huge amount of assets have been allowed to develop in areas which are deemed to be potentially hazardous. This has automatically inflated the figures for the damages which would be incurred should a hazardous event occur, and has led to the need for greater maintenance costs to protect assets that ideally would have been situated elsewhere.

5.1.2 The cost of protection

Without any coastal and flood defences, the annual average economic damage from flooding and coastal erosion in these areas would be over £3.5 billion per year, whilst current standards of defence reduce annual average damages to approximately £0.8 billion per year. Considering the damages that are prevented by the current level of protection, it is clear that the £0.3 billion needed for capital works and maintenance to provide and maintain present defence standards is justified. However, continuing to invest at levels of approximately £0.24 billion per year will result in increasing annual average damage possibly at the rate of some £10-15 million per year (all figures from DEFRA, 2001). This is concerning as it has serious implications for the sustainability of coastal and flood defences into the future.

Association of British Insurers (ABI, 2004) statistics show that storms and coastal flooding in January and February 1990 led to £2.1 billion in insurance claims, the highest figure for weather related claims to date. Over a 4 week period, 3 million claims were received. In the UK storm and flood losses in the period 1998-2003 totalled £6.2 billion, with the prospect of tripling by 2050. Weather risks are already increasing by 2-4% per year on household and property (all figures from ABI, 2004).

The ABI's preliminary estimates of the future costs of weather related insurance claims, in 2004 prices, predict that the costs of coastal flooding in the UK will rise from £5,000 million in an extreme year today, to £40,000 million in an extreme year in 2050, including flooding affecting London (ABI, 2004).

The Association of British Insurers restated the importance of the 'Financial Risks of Climate Change' in their 2005 report, which confirmed (ABI, 2005):

"In the UK, climate change could increase the annual costs of flooding by almost 15-fold by the 2080s under the high emissions scenario, leading to potential total losses from river, coastal and urban flooding of more than \$40 bn (£31 bn). If climate change increased extreme European flood losses by a similar magnitude, annual costs could increase by a further \$120 – 150 bn (£94 – 117bn). In the UK, taking account of climate change in flood management policies, including controlling development in floodplains and increasing investment in flood defences, could limit the rising costs to a possible four-fold increase (to \$9.7 bn or £7.5 bn)."

Another area of future costs, apart from the economic damage discussed above, is the anticipated cost of adaptation. The UK Government DETR produced a report on 'Potential UK adaptation strategies for climate change' in 2000 (DETR, 2000). When costing the impacts of adaptation to climate change, the report assumes an increase in damages caused by coastal flooding of a factor of 2 or 3 over the next 50 years. This would result in an estimated requirement for an

additional £50 million each year for 50 years to strengthen and maintain coastal flood defences in England and Wales, and an additional £1.25 million each year for 10 years in Scotland. These costs would include strengthening and perhaps realigning existing coastal defence structures.

The UKCIP/Metroeconomica produced a report entitled 'Costing the impacts of climate change in the UK' in 2004 (UKCIP, 2004) which aims to allow organisations, such as local authorities, to calculate the resources they'll need for adaptation to climate change.

5.1.3 Implications of climate change

For coastal and flood defences to be able to accommodate climate change a further increase in investment of between 10% and 20% is likely to be required over and above that required to meet indicative standards under present day conditions. Without the acknowledgement of climate change and its implications for future flood and coastal defences, average annual damages will increase by more than 200% on the coast by the year 2050. This again highlights sustainability issues with present defences, particularly as replacement costs have been estimated at £10,300/km/yr for coastal flood defence, £8,400/km/yr for tidal flood defence, and £53,700/km/yr for coastal protection (DEFRA, 2001). These costs have been estimated through consultation with the Environment Agency and various local authorities, and are based on the assumption that the life span of a defence will be approximately 50 years with an additional 10 years residual protection (DEFRA, 2001). It is predicted that a continuation of spending on coastal defence at the current level will see the annual average damage set to increase by 3-9 times by the 2080s, although the worst case spending scenario is still less than current flood losses of £1 billion per year (Foresight, 2004). The costs here remind us of the importance of taking cost-effective preventative action now rather than deal with the consequences and costs of inaction in the future. With a changing climate and uncertainty over the implications beyond the scope of the predictions, preventative rather than remedial action is essential.

Financial implications other than those related to coastal and flood defences are largely associated with the impact of climatic perturbations on assets found within the coastal zone. It has been found that storm tracks are changing and more storms are affecting southern England as a result of milder winters in central Europe (Crichton, 2003). Having not traditionally experienced this level of impact, buildings are not constructed to a sufficiently high standard to enable them to withstand the effects and damage can be significant. Additional changes expected include an increase in the frequency and severity of extreme high water levels as a result of changes in tidal range, a rise in sea level, an increase in storm surge height, and an increase in the frequency and intensity of windstorm events (suggested by the Hadley Centre model only) (Crichton, 2003). These are all factors that are likely to cause a rise in the frequency and severity of flooding events, and the consequent damages. Rainfall in the autumn is projected to increase significantly, with more frequent and severe events. At the same time rainfall in the summer will reduce, but there will still be short duration extreme rainfall during thunderstorms, which will runoff faster when the ground is dry (Crichton, 2003). The south east of England has an added localised contributing factor which is caused by the sinking of the land due to tectonic tilt caused by post glacial rebound (Crichton, 2003), which will accelerate relative sea level rise and exacerbate flooding and coastal erosion in this region even further. Saltmarshes in the UK could potentially benefit from abandonment of

uneconomic coastal farmland under some future scenarios, but habitats such as coastal grazing marsh are threatened under every scenario (Foresight, 2004).

It is thought that the floods experienced across Europe in 2002 may be an indicator that climate change has already begun, and funding has been made available in England for increased investment in defence measures since this event. An increase of 25% was added to the annual budget in 2001-2002, including a one-off payment from the Deputy Prime Minister bringing the total to £150 million (Crichton, 2003). However, spending was reduced back down to the average in the subsequent year, raising concern from the insurance industry. The Association of British Insurers (ABI) forged a two-year agreement with the Government on flood cover, during which time ABI member companies were committed to continue to insure their existing policyholders, save in exceptional circumstances (ABI, 2002), whilst the ABI worked with the government to improve the UK's system of flood management. However, one of the ABI's objectives was to encourage greater investment in flood defences, asking for an increase of £435 million by 2005/2006, a figure that the government has not agreed to provide. It should be noted that the additional funds that have been offered by the government are to come from local authorities, which may not be prepared to deliver (Crichton, 2003).

In July 2004 the UK government launched the 'Making space for water' consultation exercise, which ran until 1 November 2004. The consultation document sought views on a broad range of flood and coastal erosion risk management issues for England to inform development of a new strategy. The intention is that the new strategy (IWCCE, 2006):

- builds upon work to take account of sustainable development and the government's strategic priorities;
- addresses the messages from the Foresight 'Future Flooding' report and reflects lessons learned from the flood events in the recent past;
- addresses the challenges and pressures we will face in the 21st Century such as climate change, development pressures and rising levels of risk and cost; and
- develops a more integrated and holistic approach to the management of flood and coastal erosion risk using a portfolio of measures.

The new strategy for flood and coastal erosion risk management for England will cover the next twenty years or so (whilst also looking beyond), with a commitment to regular reviews.

The Stern Review on the economics of climate change

The UK Chancellor announced on 19th July 2005 that he had asked Sir Nick Stern to lead a major independent review of the economics of climate change, to understand more comprehensively the nature of the economic challenges and how they can be met, in the UK and globally. The 'Stern Review on the economics of climate change' is due to report to the UK Government in Autumn 2006. The terms of reference of the review focus on the economics of moving to a low-carbon global economy but also include the following tasks (HM Treasury, 2006):

"Examine the evidence on:

- *The economic, social and environmental consequences of climate change in both developed and developing countries, taking into account the risks of increased climate volatility and major irreversible impacts, and the climatic interaction with other air pollutants, as well as possible actions to adapt to the changing climate and the costs associated with them;*

Based on this evidence, provide:

- *An assessment of the potential of different approaches for adaptation to changes in the climate."*

The Stern review is intended to change the debate from one which views economic costs against environmental benefits, to one which recognises that there are economic costs and benefits of both action and inaction (UK Prime Minister, Rt. Hon. Tony Blair, 2006).

Predicted sea-level rise around the UK coast

In November 2005 the UK Climate Impacts Programme (UKCIP) published updates to regional net sea-level change estimates for Great Britain. These new estimates are based on the work published in 2002 which included global estimates of predicted sea-level rise, with the new addition of updated calculations of isostatic adjustment data, or relative land/sea-level changes (the estimates of global sea-level change were not revised). The sea-level rise estimates were provided as follows (UKCIP, 2005):

	Regional Isostatic Uplift (+ve) or Subsidence (-ve) (mm/yr)	Net Sea-level Change (cm) Relative to 1961-90					
		Low Emissions 'Low' IPCC Estimate			High Emissions 'High' IPCC Estimate		
		2020s	2050s	2080s	2020s	2050s	2080s
East of England	-0.8	8	13	17	18	42	77
East Midlands	-0.8	8	13	17	18	42	77
London	-0.8	8	13	17	18	42	77
Northern Ireland		No isostatic adjustment data available					
NE England	0.2	3	5	6	13	34	66
NW England	0.6	1	2	3	11	31	63
Scotland	0.8	0	1	0	10	30	60
SE England	-0.5	6	11	14	16	40	74
SW England	-1.0	9	15	20	19	44	80
Wales	-0.5	6	11	14	16	40	74
West Midlands		No coastline or tidal estuaries (at present time)					
Yorkshire & Humberside	-0.7	8	13	17	18	42	77

Table 6: Updated net sea-level change estimates around the UK coastline, November 2005 (UKCIP, 2005).

Table 6 provides new estimates for the UK Study Areas described below, sea-level rise of up to 74cm by 2080 in the SCOPAC Coastal Study Area (section 6.1.4) and 66cm in the North Yorkshire Coastal Study Area (section 6.1.5).

The Association of British Insurers 2005 report on the Financial Risks of Climate Change, (ABI, 2005) predicts that in addition to increases in average sea-level,

extreme sea levels will be experienced more frequently, particularly on the east coast of the UK, occurring with 10 – 30 times the current frequency.

5.1.4 SCOPAC Coastal Study Area, central south-coast of England

Established in 1986, the Standing Conference on Problems Associated with the Coastline (SCOPAC) is a Regional Coastal Group of local authorities and other organisations which share an interest in the sustainable management of the shoreline of central southern England. SCOPAC's area of interest extends from Lyme Bay in the west to Shoreham-by-Sea in the east and includes the Isle of Wight and the coastal waters.



The area of operation of the SCOPAC Coastal Group, UK

The aims and objectives of SCOPAC are to:

- (a) To ensure a fully co-ordinated approach to shoreline management and related matters between neighbouring authorities on the central section of the south coast of England.
- (b) To eliminate the risk of shoreline management strategies carried out by one authority adversely affecting the coastline of a neighbouring authority.
- (c) To provide a forum for the exchange of information on the success or failure of specific types of shoreline management strategies and on future proposals.
- (d) To establish a close liaison with Government and other bodies concerned with shoreline management and related matters.
- (e) To identify aspects of overall coastal management where further research work is required and to promote such research.

Membership of SCOPAC comprises the maritime districts of Hampshire, Dorset, West Sussex and the Isle of Wight, together with the respective County Councils. Full membership of SCOPAC is restricted to those authorities with: (a) Statutory responsibilities for the coastal zone, and (b) a democratically elected base.

SCOPAC MEMBERSHIP

Full Members

- Arun District Council
- Bournemouth Borough Council
- Chichester District Council
- Christchurch Borough Council
- Dorset County Council
- Environment Agency Anglian Region
- Gosport Borough Council
- Hampshire County Council
- Havant Borough Council
- Isle of Wight Council
- New Forest District Council
- Poole Borough Council
- Portsmouth City Council
- West Dorset District Council
- West Sussex County Council
- Weymouth and Portland Borough Council
- Worthing Borough Council

Associate Members:

- Beaulieu Manor Estate
- Chichester Harbour Conservancy
- Crown Estate
- Hampshire & IW Wildlife Trust
- Isle of Wight AONB Partnership
- Poole Harbour Commissioner
- Purbeck District Council
- Southern Sea Fisheries District Commissioners
- Eastleigh Borough Council
- English Nature
- Fareham Borough Council
- Southampton City Council

Table 7: Local Authority and Stakeholder Members of the SCOPAC Regional Coastal Group, central-south coast of England.

Published estimates of future climate change have been reviewed a best estimate applicable to the SCOPAC coast has been derived (SCOPAC, 2001). The key expected changes up to 2080 are:

- Rainfall to be greater in winter (up to 23% increase) but less in summer (up to 20% reduction);
- Global temperature predicted to increase up to 4.7°C;
- Extreme sea levels to rise about 84cm for the 1 in 50 year event;

- Wind and locally generated waves to undergo little change, although wind speed and wave heights likely to increase slightly in the west and decrease slightly in the east of the SCOPAC area; and
- Wave direction to change, an example for Lyme Bay, Dorset predicted a 2° shift in mean wave direction and the potential for the longshore drift direction to be reversed.

The anticipated implications of climate change and sea level rise present a significant challenge to future coastal management in the SCOPAC area. It is expected that there will be increased levels of risk to many coastal assets. Central and local government, including the SCOPAC members, will have to develop and implement policies that address the increasing risks, whilst also meeting the inevitable financial constraints. *SCOPAC "believes that the question of climate change impacts is probably the most important issue to be faced by coastal local authorities and the communities they represent, alongside other organisations, in the coastal zone".*

One of the major hazards climate change will bring for the SCOPAC area (SCOPAC, 2001) is the potential for reactivation of relic landslides due to increased toe erosion and elevated groundwater levels. Such slopes are identified around Lyme Regis, Dorset, and within the Undercliff and on the north coast, of the Isle of Wight, discussed below. The exceptionally wet winter of 2000/01 has already resulted in intensification of reactivations at some locations and is an indication of the conditions that might be expected to occur more frequently in the future.

It is likely that future climate change will make it technically more difficult and increasingly expensive to 'hold the line' of current coastal defences, where they are present. Key pressures are identified as follows: (i) overtopping due to rising sea-levels; (ii) growing potential for combined tidal and fluvial flooding on tidal rivers; (iii) losses of beaches and marshes in front of defences; (iv) increased wave forces on structures; (iv) changing patterns of drift resulting in altered patterns of erosion and deposition; (vii) possible reduction of toe support and an increase in groundwater levels within stabilised cliffs; and (viii) an increased potential for "flash flooding" of low-lying urban areas caused by intense rainfall events.

Relatively few beneficial impacts of climate change can be identified on the SCOPAC coast. Eroding cliffs should supply additional sediments where they remain free to erode. Increased tidal prisms of estuaries may assist in tidal flushing and maintenance of navigable channels. Warmer conditions may encourage coastal tourism.

The Isle of Wight

In 2005 a report was published entitled 'Surviving Climate Change in Small Islands' by the Tyndall Centre with the UK Overseas Territories Environment Programme (Tyndall Centre, 2005). The report recognises that small islands are often economically, socially and physically vulnerable because they are often unable to produce all their own goods and services, have limited resources and many rely on tourism to generate income. Islands are already at risk from environmental hazards such as coastal and river flooding and storm surges, and will be placed under increasing pressure by the impacts of climate change. *"Unfortunately, while small islands are not responsible for the causes of climate change, they are likely to be the first to experience the worst effects of climate*

change, particularly through sea-level rise on low lying islands or through water shortages on porous and low lying islands.” (Tyndall Centre, 2005). Preparation for future hazards is essential, including understanding existing vulnerabilities and actions to reduce the threat of disaster. Adaptation is required now to cope with forthcoming risks.

The Department for Environment, Food and Rural Affairs (Defra) has policy responsibility for flood and coastal defence in England. However, delivery is the responsibility of a number of flood and coastal defence 'Operating Authorities'. In the case of the Isle of Wight on the south-central coast of England, the Operating Authorities are the Isle of Wight Council and the Environment Agency.

As identified in the 1997 Shoreline Management Plan, of the 110km of the shoreline of the Isle of Wight, 45km is defended against erosion. The remaining frontage consists of natural cliff (60km) and low lying coast (5km) (IWCCE, 2006).

On the undefended coast the rate of erosion of clay and sandstone cliffs average 0.3-0.5m retreat per year whilst for the more resistant chalk section the average rate is 0.1m per annum.

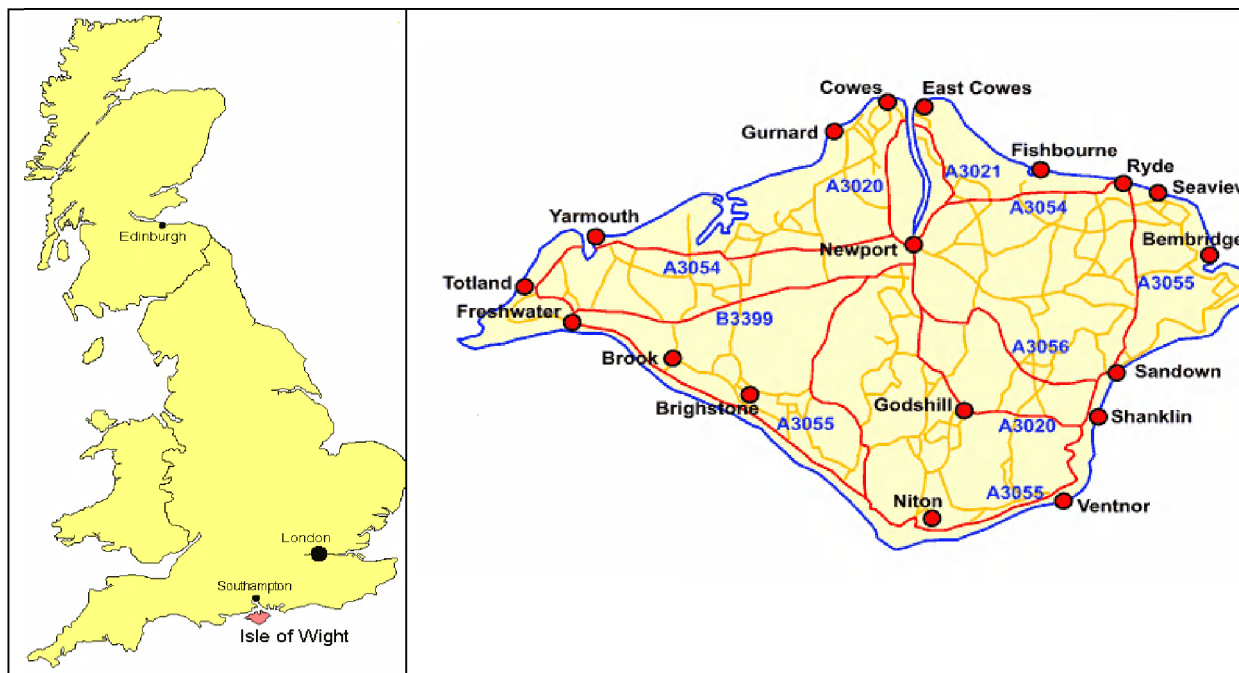
Much of the Isle of Wight coastline is unstable as a result of historic coastal and climate change events and marine erosion has been identified as the key factor in promoting coastal instability.

The 12km 'Ventnor Undercliff' of the Isle of Wight is the largest urban landslide complex in north-western Europe and a strategy is in place for stability management. Existing coastal defences assist in reducing ground instability and protect property and infrastructure a considerable distance back from the coastline. A similar strategy is in place for the Cowes-Gurnard frontage on the Island's north coast.

In addition to inspections of coastal defences, the Council monitors ground instability automatically at key locations (Luccombe, Bonchurch, Ventnor, St Lawrence, Niton, Blackgang and Freshwater) and undertakes risk assessments of unstable clifflines as appropriate. Meteorological conditions are also continuously recorded.

The Ventnor Undercliff, Isle of Wight, UK

The most extensive coastal landslide problem in Great Britain is at Ventnor, on the Isle of Wight, where the whole town has been built on an ancient landslide complex. Although present day coastal retreat is minimal, long-term erosion has helped shape a belt of unstable land which extends almost 1km inland, and 12km in length. Contemporary movements within the town have been slight. However, because movements occur in an urban area with a permanent population of over 6,000, the cumulative damage to roads, buildings and services, and also to public and insurers confidence has been substantial. Over the last 100 years about 50 houses and hotels have had to be demolished because of ground movement. The total cost of landsliding in this area has averaged 1.4 million pa over the last twenty years in terms of structural damage, insurance costs, engineering measures and monitoring (McInnes, 2000b). Investigation, mapping and public participation in steps to improve the ground stability conditions have improved confidence in the area in recent years.



The location of the Isle of Wight, UK

The Isle of Wight Council has invested heavily in protecting and strengthening coastal defences along the Undercliff (to protect the toe of the landslide), over the last ten years. Approximately £12m has been spent on this function, as coastal erosion is a key factor in terms of promoting ground instability. Coastal protection has been undertaken with the assistance of grant aid from the DEFRA under the 1949 Coast Protection Act. The Isle of Wight Council is the Coast Protection Authority and Operating Authority for the Isle of Wight, and has promoted schemes where they are technically and environmentally sound and show a positive benefit cost.

Landslide management involves reconciling a number of conflicting demands, including reducing risk to vulnerable properties, important economic resources and facilities, and protecting areas of scenic, geological or ecological importance. It is important, therefore, that management decisions are based on the best possible understanding of landslide systems and the wider environment, and how to manage and protect it. Landslide management will generally involve a partnership between a wide range of interests, including planners, developers, insurers, environmental managers and the public, together with engineers and geoscientists.

The Isle of Wight Centre for the Coastal Environment, part of the Isle of Wight Council, UK, has developed a 'Coastal simulator' for the 110km coast of the Isle of Wight. The GIS-based system uses 3 orthorectified sets of aerial photos to accurately map coastal retreat from the 1940s to the present day to formulate erosion rates, which are then incorporated into projections of the future coastline based on different coastal defence and climate change scenarios. The projected future coastlines can then be overlaid onto Ordnance Survey base-mapping data to assess the locations and distribution of properties that may be at risk if nothing is done to mitigate the hazard and adapt. This is a useful tool to communicate the impacts of coastal change from scientists to planners, in a systematic and adaptable way.



View of the belt of fallen ground forming the Ventnor Undercliff Landslide Complex, on which terraces of the town of Ventnor has developed since Victorian times (Isle of Wight, UK).



Storm waves at Steephill along part of the Ventnor Undercliff Landslide Complex (Isle of Wight, UK)

5.1.5 North Yorkshire Coastal Study Area, north-east coast of England

The north-east facing coast of North Yorkshire is a coastline of high cliffs and rocky shores, followed by the popular coastal path. The main natural hazards are erosion and reactivation of landslides, sometimes affecting the coastal towns and villages and threatening properties and access. The adjacent North York Moors National Park demonstrates the quality of the natural environment and surrounds the coastal seaside resorts and fishing villages which characterise the coast. The large town of Scarborough is an important family tourist resort town. Between the sandy beaches of the North and South Bays is the harbour overlooked by a rocky headland. Both North and South Bays are backed by the town frontage, with coastal defences protecting built assets and steep coastal cliffs.

Holbeck Hall Landslide, Scarborough, 1993.

Early on Friday 4 June 1993, a large portion of Scarborough's South Cliff collapsed into the sea, on the Northeast coast of the UK.



View from South Bay to North Bay, Scarborough, UK

In the immediate slip area the cliffs had been graded and drained in the late 1890s. The base of the cliff was protected by a sea wall and two retaining walls behind which the cliffs were graded back at a slope of approximately 30 for a horizontal distance of 105m. The distance to the top of the hotel from the top of the cliff was 50m and the total distance from the sea defences to the hotel was 155m.

After the landslide the top of the cliff had regressed by 50m up to the hotel, the toe of the slip extended across the beach for 100m and had buried the existing sea defences. The landslip measured approximately 100m wide and 250m from back to toe. An estimated 1,000,000 tonnes of material was displaced.

The South Cliff has suffered from many small landslides in the 1890s and the hotel gardens and landscaped parts below them were designed and built to aid stabilisation. A large slide destroyed part of the golf course and a section of the Cleveland Way footpath in 1979; this slide was of a similar magnitude to the 1993 slide. Further minor slips occurred following heavy winter rain in 1979. Following these failures the slopes were regraded and gabion protection installed at the toe together with improved drainage measures. The cost of works exceeded £250,000.

Immediately after the landslip, began the development of the stabilisation and monitoring scheme proposals which involved retention of consultants, site investigation and monitoring; the total cost of the preliminary investigations, reports etc was well over £100,000 exclusive of Scarborough Borough Council staff costs.

The final cost for the emergency earthworks, drainage and slope stabilisation and coast protection was £1.5m.

Arising from the landslip a number of important lessons were learned:

Safety: Any crisis brings the need for a rapid response to ensure public safety. Security is expensive in this case it cost £50,000.

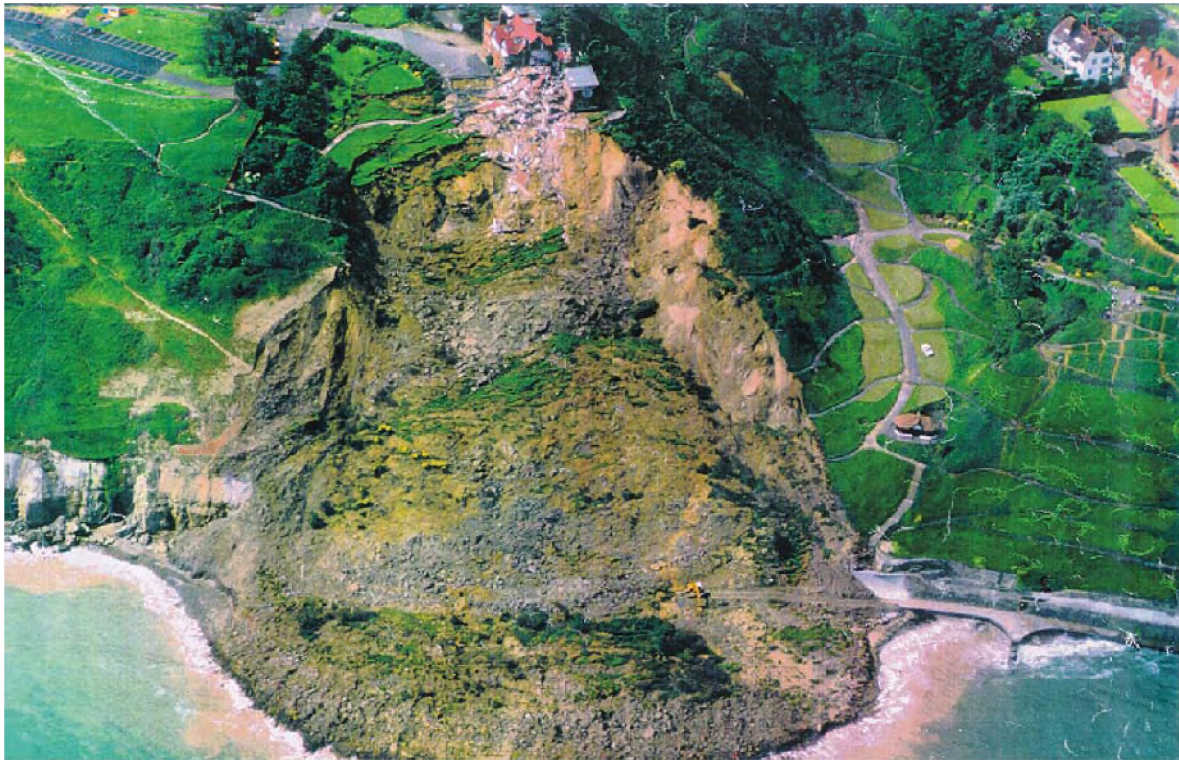
Clay Cliffs: The fact that cliffs have been stabilised in the past is no guarantee of permanent stability. Many cliff stabilisation schemes installed during the early twentieth century and are nearing the end of their design life. Stabilisation works that rely on good drainage are vulnerable. It must be debatable if drainage installed up to 80 years ago, even if it is intact, is operating effectively.

Speed of Movement:

The speed with which the movement occurred: from the first identifiable cracking until the landslide was less than two months. A timescale within which it is impossible to investigate the need for, much less to commission and execute major earthworks.

Strong Local Government:

The management of this incident illustrated the value of having locally strong Local Government with the ability to respond promptly and with the requisite degree of commitment to a major incident.



Holbeck Hall Landslide, Scarborough, UK, June 1993



*Holbeck Hall
landslide after
remediation works
were completed,
North Yorkshire, UK.*

5.2 Costs of Coastal Risks and Climate Change in Poland

The length of the Polish coastline is 845 km. Of that 500 km is open seacoast and 345 is formed by the banks of two large lagoons (Vistula Lagoon and Szczecin Lagoon).

During the last 15 years the average rate of retreat of the Polish open sea coastline was about 0.8 m/year, which, in Polish conditions, corresponds to a loss of about 10 m³ of soil per metre of coastline. The cost of replacing the eroded soil and of rebuilding the dune system, amounts to approximately €20million annually.

Due to legislation and effective management of the coastal zone (especially set-back lines), there are currently few developed sites where assets are at risk due to erosion or flooding. However, this level of assets at risk is likely to increase with sea level rise due to climate change.

Views of the Polish Coastline:





Views of the Polish Coastline

Three sea level rise scenarios have been analysed in Poland: a rise of 30 cm, 60 cm and 100 cm between the years 2000 and 2100. The most likely scenario is thought to be a rise of 60cm. Based on this scenario for the whole Polish coastline (including both lagoons) the anticipated costs are as follows:

- If no measures were taken, the total area in risk of periodic inundation is nearly 2,200 km², and potentially 120 km² could be lost due to marine erosion.
- The estimated value of lost assets would amount to approximately €90 billion, and approximately 178 thousand people would have to be relocated.
- Secondary costs related to relocation would be significant and would include for example, the generation of new work places (costing an estimated €50 billion).
- Additionally, the value of assets at risk of periodic problems would amount to approximately 65 billion Euros and would affect approximately 108 thousand people.
- The effects of sea level rise would indirectly influence a further 1.5 million inhabitants of coastal areas that border the primary areas of risk.
- Ecologically, there are 436 km² of areas of outstanding natural value (European or nationally designated), within the area of risk, which would be destroyed or extensively damaged.

In an attempt to mitigate the above impacts of climate change, a long-term (50 year) coast protection strategy has been developed, which incorporates not only technical, but also land management, legal and organisational factors. The strategy indicates that the most appropriate measure to mitigate the predicted impacts of climate change is selective retreat. Selective retreat means that an appropriate level of safety is ensured for all valuable areas. However, even with the implementation of this strategy, approximately two thousand people may have to be relocated.

The annual cost of implementing this strategy is estimated to be €20 million during the first 10 years, €25 million during the next 15 years and €28-30 million during the last 25 years. These costs include all coastal defence measures, monitoring and research, but do not include the cost of relocation and of possible measures necessary in the hinterland area.

5.3 Costs of Coastal Risks and Climate Change in Italy

5.3.1 Regione Marche Coastal Study Area, central-east coast of Italy

The Marche Region stretches for 172km along the east coast of Italy, on the Adriatic Sea, orientated NW-SE. The Region includes 23 Common territories and 4 Provinces. Natural hazards are a key issue for the Regional and Provincial Authorities in the area, which is one of the foremost areas in Italy for investigating and addressing worsening natural hazards and risks.

Resident population along the coastline is approximately 565,200 people in a 959km² area (40% out of a total population of about 1,430,000 in the Region, in 10% of the total area of about 9,700 km²). Resident population density in the coastal area is almost 15,000 inhabitants living in each square kilometre, and nationally there are a little more than 62,000 inhabitants for each kilometre of coast line. There are 9 harbours, one of which is of a national interest (the maritime harbour of Ancona); the other eight are tourism and commercial fishing destinations.



The location of Regione Marche, Italy



Coastal infrastructure, coastal defences and rockfall risk at Pedaso, Regione Marche, Italy

The chief city of the Region, Ancona (of approximately 100,000 inhabitants), and the second regional town of Pesaro (of about 90,000 inhabitants, also the capital city of Pesaro–Urbino Province), have both been built directly next to the shoreline. The other main towns of the Region (Fano, Senigallia, Civitanova Marche, San Benedetto del Tronto, all with more than 40,000 inhabitants) are also located on the coastal front, forming near continuous conurbation along the Region's coastline, including minor towns and loose residential and commercial settlements along the main transportation infrastructure connecting the Adriatic coastline from north to south. The principal routes of national importance (highway A14, motorway SS 16 and the Bologna–Bari railway) flow along the Marche Region sea border; in some locations the railway track is directly adjacent to the shore and often requires urgent intervention to prevent strategic functional damage arising from rapid coastal erosion phenomena.



The cliffs and coastal developments at Ancona, Regione Marche, Italy.

In terms of physical landforms, the continuous flat beach shoreline (81% of the total length) is broken by the high cliffs of San Bartolo Hill (near Pesaro, in the northeast of the Marche Region) and of Mt. Conero (near Ancona), where the foot of the cliffs are directly washed by sea waves. These two steep cliffs and their surrounding areas are of high environmental and historical-artistic value, which has led to their designation as Natural Parks.

So, almost the entire coastal line of sand or gravel beaches is an important tourist destination, concentrated in the period of May to September. The gross

economic income, directly due to coastal tourism industries (hotel accommodation and beach services), has been carefully estimated at €1,070.00 Million (12.3 Million people x €87/each per day). In Italy, tourists can go to free beaches, which have no facilities or services, or to serviced beaches, where you can rent (for the whole season or the day) beach umbrellas and deck-chairs, and where you can find toilets, water and other conveniences such as beach-front bars and restaurants, commercial activities strongly dependent on the tourists presence, many of them open only in the bathing season (at least from June to September). The beaches are often privately owned and sectioned off by neighbouring hotels, and the intensity of this beach-tourism industry can be seen in the photo below.

These primary incomes drive a strong indirect network of activities (local summer commerce, cultural activities, amusements) as well as a local economic benefit which is converted into the local standard of life; the growth of the beach-tourism industry in recent decades has been reflected in growth in the building industry, in the quality of public and private services on offer, in a high standard of living for an increasing number of people, in the capability to develop and undertake manufacturing and production business, and in a substantially full employment rate.

Therefore the coastline of the Marche Region can be considered both economically and environmentally highly valuable; but the intense urbanization in the last five decades (with development of residential and tourism structures, industrial and commercial activities and infrastructures) has been badly harmonized with physical and environmental features of the coastal area, as it is now affected by different kinds of natural hazards and risks (coastal erosion, river flooding, landsliding, water pollution, seismic risks). Among these, coastal erosion represents one of the most important factors of concern with regards to the stability of the economic system connected to the tourism industry.

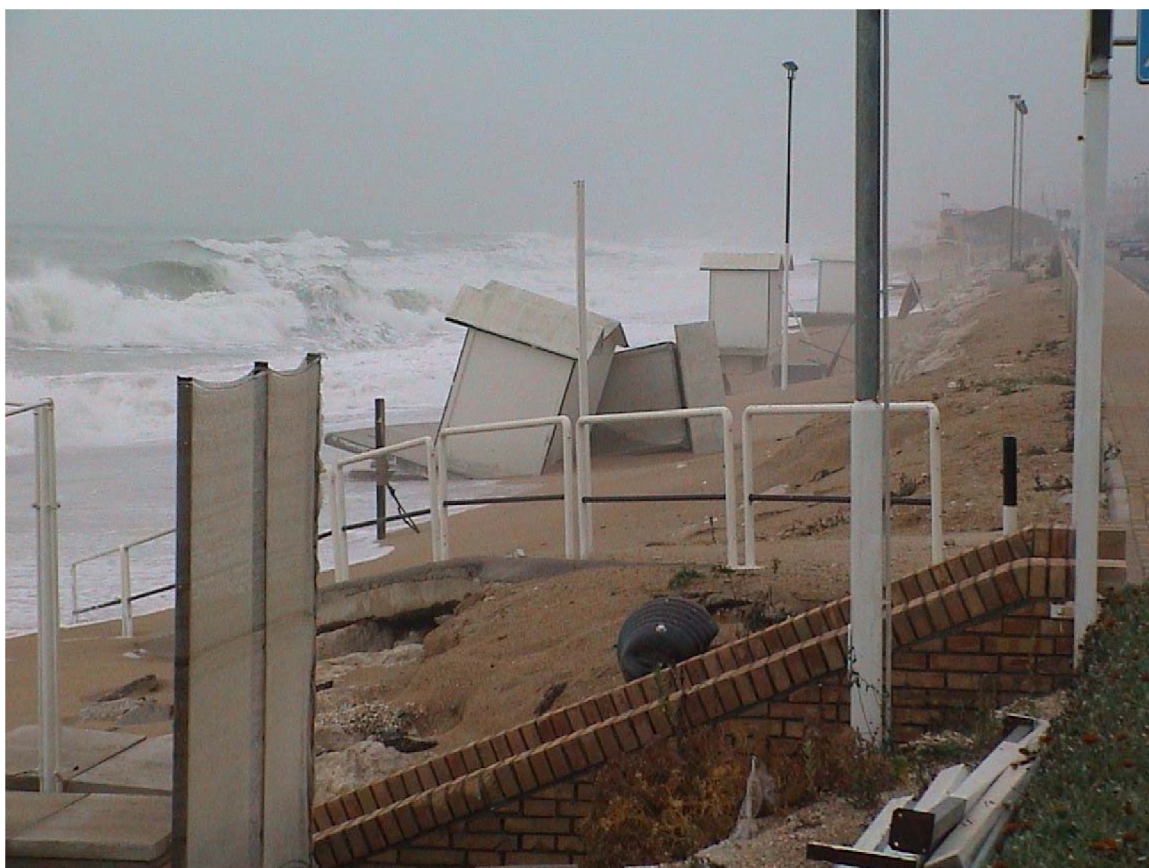
The first coastal defence interventions were built in the second decade of the 20th century when the embankments of the railway, constructed in the late 19th century, were attacked by sea flooding. After this initial protection (walls of huge rocks directly set on the railway embankment slope), a long series of interventions were emplaced along sections of the coastline, as can be seen in the photo of Pedaso.

Coastal protection works defend approximately 100 km (58%) of the coastline from coastal erosion; excluding steep cliffs areas (the two natural parks) and harbours structures. Almost 70% (90 km) of the beach shoreline has been protected.

Many different types of coastal defences have been tested and built; principally rock armourstone located directly on the shoreline where built structures are at risk of flooding, but also offshore rock barriers with crests slightly above average sea level (preventing erosion) or slightly below the surface of the sea (to promote environmental maintenance) – in some locations the techniques have been combined, due to the changing design priorities through time.



The intensity of beach-related tourism industries in Regione Marche, Italy.



Storm damage to the tourism infrastructure and beach profile, Regione Marche, Italy.

Rock armourstone accounts for 95% of protection works, and 5% is represented by beach replenishment techniques, which have very recently been incorporated into regional policies.

The Marche Region developed two strongly related planning instruments in 2004:

- a) to face coastline erosion: a regional law concerning the Integrated Management of Coastal Areas, being followed by a specific Plan (in preparation) to define criticisms of continuous interference between the shoreline and the sea action;
- b) to face river flooding and landsliding: the Plan for Hydrogeological Assets concerning river flooding and landsliding at a regional scale - including coastal areas- aiming to define real hazard and risk conditions, to set land use rules, to locate priority interventions to raise safety conditions and prevent new phenomena.

In these two Plans, expenditure that has occurred on interventions in the last 10 years has been considered; and costs required in the future years have been estimated as follows (actual expenditure will depend on resources and political priorities):

- a) the Plan for Integrated Management of Coastal Areas ("Piano di Gestione Integrata delle Aree Costiere", scheduled for final approval in mid-2005) estimates a total annual cost of €12 Million, which includes interventions for:
 - emergency action and remediation of the present coastal defence system (€5.5 Million);
 - prevention, mostly consisting of intervention for the reconstruction of the undersea shoreline by replenishing sand deposits (€6.5 Million);
- b) the Plan for Hydrogeological Assets ("Piano Stralcio di Bacino per l'Assetto Idrogeologico dei bacini di rilievo regionale" or P.A.I., approved in January 2004) estimates, in the coastal area, a total annual cost of €6 Million, which includes interventions for:
 - remediation and emergency action on coastal landslides (rockfalls from the cliffs of the Pesaro area and the Ancona – Numana cliffs) (€3 Million);
 - remediation of flooding risks in river mouth areas and restoration of natural transportation dynamics along the river beds (€3 Million).

A reasonable estimation of social and environmental costs due to natural hazards is not easy, as the losses can be distinguished as permanent and temporary, functional and structural, direct and indirect, and primary and secondary.

Important losses would result in the direct and indirect tourism framework (hotels, restaurants, museums and artistic locations, landscape tourism) from destabilization of the primary shoreline activities (bathing plants with operators).

Landsliding in the Ancona area could seriously damage parts of the urban development as well as primary national infrastructure (the main railway and motorway links connecting northern and southern Italy run along the Adriatic coast). Environmental and historical assets would also be permanently damaged if landslides occurred in the Monte Conero park area, in which several operators manage their economic activities reliant on environmental quality.



Cliffs of Regione Marche, Italy, with rockfall risk to cliff foot development and industry.

In one area such as Regione Marche, different priorities are present, requiring complex analysis and leading to difficulties in defining absolute priorities in the design of coastal defence interventions. Therefore, improving information and data availability represents the best route to wise decision-making.

5.4 Costs of Coastal Risks and Climate Change in France

> Assessing the present and future costs of coastal risk management

From: The French Study Areas Report for RESPONSE, also contained on the Project CD-Rom. *Reference: C. Vinchon, D. Idier, M. Garcin, Y. Balouin, C. Mallet S Aubie L. Closset 2006, Response of the Coastline to Climate Change. Specific Report for the RESPONSE LIFE-Environment Project: Evolution of coastal risks (Erosion and marine flooding) on the Aquitaine and Languedoc-Roussillon pilot regions, BRGM/RP 54718-FR, July 2006*

5.4.1 Languedoc-Roussillon and Aquitaine Coastal Study Areas, southern and south-west coasts of France

A cautionary remark

In the previous section dealing with existing assets at risk from hazard increase due to potential climate change, it was stressed that the mapped data on assets did not specify their value endangered or give any indication as to the nature of the damage incurred.

In the context of the RESPONSE project, the task was intended to be taken a step further in asset definition by assessing the present and future costs of coastal risk management. Following the cost typology described in the scoping report on coastal risk costs, included in the interim report of March 2005, different cost references have been sought so as to evaluate the present and future cost of coastal risk management.

Data collected on the present cost of coastal risk management have yielded very heterogeneous results, both for different types and within a single type of cost, largely due to the variety of stake holders and projects and the very different scopes of the costs involved.

The decision was made to quote these figures for indicative purposes, but to take care to consider them as a cost range. Furthermore, no attempt is being made to predict future costs in view not only of this heterogeneity of the available data but also because it is not known which strategy will be applied.

Factors affecting choices made for coastal management will naturally include political considerations, but will also take into consideration cost-effectiveness ratios, including a complete scope of implied costs. Such ratios cannot be calculated on a regional scale, and will have to be applied to specific management projects. In this chapter, elements are provided on the assets concerned by increased risk, to gain a regional view of which strategy, if not which cost, might be entailed.

Present-day coastal Risk management costs

Data sources

The figures were derived from the following documents and from oral communication on the part of several organisms.

Hard or soft management data were obtained from several case studies given by the maritime service (SMNLR¹ in the Languedoc-Roussillon region and SMN Gironde and Landes DDE - departmental direction for public works - in the Aquitaine region) giving the global cost of projects, and from a study conducted by CETMEF giving the linear (meters of works) cost of work, calculated in updated costs from data supplied by maritime services.

Data on environmental assets has been drawn from a SMNLR study regarding management strategy for erosion (2003); it furnishes a relative, indexed value of natural assets.

Additional information was made available by CELRL, the Service des domaines (the economic value of natural land) and ONF (dune management costs).

Data on natural disasters came from Munich-Re, a German reinsurance company. However, the figures provided do not distinguish coastal damage from other types of damage. No data was able to be obtained from other reinsurance companies.

Results

Economic costs

Mitigation costs

Table 8 provides a synthesis of the collected data in terms of economic cost referring to the cost of mitigating or attenuating the effects of natural hazards. It was prepared in order to show the known costs involved in the different possible management choices. Directly linked with the value of the assets involved, the choices will be:

- maintaining and upgrading defence works,
- restoring natural processes,
- retreat, implying loss of land and expropriation. This cost is reflected in land value.

This review is not exhaustive. Data sources are indicated in the table, with figures referring to specific projects (data collected from DDE , SM, ONF, CELRL, ...) or from the synthesis concerning the cost of hard defences made by the CETMEF (unpublished). The figures must be construed as a range of values, to be discussed and improved on in the event new data are obtained. Besides, it refers to different units: costs are expressed in euros per linear metric reference for hard and soft defence works, euros per area for land value and euros per cubic meter for sand nourishment. The economic value of natural land when included in the DPM is cited for the sake of comparison. However, such land is legally inalienable; its natural value is estimated on the basis of a relative index proposed by SMNLR and given in Table 9.

¹ A list of acronyms used in this text is provided in table 1 of the report.

It is seen that the average cost of defence works can vary widely according to composition (concrete, wooden piles, rock fill) and size, but also to the distance to the sources of fill materials. The table also shows that the cost range for soft defences is lower.

The cost review on restoring natural processes is far from complete. Costs of beach nourishment are given, as well as an example of an hydraulic by-pass project.

In the Aquitaine region, information on specific projects was contributed by the Landes DDE and SMN Gironde (Annex 1, table 1). No cost data could be obtained from the Pyrénées-Occidentales department. The same range of cost is obtained when cumulating works per township since the 1950's (from 100 K€ to 4000 €). These ranges cover cost data for all types of hard and soft defences, when present, some being projected (i.e., Cap Breton). The information is likely not to be exhaustive either.

Strategic option	Details		Languedoc-Roussillon: present value	Aquitaine: present value	Data for other regions	Data sources
Retreat: land loss	urban zones		≥2.5 M€/ha			SMNLR
	natural zones (DPM)*		5000 €/ha	1500 to 3500 €		DPM, CERLM
	industrial and commercial zones		>0.5M €/ha			SMNLR
	touristic and leisure zones		1M €/ha			SMNLR
	agricultural land salt (including marshes)		5000 to 10000 €/ha			SMNLR
	forest land			1000 to 6000 €		ONF
	public infrastructures		3 M€ /ha			SMNLR
	infrastructures		0.3 to 5 M€/ha			SMNLR
reconstruction of natural processes	preliminary study					
	dune management			3000 €/km-yr		ONF
	by-passing and maintenance)**			1,450,000 €		SM33
	beach nourishment		6 to 50 €/m ³	9 €/m ³		CETMEF
maintenance or upgrading of hard defences	groynes	new	330 to 4800 €/mlw	290 €/mlw		CETMEF
		upgrading		500 €/mlw		CETMEF
		concrete groynes			570 €/mlw	CETMEF
		steel sheet groynes			4000 €/mlw	CETMEF
	breakwaters	new	4600€/mlw			CETMEF
		upgrading	60 €/mlw			CETMEF
		wooden Bw			270 €/mlw	CETMEF

	upper walls	beach	rock	new		1800 €/mlw		CETMEF
				upgrading		290 €/mlw		CETMEF
	cliff engineering			concrete coating		no data		
				Schread ?		12 €/mlw		CETMEF
				injection				
Soft defences				wooden piles groynes			185 €/mlw	CETMEF
				wooden paling		28 €/m		CETMEF
				screen		12 €/m ²		CETMEF
Emergency	population at risk				218 h/km ²	91ha/km ²		INSEE

Table 8: Data collected on different types of defences in the Languedoc-Roussillon and Aquitaine regions.

In the Languedoc-Roussillon region, information on specific projects was given by SMNLR (Annex 1, table 2). It shows that the budget for reinforcing a sedimentary cell varied on an order of 100 to 3000 k€² between 1948 and 2003 to protect the coasts of urbanized and tourist shorelines. The cost ranges cover hard defences (groynes, seawalls and breakwaters) and beach nourishment from existing data, but this cannot be considered exhaustive.

Generally speaking,, those figures, whatever solution is chosen underlines the fact that the choice of defence strategy is to be closely compared to the value of the assets involved and backed up by a cost-effectiveness ratio study.

The economic costs of catastrophic events

Data on catastrophic events are shown in Table 9. Supplied by only one reinsurance company, they are not exhaustive and do not give information on the impact of the events on the coastal zone concerned. The table expresses the costs of the events in terms of insured and economic loss, as well as the population involved. Nevertheless, it displays a high cost range in terms of economic value ranging from a tenth to a hundredth of a million US dollars and/or euros.

² Those figures indicated have not been updated for price increases.

Event	Starting date	Ending date	Sector ?	Region	Description	Deaths	Economic Losses US M\$	Insured losses US M\$	Injured	Missing	Evacuated
Winter storm Nana	11 Feb. 1990	12 Feb. 1990	N, S, W,	Brittany, Pays de Loire, Lower Normandy, Biarritz	Wind speeds up to 160 km/h, hail. Houses and cars damaged. Numerous trains delayed. Roads blocked by downed trees and traffic signs. 75-meter-high crane overturned, tanker drifted from mooring in port of Brest. Promenade of Biarritz flooded. Also affected: the United Kingdom and Ireland.	0	60	30	0	0	0
Severe storm	13 Aug.1990	13 Aug.1990	SW	Garonne area , Agen, Damazan	Violent storm accompanied by torrential rain, lightning and hail. Cars and houses damaged in Agen and Damazan (80% of roofs), vineyards and crops damaged/destroyed.	1	50	31	0	0	1300
Winter storm	25 Dec.1990	27 Dec. 1990	W,	Aquitaine	Strong gusts. Power supply disrupted. Ship capsized.	0	0.1		0	0	0
Severe storm	8 Aug.1992	9 Aug. 1992	SW,	Bayonne	Thunderstorm, high wind speeds, heavy rain, hail. Houses (roofs) and caravans damaged. Trees downed, 30 wildfires. Vineyards (Margaux, Médoc , Haut-Médoc) damaged.	1	25	10	0	0	0
Flash flood	11 May 1993	11 May 1993	SW,	Aquitaine , Bergerac	Tempest, heavy rain, hail. Vineyards damaged.	0	1		0	0	0
Severe storm	11 Sep. 1993	12 Sep. 1993	NW,	West coast, Arcachon	Wind speeds up to 130 km/h, high waves . Houses damaged (roofs, cellars flooded), trees downed, roads blocked. Power lines interrupted. Vessels damaged . Missing: 5	0	5		0	5	0
Windstorm	7 Feb. 1996	9 Feb. 1996	SW,	Atlantic coast . Spain, N, Bilbao	Wind speeds up to 160 km/h. Torrential rain, mudslides, snow drifts up to 6 metres. Riverbanks burst. Houses, roads, bridges, boats damaged . Ferry traffic affected . High tension insulators damaged, power failure (230,000 without electricity).	5	3		24	1	0
Flash floods	8 Dec. 1996	8 Dec. 1996	SW,	Languedoc-Roussillon, esp. Béziers	Heavy rain, thunderstorms. Flooding along numerous rivers. City of Béziers submerged. Dozens of houses, railway lines and roads flooded. Traffic affected.	0	150	100	0	1	100
Windstorm	16 Apr. 1998	17 Apr. 1998	W,	west coast, esp. Bayonne	Wind gusts 120 km/h. Port affected , crane damaged. Traffic disrupted.	0	0.1		1	0	0
Severe storm	7 Aug. 1999	8 Aug. 1999	SW,	Gironde, Bordeaux, Montpellier	Gusts up to 140 km/h, thunderstorms, lightning, heavy rain. Numerous buildings damaged, camp grounds affected, cars damaged. Roads, railway lines blocked. Trees and power lines downed. Losses to agriculture. .	5	1		2	0	2
Winter storm Martin	27 Dec. 1999	27 Dec. 1999	W, SW,	Charente Maritime, La Rochelle, Landes, Bordeaux, Lot-et-Garonne	Wind speeds up to 150 km/h, gusts up to 198 km/h (Ile d'Orlons). Benedictine abbey Mont Saint-Michel damaged. Versailles: >10,000 trees uprooted (2 times more than in 1990), damage to the castle est. US\$ 9.5m. Valmy (Eastern France): historic wind mill destroyed. Paris: Circus tents destroyed, Seine embankments damaged, Orsay museum damaged. Houses, businesses damaged, road, railway and air traffic disrupted, airports closed, roads, bridges closed. Power failure: > 1 million houses without electricity.	8	4000	2450	0	0	0

Table 9 : Data on catastrophic events issued from Munich Re (Nat cat Service -1990 to 2004) W and SW Europe

Environmental costs

Table 8 gave the total value of natural land for the two regions, calculated on the basis of a value per square meter of 0.5 to 1€ provided by the Service des Domaines" (state property department) for the DPM (maritime state property. This land is supposed to be inalienable, but can be illegally occupied. A ruling in a law case concerning the expropriation of occupied public coastal land in the Languedoc-Roussillon region (quoted ?) cited a higher estimate.

While a value in euros can indeed be assigned to urbanized coastal land, an appraisal of public maritime zone does not allow the environmental value of land to be evaluated. Table 10 summarizes these values: it is based on an evaluation made by SMNLR in 2003 that assigns a relative value to natural assets using a scale from 0, the lowest, to 5, the highest relative value. It needs further discussion in terms of sustainable development and cost-effectiveness ratio.

Evaluation of natural zones (Languedoc-Roussillon)	SMNLR index
Zones covered by legislation	2
Zones in scientific inventories	2
Zones designated under International directives	2
CELRL-owned land	2
CELRL-managed land	2
Forest (except coniferous)	3
Coniferous forest	4
Lawns, pastures, moors, scrub	3
Dunes and beaches	4
Marshes	4
Schorres	3
Salt lagoons	4
Landscapes	0 to 1
Historical and archeological heritage zones	5

Table 10: Indexed evaluation on a scale of 0 to 5 of natural assets (from SMNLR).

This indexation was designed to provide a relative valuation for natural assets in the Languedoc-Roussillon region. It could be extrapolated to the Aquitaine region, in the framework and for the purposes of this project, apart perhaps from the coniferous forests there, which are often agro-economic in nature.

Social costs

The costs of catastrophic events

Social costs are indicated in Table 11. Again, this does not allow the impact on the specific coastal area to be discriminated, but does show that deaths, and missing and injured persons can be involved, more specifically in storm events.

	Significant risk increase (km of coastline)	Drastic risk increase (km of coast line)	Significant risk increase (% of total coastline)	Drastic risk increase (% of total coastline)	Total risk increase per asset (% of coastline)
Agricultural	1 to 3	0 to 1	0.3 to 1%	0 to 0.3%	0.3 to 1.3%
Industrial	1 to 3	0 to 0.5	0.4 to 1%	0 to 0.1%	0.4 to 1.1%
Tourist	2 to 9	0.5 to 3	0.7 to 3%	0.3 to 1%	1 to 4%
Urban	10 to 38	3 to 7	3 to 13%	1 to 2 %	4 to 15%

Table 11: Length of coastline in the Aquitaine region concerned by assets exposed to risk due to an increase in coastal hazard.

Costs of mitigation

Social costs are difficult estimate: The best approach is to examine what expropriation of landowners or defence would cost. No figures can be given here.

Data on population in coastal areas are derived from territorial diagnostics coordinated in both regions by INSEE on the basis of the 1999 census.

Coastal communities of Aquitaine region townships have a relatively low population density (80 inhabitants per square kilometre, increasing to 91 inhabitants per square kilometre, in coastal localities). This density, however, is unequally distributed along the coast, with a very high density in the Pays Basque (501 inhabitants per square kilometre) and in the vicinity of the Arcachon Basin, while the northern Landes and Medoc areas average 20 and 27 inhabitants per square kilometre, respectively

Languedoc Roussillon figures show a high density of population in coastal Languedoc-Roussillon townships, with 218 inhabitants per square kilometre, i.e., 349,000 inhabitants, expected to rise to 440,000 over the next ten years. This density is fairly equally distributed over coastal localities except for some towns in the Aude department, near Narbonne, where the density is lower.

The evolution of Risk management costs over the 21st century

Hypothesis on the choice of strategies

Coastal risk management in the coming century will need to consider the impact of climate change on the coastal system, i.e., a sea-level rise hypothesis of 25 to 88 cm and an increased frequency and intensity of storms. Maps 6 prepared a gradation of possible impacts on the studied area ranging from an insignificant change in erosion and/or flooding hazard to significant or dramatic changes.

It should be recalled that “no change” does not imply “no hazard.” The hazard may already exist and be maintained at least at its present level throughout the coming century.

In addition to the likely increase in catastrophic events and associated costs, estimating cost evolution for coastal risk prevention is strongly dependent on the strategic choices made for managing this risk. Choices will be made as to:

- the increase in hazard,
- the value of the assets involved.

Increased frequency and intensity of storms are liable to induce more frequent catastrophic events. **Emergency management and remediation** is already calculated in tens to hundreds of millions of dollars or euros, and the catastrophes are responsible for human loss of life or injuries. Logically, the consequences will be multiplied by the number of such events unless measures are taken to adapt to the risk. Also, it is to be remembered that population in coastal communities is expected to increase in the coming century.

Maintaining and upgrading hard defences is likely to be the choice in areas where increased risk is predicted to be drastic and where the value of assets is very high (urban assets, expected to increase in the coming century, as well as tourist and industrial assets). Hard defence is nevertheless an expensive strategy, both to build and to maintain. Adaptation to risk change should therefore call for preliminary studies, to propose a cost-effectiveness scheme as part of integrated management of the sedimentary cell involved. Also, the return periods for catastrophic events must be evaluated so as to be integrated into upgrading defences to a condition compatible with an acceptable level of risk.

Restoring natural processes also implies preliminary studies to improve knowledge of those processes in the context of each sedimentary cell. This strategy is more likely to be chosen when such restoration will decrease or eliminate the erosion hazard. It will have little effect on flooding hazard. Settling for such a process appears, in terms of present cost, cheaper than maintaining hard defences. It is, however, conditional upon the sustainability of beach nourishment or bypass structures. It may also entail the destruction of ineffective defence works.

Retreat strategy is more likely to be chosen in situations where asset values are low (agricultural or natural assets). This also implies a cost-effectiveness study. The cost of such a strategy is evaluated from the economic value of the land loss. Long-term societal costs must also be taken into consideration, but these are difficult to evaluate.

Application to French pilot regions

Results presented in earlier chapters showed which assets were exposed to greatest risk by increased hazard due to potential climate change. It was underlined that differences in the style of development and the evolution of assets in the two regions considered lead to different figures relative to coastline placed at risk.

The present population of the **Aquitaine coastline** is 420,000, with a very high concentration in the Pays Basque area. Coastal population is expected to reach 530,000 in 2020 (INSEE).

On the basis of the present study, the coastline submitted to increased hazard amounts to around 90%, only some 5% of this being drastic. Over around 40% of this total length, assets are placed at risk by this hazard, with the change likely to be drastic in 8% of instances. The risk is mainly linked to erosion.

Urban and tourist assets subject to increased risk are mainly located, in connection with population density, behind the cliffs of the Pays Basque area, considered less erosive, and in several towns such as Cap-Breton, Soort-Hossegor or Soulac characterized by dune morphology considered vulnerable to erosion.

The reader should recall that the very heavily urbanized Arcachon Basin, behaving as a semi-enclosed bay, was not considered in this study.

Few industrial assets are implicated, again located mostly in the Pays Basque area, or in the low-lying lands near coastal river beds.

Environmental assets cover the whole Aquitaine coastline.

According to the CORINE land-cover and IPLI databases, more than half the Aquitaine coastline considered has few to no assets at the present time.

Where assets are few and the cost of land low (natural land - DPM), a retreat strategy should be considered, whilst a combination of soft and hard defences is likely to be the preferred strategy in the Pays Basque area and the tourist towns mentioned above

The **Languedoc-Roussillon** coastline presents a high and uniform density of population, with 349,000 inhabitants in coastal communities and an expected increase to 440,000 inhabitants in the next ten years (INSEE).

Judging by RESPONSE calculation and mapping, around 38% of the calculated coastline length for the Languedoc-Roussillon region submits its assets to a change in risk, 3/4 of this being expected to experience a drastic change. Both erosion and marine flooding are involved. The assets at risk are varied in nature and can cumulate behind the same coastline segment.

The Languedoc-Roussillon region displays intensive urbanisation and tourist development (due to a likely concomitance of the two assets, tourism may not have been well distinguished from urbanization and therefore under-evaluated in the data used to map assets).

It should be emphasized that the Languedoc-Roussillon region, despite its degree of urbanization, also has many classified environmental habitats. The values of industrial and agricultural assets also are far from insignificant.

In view of the importance of assets in the Languedoc-Roussillon region, a strategy of defence rather than retreat is clearly appropriate, just considering the present value of urban land. The case study (Annex 2) of the Lido de Sète project (51M€), however, does underline the fact that although local authorities today are prepared to invest in managing coastal risk, they also try to work out a strategy that will achieve some sort of balance between retreat and defence, and will opt for soft defence when possible.

Conclusions on evaluating the costs of coastal risks and coastal risk changes

Comparisons of results between the Languedoc-Roussillon and Aquitaine coastal zones show that:

- The weight of assets and population involved in the Languedoc-Roussillon region in conjunction with a widespread drastic increase of coastal hazard will imply a high-cost impact of climate change, likely to prompt a combination of different defence strategies, in line with the best cost-effectiveness ratio.

An awareness of this situation already exists in the Languedoc-Roussillon region, where a strategy has already been elaborated for the coming decades, to which any management project must refer.

- The disparity of assets on Aquitaine coastline and a hazard increase that is for the most part significant rather than drastic should allow retreat to be envisaged and planned in areas where no assets are implicated. Attention will need to focus on the Pays Basque coastline, where most of the assets are concentrated, as well as on the coastal towns of the Landes and Gironde areas, which are subject to a drastic change in hazard. On these segments, cost-effectiveness studies should have to be conducted to inform the best strategic choice.

Up to now, the Aquitaine region has mainly developed pre-existing resorts dating from the mid-sixties to 1970 (MIACA), but no strategy has yet been built at a regional scale

A comparison between those two regions and, beyond that, with other pilot regions in the study clearly shows that no estimates of future costs engendered by coastal risks can be given. These will be closely related to the strategies chosen. The choices will have to take into account asset values, predicted damage and the strategy's cost-effectiveness on a long-term basis.

Strategic choices in the coming century will of course have to factor in other criteria than knowledge of a range of hazards and asset values. Nevertheless, the purpose behind the effort made in this study to collect and exploit data is to inform coastal management and development at a regional scale, and it is important that they should be used in support of strategic choices with which our societies will be confronted in future.

At the core of this study is an effort to anticipate hazard change and its associated effects. Evolution in assets is also to be considered, including a predicted increase in coastal populations, and must be borne in mind when making strategic choices.

Annex 1 : French Projects and works costs tables

Annex 2 French Case studies

6. Conclusion and Key Message

Risk management is sometimes considered an expensive luxury when there is a lack of awareness of the actual risks associated with natural hazards and climate change. However, examples of the high costs associated with a lack of planning can be found from local to global scales, as discussed in this report.

According to the report 'Climate Change and the Financial Sector' produced by Allianz Group and WWF in June 2005 *"Europe is not only warming 40 percent faster than the world as a whole, but has already sustained severe damage from climate change. Storms in 1999 and floods in 2002 each cost 13 billion euros, while a heat wave in 2003 cost 10 billion euros. Although no precise estimate of all future costs can be made, a European Commission paper puts the future cost of all the potential cumulative global damage at 74 trillion euros at today's value if effective action is not taken."* (Allianz Group and WWF, 2005).

The most significant message of the report is the increasing magnitude of the costs associated with natural hazards in the coastal zone, particularly in terms of damage to assets, protection and maintenance of defences. In addition to the actual costs there are substantially larger potential costs that could arise as a result of the huge amounts of assets that are at risk from natural hazards in the coastal zone across the EU. The report has highlighted the fact that the costs associated with protecting these assets are small in comparison to the losses that would be incurred if no action were to be taken, thus proving relatively cost-effective. However, despite uncertainty over future conditions, there is a recognition that climate change will increasingly lead to significant rises in the costs of natural hazards over the coming decades. It will be impossible to develop strategies that negate climate change because the future level of risk cannot be defined to that level of accuracy. It is therefore only possible to decrease risk and vulnerability natural hazards to an acceptable level.

It has been widely agreed that investment must increase to react to the predicted rise in costs associated with climate change within the coastal zone, particularly in order to develop and implement adaptable and sustainable recommendations for future coastal management. However, this will still be cost-effective even if the value of assets at risk from natural hazards under climate change scenarios does not increase as expected. Hazard mapping is likely to provide the most effective way of providing a basis for managing natural hazards in the coastal zone, as utilised by Swiss authorities as a means of providing zones restrictive of development. One of the major sources of costs produced by natural hazards is damage and losses caused as a result of development in unsuitable areas of the coastline. With uncertainty over climate change there have been calls to internalise the risks associated with natural

hazards into the planning framework as a means of controlling the impacts and costs. In this way it would be possible to move towards creating a culture of prevention, advocating cost-effective preventative action rather than costly post-disaster remediation.

In the UK, for example, a Local Government Association survey published in June 2004 (LGA, 2004) estimated that only 11% of local authorities have published an action plan on climate change, and the three most important difficulties facing local authorities in dealing with climate change are cited as insufficient staff, or staff time (87%), other issues take higher profile in the council (86%) and lack of funding (85%).

The RESPONSE LIFE-Environment Project provides a methodology for regional and local authorities and other interest groups to identify and assess the risks arising from climate change along their coastline, enabling them to prioritise the results and assist the formulation of a cost-effective preventative response. This approach is demonstrated in the 'Training Pack'. The RESPONSE Project also provides a range of examples in the 'Good Practice Guide' of innovation and best practice illustrating how, once identified, these risks can be managed and reduced.

REFERENCES

ABI (2005), Financial Risks of Climate Change, Summary report, June 2005. Association of British Insurers, with Climate Risk Management and Metroeconomica, UK.

ABI (2004) A Changing Climate for Insurance: A Summary Report for Chief Executives and Policymakers. Association of British Insurers, London.

ABI (2002) Renewing the partnership – how the insurance industry will work with others to improve protection against floods. Report by the Association of British Insurers.

Acacia (2000), Assessment of potential effects and adaptations for climate change in Europe; A concerted action towards a comprehensive climate impacts and adaptations assessment for the European Union. University of East Anglia, UK. Jackson Environment Institute.

Allianz Group and WWF (2005), Climate Change & the Financial Sector: An Agenda for Action. A publication of Allianz Group, Germany and WWF International, Switzerland.

Berz, G.A. (1999) Catastrophes and Climate Change: Concerns and Possible Countermeasures of the Insurance Industry. Mitigation and Adaptation Strategies for Global Change 4: 283-293, 1999.

Blair, Tony (RT Hon), UK Prime Minister (2006), Open Letter to 'Stop Climate Chaos' Coalition, 28th February 2006. London, UK. www.number10.gov.uk

Cambridge University Press (2006), Avoiding Dangerous Climate Change. www.cambridge.org/9780521864718. Cambridge University Press, Cambridge, UK.

Crichton, D. (2003) Climate Change, risk and insurance. South East Climate Change Forum Annual Conference, Oxford. See <http://www.climatesoutheast.org.uk/>

Crichton, D. (2003) "Flood Risk and Insurance in England and Wales: are there lessons to be learned from Scotland?" Technical Paper 1, Benfield Grieg Hazard Research Centre, London.

DEFRA (2001) National Appraisal of Assets at Risk from Flooding and Coastal Erosion, including the potential impact of climate change.

DETR (2000), Potential UK adaptation strategies for climate change, Summary Report, May 2000. 99DPL013. ERM for the Department of the Environment, Transport and the Regions, UK

Environment Agency (2004), for Thames Barrier data:



<http://www.environment-agency.gov.uk/regions/thames/>

EUROPA (2002) <http://europa.eu.int/rapid/pressReleases/>

European Commission (2004), Flood risk management: Flood prevention, protection and mitigation. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Brussels, 12.07.2004, COM(2004)472 final.

European Environment Agency (2006), The changing faces of Europe's coastal areas. Report No. 6/2006. European Environment Agency, ISSN 1725-9177.

European Environment Agency Briefing (2006), The continuous degradation of Europe's coasts threatens European living standards. EEA 2003-06. European Environment Agency, ISSN 1830-2246.

European Environment Agency (2005), Vulnerability and Adaptation to Climate Change in Europe. EEA Technical report no. 7/2005, Draft, Copenhagen.

European Environment Agency (2004) Mapping the impacts of recent natural disasters and technological incidents in Europe. Environmental issue report No. 35.

European Environment Agency (2004) Impacts of Europe's Changing Climate. European Environment Agency Report.

EUrosion (2004) Living with coastal erosion in Europe: Sediment and Space for Sustainability, PART I: Major findings and Policy Recommendations of the EUrosion project.

Foresight (2004) Future Flooding Executive Summary. Office of Science and Technology, UK.

G8 Gleneagles Communiqué, 8th July 2005. Gleneagles Summit, Scotland.

Geological Society (2001) The Earth in our hands: how geoscientists serve and protect the public. The Geological Society of London: London.

Glade T. and Crozier M. (1999) Frequency and Magnitude of Landsliding: Fundamental Research Issues. Z Geomorph N F Suppl - bd/15 pp 141-156 Stuttgart.

Hadley Centre (2004), Uncertainty, risk and dangerous climate change, Recent research on climate change science from the Hadley Centre, December 2004. Hadley Centre - Met Office and Defra, UK.

Health Protection Agency (2004) www.hpa.org.uk/hpa/news/articles/issues/

HM Treasury, UK (2006), Stern Review on the economics of climate change. Article of 31 January 2006. HM Treasury website (Home >Independent reviews >Stern

review on the economics of climate change.
http://www.hmtreasury.gov.uk/independent_reviews/stern_review/economics_climate_change/sternreview_index.cfm

IPCC (2001a) Climate Change 2001: Synthesis Report. Cambridge University Press, Cambridge.

IPCC (2001b) Climate Change 2001: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge.

IPCC (1997) The Regional Impacts of Climate Change: An Assessment of Vulnerability.

A Special Report of IPCC Working group II) Cambridge University Press, Cambridge.

IPPR (2005), Meeting the Climate Challenge, Recommendations of the International Climate Taskforce. ISBN 1 86030 264 5. Institute for Public Policy Research, London; Center for American Progress, Washington, D.C.; The Australia Institute, Canberra.

ISDR (2002) Living with Risk, A global review of disaster reduction initiatives. UN: Switzerland.

IWCCE (2006) High Level targets for Coastal Defence; Policy Statement on Flood and Coastal Defence (Target One). Isle of Wight Council, UK

Ledoux, L. (ed) (2004) Wetland Valuation: State of the Art and Opportunities for Further Development. A Report on the Workshop. CSERGE Working Paper.

LGA - Local Government Association (2004) Sustainable energy and climate change, a survey of local authorities. LGA Publications, London.

McInnes, R., Tomalin, D. & Jakeways, J. (2000a) LIFE-Environment Project: LIFE – 97 ENV/UK/000510 1997-2000 Coastal change, climate and instability: Non-technical Summary Report. Isle of Wight Council, Isle of Wight, UK.

McInnes, R., Tomalin, D. & Jakeways, J. (2000b) LIFE-Environment Project: LIFE – 97 ENV/UK/000510 1997-2000 Coastal change, climate and instability: Final Technical Report. Isle of Wight Council, Isle of Wight, UK.

McInnes, R. (2000c) Managing ground instability in urban areas. A guide to best practice. Isle of Wight Council, Isle of Wight, UK.

McInnes, R. (2003) Coastal Defence, A Non-Technical Guide. Cross Publishing: Isle of Wight.

MICE (2005), Modelling the Impacts of Climate Extremes (MICE Project). August 2005. Funded by the EU Energy, Environment and Sustainable Development Programme (Contract EVK20CT2001-0018), MICE team, University of East Anglia, UK.

Munich Re (2006), Annual review: Natural catastrophes 2005. Knowledge Series, Topics Geo. 302-04772. Münchener Rückversicherungs-Gesellschaft, Germany.

Munich Re (2006), The five largest natural catastrophes of 2005. Münchener Rückversicherungs-Gesellschaft, Germany. MRNatCatSERVICE

Munich Re (2006), Climate change – Modest warming, dramatic effects, article by Gerhard Berz. www.munichre.com see: Topics and Solutions, Georisks, Climate Change and Insurance. Münchener Rückversicherungs-Gesellschaft, Germany.

Munich Re (2003) Natural catastrophes and climate change – the insurance industry's fears and response options. www.munichre.com Münchener Rückversicherungs-Gesellschaft, Germany.

Munich Re (2003) Topics, Annual Review: Natural Catastrophes 2002. Münchener Rückversicherungs-Gesellschaft, Germany.

RMS (2003) Central Europe Flooding, August 2002. See: http://www.rms.com/Publications/Central%20Europe%20Floods%20Whitepaper_final.pdf

SCOPAC (2001). Preparing for the Impacts of Climate Change: 'A Strategy for Long Term Planning and Management of the Shoreline in the Context of Climate Change Predictions'. Summary Report. Halcrow, UK.

Sperling, F. and Szekely, F. (2005). Disaster Risk Management in a Changing Climate. Discussion Paper prepared for the World Conference on Disaster Reduction on behalf of the Vulnerability and Adaptation Resource Group (VARG). Reprint with Addendum on Conference outcomes. Washington, D.C.

Swiss Re (1998) Climate research does not remove the uncertainty, coping with the risks of climate change. Swiss Re publications, Zurich.

Swiss Re (2004) Sigma. Natural catastrophes and man-made disasters in 2003: many fatalities, comparatively moderate insured losses.

Tyndall Centre (2005), Surviving Climate Change in Small Islands: A Guidebook. Tyndall Centre for Climate Change Research, UK, as part of a project: 'XOT 005 Preparing for and adapting to climate change in the UK Overseas Territories', UK Overseas Territories Environment Programme. Tyndall Centre for Climate Change Research, Norwich, UK



UKCIP (2005), Updates to regional net sea-level change estimates for Great Britain
UKCIP, November 2005. United Kingdom Climate Impacts Programme.
www.ukcip.org.uk

UKCIP, Metroeconomica (2004) Costing the impacts of climate change in the UK:
Overview of guidelines.

URBANIS (2004) <http://www.ourplanet.com/imgversn/113/berz.html>

C. Vinchon, D. Idier, M. Garcin, Y. Balouin, C. Mallet S Aubie L. Closset 2006,
Response of the Coastline to Climate Change. Specific Report for the RESPONSE
LIFE–Environment Project: Evolution of coastal risks (Erosion and marine flooding) on
the Aquitaine and Languedoc-Roussillon pilot regions, BRGM/RP 54718-FR, July 2006