# Responding to the Risks from Climate Change in Coastal Zones

## A good practice guide

## About this publication

This guide to good practice has been prepared as one of the outputs from the LIFE Environment project 'Response' - 'Responding to the risks from climate change'; the project has benefited from financial support from the European Commission's LIFE Environment Programme (L'Instrument Financier de L'Environnement). The overall project has been completed by scientists from the United Kingdom, France, Italy and Poland under the direction of the Isle of Wight Council's Centre for the Coastal Environment.

The 'Response' work programme (2003-2006) is described on the project website at www.coastalwight.gov.uk/response.html The contributions of the scientific teams from the project partners, listed below, are gratefully acknowledged.

**Centre for the Coastal Environment
Isle of Wight Council, UK**

**IRPI Institute of Perugia,
National Research Council (CNR), Italy**

**Bureau de Recherches
Gèologiques et Minieres, France**

**Regione Marche, Autorità di
Bacino Regionale, Ancona, Italy**

**Provincia di Pesaro e Urbino, Italy**

**Provincia di Macerata, Italy**

**Maritime Office in Gydnia
(Urzad Morski w Gdyni), Poland**

**Scarborough Borough Council, UK**

**SCOPAC Regional Coastal Group
Central-southern coast of England, UK**

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# Acknowledgements


## About the LIFE project 'RESPONSE'

This Good Practice Guide has been prepared with financial support from the European Union LIFE Environment Programme (EC DG Environment) and is one of a number of outputs from the three year study **'Response'** (Responding to the risks from climate change, 2003-2006). Further details about the project can be obtained from www.coastalwight.gov.uk/response.html The study was led by the Isle of Wight Council's Centre for the Coastal Environment and this publication draws upon its experience of coastal risk management and that of its project partners gained over many years and specifically over the lifetime of this study.

The Isle of Wight Council particularly wishes to acknowledge the contributions of the **'Response'** project partners together with the expertise of the team from consultants Halcrow, together with Dr E M Lee, who have provided valuable support to the study.

## Photo credits

BRGM: Plate (i), 5.6; Andrew Butler: 5.3; Editions d'Art Jack: 2.1; Editions de Goubey: 1.1; EID Méditerranée: 5.2. Fabio Gemolo: 6.3; Isle of Wight Centre for the Coastal Environment: 1.3, 1.4, 2.4, 2.7, 4.2, 5.6, 5.7, 5.8, 5.9, 6.4, 6.5, 6.6, 7.1; Dr Eric Leroi: 6.1, 6.2, Regione Marche: 6.7; Ville de Sete, France: 2.6, back cover centre; South Downs Coastal Group: 5.4, 5.5; Wight Light Gallery: Front and back covers, Plate (ii), 1.2, 2.2, 2.3, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 5.1.




**Cover illustrations:** Main picture: Ventnor Undercliff, Isle of Wight, UK, which forms the largest urban landslide complex in north-western Europe.

Back cover insets:
Left: Lyme Regis, Dorset, UK. Right: Sirolo, Marche Regione, Italy.
Middle: Sete, France

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Plate (i): *Rockfall on the coastal road, Les Saintes, French West Indies. On islands important highways often follow the coastline. Such routes are particularly susceptible to natural hazards including coastal erosion, flooding and landslides.*

# Executive Summary

The coastal zones of the European Union have been progressively developed in recent centuries. Coastal zones not only make a very significant contribution to the economic well-being of member states but also provide opportunities for relaxation, recreation and enjoyment within a diverse range of outstanding natural environments. Over the last ten years considerable efforts have been made by the European Commission to encourage improved coastal management and this has led to the development of national strategies for the coast in support of the principle of sustainable development. As part of this process a thorough consideration of natural hazards, and the resulting risks to people, property and the environment, must be made. Risk management strategies for vulnerable areas provide a framework for addressing hazards arising from coastal erosion, flooding and landsliding.

Climate change is, without doubt, going to exert an increasing influence on our lives over the next decades by affecting the severity of coastal erosion, flooding and landslide events. Many climate impacts, particularly the most damaging ones, will be associated with an increased frequency or intensity of extreme events. This is an important area for further work since many studies do not explicitly take into account the effects of extremes, although it is known that such extremes pose significant risks to human wellbeing; the heatwave that affected Europe in 2003 being a prime example (Defra, 2005[1]).

It is clear that climate change will place increasing pressure on certain coastal frontages as well as necessitating changes in our approach to the management of risks arising from sea level rise, changing weather patterns and resulting coastal erosion, flooding and landslip. It is recognised that it is impossible and, indeed, undesirable to defend all parts of the European coastline and the development of risk management strategies to help address such coastal problems must be based upon a thorough understanding of coastal evolution and natural processes.

With financial support from the LIFE Environment Programme (L'Instrument Financier de L'Environnement)[2] it has been possible to undertake sequential investigation and demonstration programmes which commenced with the 'Demonstration programme on the integrated management of coastal zones'[3] (1996-1999), followed by 'Coastal change, climate and instability'[4] (1997-2000) and a further demonstration project (of which this publication forms part), called 'Response' ('Responding to the risks from climate change', 2003-2006)[5].

Even over the lifetime of the LIFE 'Response' project there has been a very significant increase in the amount of research, exchange of information and awareness-raising on the subject of climate change. The year 2005 was the second warmest year since 1860, although 1998 holds the record. The last decade has, in fact, seen eight of the ten warmest years since records began. The sea surface temperature in the northern Atlantic has also been the highest since 1880. The vital need for advice and guidance on how to respond to the resulting coastal risks has been demonstrated by an increasing number of devastating natural events which have affected many parts of the world including Europe. Climate change is, by necessity, one of the main topics embodied within European environmental and energy policies.

Although 2005 was designated as the 'Year of disasters' by the World Meteorological Organisation Europe has, in fact, seen over a hundred major floods since 1998 including the catastrophic events affecting developments alongside the Rivers Danube and Elbe in 2002 which resulted in some seven hundred fatalities, the displacement of nearly half a million residents and losses of over twenty-five billion Euros; further serious flooding took place in spring 2006.

Research supported by the European Commission (EUrosion, 2004)[6] highlighted that over 20% of the European coastline faces serious problems resulting from coastal erosion with thousands of kilometres affected by significant retreat. The present and future challenges involve management of increasing levels of coastal risk, whilst at the same time seeking to maximise opportunities for preserving and, where possible, enhancing our coastal environments. It is vital to avoid past mistakes which have, in some cases, increased risks or caused serious environmental damage.

The purpose of this guide is to assist those within regional and local authorities, together with other stakeholders with an interest in coastal zones, by providing advice on sustainable coastal risk management through the preparation and use of integrated coastal evolution and risk maps.A sequence of maps to inform planning of coastal risks in the context of climate change has been developed as part of the EU LIFE Environment 'Response' project (McInnes et al, 2006[5]). The Response project partners have based their research on detailed investigations within five European coastal regions which are representative of conditions fronting the European seas.

The advice and guidance draws on practical experience from work undertaken over the last three years ('Response'[5], 2003-2006), within five study sites in England, France and Italy. The project team hopes that this new publication will prove to be of real practical value to those involved in coastal risk management, although it is recognised that many of the recommendations may also be applied in other environments such as mountainous regions.

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# Introduction

The coastal zones of the European Union are subjected continuously to the natural processes of weathering, marine erosion, flooding and landsliding. The impacts of these processes and events vary from one part of the coastline to another and depend upon the geological structure of the coastline, the durability of the rocks exposed on each particular coastal frontage as well as the relative exposure of that frontage to the impacts of waves and tides. Eroded and weathered materials that accumulate at the base of cliffs or on the foreshore are transported from one part of the coast to another by the process of longshore drift. Sedimentary materials may be deposited around the coastline where 'sediment transport pathways' are interrupted by major headlands, estuaries or sediment 'sinks'. Human development activity has imposed itself on this continuously evolving and changing coastal environment with coastal defence structures being constructed in an attempt to 'fix' the position of the coastline in order to protect coastal cities, towns, villages and strategic infrastructure.

For thousands of years settlers have been attracted to the coastal zones for strategic, economic or recreational reasons and the resulting developments have often been defended against coastal erosion or flooding by the sea. Many parts of the European coastline were subjected to intensive development, particularly in the late 19th and early 20th centuries, as the sea air, bathing and sailing became fashionable. However, changing coastal conditions and the presence of some developments in vulnerable locations have necessitated the construction of considerable lengths of seawalls and other coastal defence structures in order to protect these assets. In some places coastal developments have caused significant impacts on the natural coastal systems which have resulted in adverse consequences for the adjacent downdrift frontages causing an exacerbation of erosion or coastal instability.

Recent research has shown that natural processes such as coastal erosion have resulted in the loss or damage to hundreds of properties in recent years whilst the market values of many others have been affected because development has taken place at inappropriate locations (EUrosion, 2004[1]). Coastal flooding has an impact on extensive frontages and the increasing interaction between natural hazards and the developing coastal population will inevitably result in increasing risks unless coastal risk management systems are put in place. Scientists have told us clearly that we must face up to climate change or else accept dramatic consequences (European Commission, 2002[2]). Climate change is already happening and having widespread impacts on coastal zones with substantial economic costs for people and damage to eco-systems. There is the recognition that strategies are needed at the various administrative levels in order to research, understand and adapt to the challenges of climate change. No matter how effectively we attempt to tackle the causes of climate change now, there will be unavoidable climate change due to our past greenhouse gas emissions, so we need to plan for what lies ahead.

Investigations into the impacts of climate change in coastal zones follow on from previous demonstration projects which have benefited from financial support from the European Commission's LIFE Environment Programme. As part of the Commission's 'Demonstration Programme on the integrated management of coastal zones' (1996-1999)[3] studies were undertaken at thirty-five sites around the European coast in order to identify lessons learnt and contribute to best practice from a diverse range of coastal environments. More specifically a further LIFE Environment Project 'Coastal change, climate and instability' (1997-2000) started to consider the issues of coastal and climate change in terms of the utilisation of palaeo-environmental and geomorphological techniques, as well as management skills, in order to help understand and address present and potential problems of coastal change, as well as instability in both coastal and mountainous locations (McInnes et al[4]). The purpose of the 'Response' project ('Responding to the risks from climate change', 2003-2006[5]) is to provide practical advice and guidance to assist the implementation of sustainable regional-scale strategies to address natural hazards in the context of climate change.

Natural hazards have serious impacts on the coastal zones of most European member states. The costs of emergency action, remediation and prevention can represent a significant burden to the communities affected with a proportion of the costs often falling on regional or local authorities with limited resources. It is now widely accepted that the risks arising from climate change are real; sea level rise poses a particular risk to coastal communities from increased marine erosion, sea flooding and landsliding activity. In order to safeguard life, property and environmental assets in coastal zones it has been necessary to establish clearly the extent of current coastal risks as well as climate change impacts and to advise on frameworks for the implementation of sustainable risk management strategies in order to try and mitigate future risks.

Significant lengths of the coastline of the European Union are densely developed. The development patterns can be traced back to the 19th Century or indeed far earlier. In fact, many of Europe's major cities and ports form concentrated coastal developments which contribute substantially to the gross domestic product for those countries. Development pressures have highlighted the need to reconcile the demands of many coastal users without increasing damage to the natural environment. To help manage these problems, over the last ten years in particular, there has been a significant change in the philosophy adopted by many with an interest in the management of coastal zones with the object of achieving sustainable development. An appreciation of coastal evolution and the extent to which natural processes must be taken into consideration in support of wise decision-making has, however, been taken up more slowly despite many obvious examples of problems being created as a result of the knock-on effects of coastal developments or coastal defence schemes on adjacent frontages.

There has been an increasing recognition that, wherever possible, the natural physical processes of coastal erosion, sediment transport and deposition should be allowed to continue without interruption. Coastal defence can be achieved, in some locations, most effectively by trying to 'work with nature', for example by encouraging the build-up of natural beach materials which form an excellent coastal defence. The need to foster a greater understanding of coastal evolution as a framework for coastal risk management has been demonstrated by both the government and coastal defence groups in England and Wales (Futurecoast, 2002[6]; SCOPAC, 2003[7])

In recent years a range of new European directives, communications and guidance has been promoted to assist management of risks as well as other issues. These include the Water Framework Directive, the Soil Thematic Strategy and the Flood Directive, in addition to the European Parliament's 'Recommendation on the integrated management of coastal zones'.

Many member states have started to identify coastal developments and other key assets that may be at increased risk from natural hazards such as marine erosion and flooding by the sea, due to the effects of climate change. Elsewhere coastal towns and villages are affected by landsliding which may be triggered by marine erosion or changes in rainfall patterns or development practices. These wide-ranging impacts on coastal developments have led to increasing demands for the implementation of sustainable strategies for the management of both coastal defences and coastal risks generally. Bearing in mind the substantial public expenditure required to maintain coastal defences, it is vital that proposed solutions are sustainable from technical, economic and environmental perspectives.

Some of the more serious risks that are evident around the European coastline have resulted from a lack of co-ordination between land use planning and development proposals. Indeed many parts of the European Union are suffering from an inheritance of unplanned communities and developments which have taken place on, or adjacent to, eroding clifflines, on coastal landslide systems, or on areas vulnerable to flooding. Despite the serious floods in eastern England and the Netherlands in 1953, and other more recent flood events, these warnings have proved insufficient to ensure the development and implementation of more sustainable coastal risk management strategies in many member states. The implications of climate change and sea level rise now present a very serious challenge for shoreline management. Wide-ranging research has shown that there will be increased levels of risk to many coastal assets from both coastal erosion and coastal flooding together with an increase in 'first time' landslides as well as reactivations of past events. Central, Regional and local government will have to develop and implement policies that address the increasing risks whilst also meeting the inevitable technical and financial constraints.

In order to assist the process of developing good practice guidance for coastal risk management, the LIFE 'Response' project ('Responding to the risks from climate change')[6] has recommended the development of sustainable strategies for regional and local authorities in order to assist them with the management of hazards in coastal zones. This is achieved by demonstrating an innovative regional-scale methodology for coastal evolution studies and risk mapping, particularly taking account

Plate (ii): Coastal landslide, Niton Undercliff, Isle of Wight, UK affecting a caravan park and the A3055 coast road. The landslide event followed prolonged winter rainfall in 2000/01 of the impacts of climate change. The Response project has assessed the current and future costs of coastal natural hazards and has provided a framework for preparing for the impacts of climate change around the European coastline. This process adopts a precautionary approach and comprises a prioritised, cost-effective and environmentally-sound methodology. The Response project considers both human and natural systems influencing the coastal zone, and, based upon the philosophy of working with natural processes, recommends a transferable methodology for coastal evolution studies and risk mapping. The methodology is based upon recognition of specific local conditions, ensuring that shoreline management decisions are appropriate and sustainable, compatible with the full knowledge of predicted impacts of climate change and suitable for informing land use development and planning systems.

A systematic approach has been adopted to assist coastal planning and this is achieved in a number of stages. First, coastal landforms are classified according to their physical type, and then the generic behaviour of each landform type, based on historical information, is assessed. For a diverse range of coastal zones regional climate change scenarios have been identified and an assessment has been made of the likely generic sensitivities to climate change of each coastal landform type. Key links between landforms complete the identification of 'coastal behaviour systems' recognising likely climate change impacts, each defined by an impact assessment based on case studies. This approach allows an analysis of a region's coastline which, through a logical succession of maps, provide a basis for assessing risk and identifying climate change 'hotspots' where particular attention is likely to be focused now and in the future in order to manage coastal risks.

Fundamental to the development of an understanding of one's coastline is a thorough appreciation of coastal evolution and natural processes; those factors requiring assessment, as a first stage, are described in Chapter One.

### Key Terminology

**Hazard** - A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period or area.

**Risk** - Expected loss (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.

**Vulnerability** - The degree to which a system is susceptible to, and unable to cope with, injury, damage or harm.

Scource - European Environment Agency

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## *Chapter One*
# Coastal Evolution, Behaviour and Climate Change

The varied geological conditions prevailing around the coastline of the European Union have resulted in the formation of a wide range of geomorphological features and have created a coast of enormous variety, scenic beauty and interest. The coastline has been formed over geological time with the diverse rock formations being created or deposited, uplifted during mountain-building phases, compressed, folded and faulted before being affected by processes including glaciation, inundation, coastal erosion, and weathering by wind and rain. An examination of the geological maps of many European countries illustrates a wide range of rock types exposed around the coastline. The nature of the coastal and seabed geology, as well as the structural form of the rocks (including the influence of joint lines, bedding planes and the angle of dip), together with other factors such as groundwater levels, natural sedimentary processes and the impacts of changes within the earth's crust have all had an influence on the appearance of the coastal zone.

Detailed mapping work has been undertaken by the Geological Surveys of a number of European member states and some of these have helped identify the inter-relationships between the terrestrial and sub-marine geology resulting in an improved understanding of coastal evolution. For example, in the Channel (La Manche) between England and France terrestrial mapping has extended to include the Continental Shelf, allowing the British Isles and France to be set within a European geological context illustrating many key structural features including major fault lines, sea basins and areas of higher ground.

The geological history does, therefore, dictate the present day structure and scenery of our coastal zones. Since their formation geological deposits have been eroded and weathered over millions of years to create our present landscape. Along the coast the most marked differences are often created through contrasts between those more resistant rocks, which form headlands and uplands, and the softer, usually sedimentary rocks, which form the lowlands and soft cliffline coastal frontages.

The coastline is constantly changing and factors such as wave size, wind speed, water depth, the strength of tides and the rates of relative sea level change, as well as rainfall and the frequency and intensity of storm events, are all influencing factors. By studying the geological maps of various countries it is possible to appreciate the overall geological structure and to identify rocks of geological Periods which, through their particular individual characteristics create major escarpments, valleys or other topographical features. Elsewhere the influence of glaciation has sculptured the geology whilst in other areas extensive deposits of more recent materials including clays, gravel deposits, landslide debris and alluvium form blankets masking the solid geology beneath. A particular influence has been the 'mountain-building' phases such as the Armorican and particularly the Alpine phase which led to the formation of the world's great mountain ranges, for example the Himalayas and the Alps. The outer ripples of these massive phases of crustal activity led to the formation of major features in north-west Europe, for example, by creating the Paris Basin and the North and South Downs of England. An examination of geological cross-sections and dip of strata, as shown on geological maps, illustrate the full extent of the folding, erosion and weathering that has taken place since the rocks were first deposited.

Many factors have led to the evolution and shaping of the coastline as we know it today. These include the changing rates in sea level rise which, in some locations, have been dramatic over the last 30,000 years. This, in turn, has influenced the nature and the severity of coastal erosion, a key factor in transforming the coastal landscape. The influence of climate is also particularly important on the coast as rainfall, and run-off carrying sediment from the hinterland down to the coast, is very significant, whilst along the coast itself the rates of erosion and transport of materials by waves, tides and currents have led to the formation of beaches and sediment sinks resulting in accretion in some places and depletion in others.

A wide range of climatic conditions including atmospheric pressure, temperature, wind speed and rainfall have all had their impact upon the geology of the coastline. These natural processes are not, however, uniform and even over the last 2,000 years particular phases of activity have been identified. Storm events such as that striking southern England in 1703 and the coastal storms that affected the North Sea in 1953 resulted in the loss of lives of over 3,000 people in the Netherlands and 300 in eastern England and within the estuary of the Thames. Since then a considerable amount of research has been undertaken into the reasons why particularly severe storm events should occur and to establish whether this forms a pattern or whether they are random events. Studies of this kind and an improved understanding of coastal evolution and natural conditions generally are vital in order to prepare for a period of increasing change over the next 100 years as the impacts of climate change become increasingly serious.

In recent years a considerable amount of research has focussed on the time period between 13,000 BP and the present day, known as the Holocene Period. During the early Holocene a steady retreat of the ice sheets was seen which led to an increase in sea levels and a readjustment of the earth's crust following the relief of weight imposed by the huge mass of the ice sheets. These changes have had varied effects across the European continent. For example, in Britain, loss of the ice sheet resulted in settlement of the land mass in southern England and an increase in land levels in Scotland, roughly divided by a 'hinge' along the line of the Scottish Borders. An examination of the evolution of the European land mass over this period and an understanding of the inter-relationship between parts of the European coastline helps appreciate regional-scale coastal evolution. For example, in 10,000 BP Great Britain was connected to continental Europe by a land 'bridge' near the Dover Straits, whilst to the north, the east coast of England was separated from Belgium and Holland by the North Sea. By about 8,000-5,000 years BP, in what was known as the mid-Holocene Period, the rate of sea level rise was starting to slow down and the major erosion and weathering processes which had led to vast quantities of eroded material being transported from both fluvial and coastal sources was also reducing. During this period sea level rise was continuing much more slowly and this led to the creation of many low-lying, inter-tidal areas at the interface between the land and sea.

Coastal erosion resulted in the severing of the mass of land between the North Sea and the English Channel about 7,500 years ago helping to create the map of Europe much as we know it today. The severing of this connection resulted in much stronger currents and significant sediment transport around the Channel coasts before settling down to a regime similar to that of the present day. A progressive on-going rise in sea levels led to the flooding of many existing river valleys around the European coast forming features such as estuaries, creeks, mudflats and saltmarshes, and this process has been ongoing since then.

*Plate 1.1: The chalk clifflines of the Côte D'Albâtre have been eroded by the sea to form caves, arches and stacks such as those at Étretat, Upper Normandy, France.*

Evidence drawn from palaeo-environmental and archaeological research has assisted the understanding of long-term coastal change in Great Britain and elsewhere (McInnes et al, 2000[1]). This research has established a wealth of information about coastal evolution and change since the last glacial maximum. Palaeo-environmental evidence can also help us understand more about past fluctuations of climate for example during peak periods known in Europe as the Medieval Warm Phase and the Little Ice Age. These phases had their own lesser influences in terms of modifying and shaping parts of the European coastline. Incidents of rainfall over geological periods have also resulted in activity or inactivity in terms of geomorphological processes. The extent of coastal erosion and the amount of winter rainfall are two factors which can influence coastal landsliding activity and research has identified that the period from 1700 to 1850 was a particularly active one in southern England (Brunsden and Lee[2], 2000).

Over the last 100 years the influence of the Little Ice Age appears to have been much less significant and a general cooling trend now has been reversed. Many people have noticed a more rapid increase in temperatures in recent decades, although this has not necessarily been a steady rise but characterised by fluctuations and episodes. This trend of warming coincides with wide-ranging international concern over increased temperatures due to the human influences of climate change known as the 'greenhouse effect'. Research has identified that the amount of sunshine reaching the earth is increasingly resulting in the acceleration of the pace of climate change. Since the 1990s there has been a widespread increase in the melting of glaciers and ice sheets, and a trend of 'global dimming' due to the interference of the sun's rays by pollutants now appears to be reversing which, if continued, could have disastrous impacts for the human and natural environments in years to come.

It is not just the influence of climatic impacts and natural processes that has affected the coastal environment. Since human colonisation of the coast for reasons of trade, defence and recreation, particularly since the Roman period, the coastline has been altered significantly. This process was most dramatic during the mid-19th century and onwards when a huge increase in coastal development resulted from the popularity of sea bathing and following publicity on the benefits of the coastal climate for health. Such human intervention has resulted in many of the coastal estuaries being developed or reclaimed, as well as rivers being channelised, modified in other ways and dredged. Such changes not only have an impact on the formation and development of estuaries but can have significant impacts on adjacent parts of the coastline, which may include an increased frequency of coastal erosion or flooding.

In order to protect coastal developments, many of which were constructed on coastlines subject to significant rates of erosion, landslip and flooding, defences were provided particularly during the late 19th and early 20th centuries. In some locations this has prevented natural erosion of soft cliffs which, in turn, has reduced the amount of sediment supply entering coastal systems with knock-on effects such as beach depletion further along the coastline. In fact, along much of the European coastline, beach levels have declined as a result of human intervention, as well as other factors including sea level rise; the consequent beach lowering also often results in increased marine erosion.

The recognition of coastal change and practical experiences of the results of this over the last three centuries has clearly demonstrated that the coastal zone is an area that is naturally dynamic and prone to significant changes over time and geographical extent. The factors which result in coastal change do not always operate at the same frequency, whilst some factors are more intense than others. Understanding the coastal response may be complex; particular changes in the rate of erosion, landsliding or other factors may depend on certain thresholds being exceeded followed by periods of relative tranquillity until another threshold is exceeded. Some of the factors which lead to more dramatic coastal changes may have, therefore, been influenced by activities in past decades, whilst others may have swift reactions. All this emphasises the need for particular care to be taken when examining coastal processes and the need to draw evidence from longer term experiences rather than making decisions based upon data derived from a short timeframe. An understanding of the processes at work around the coast is, therefore, fundamental to effective risk management (Futurecoast, 2002[3]).

All around the European coastline the influence of the geology on the coastal landscape is clearly illustrated through dramatic examples. On the Isle of Wight in southern England the more resistant chalk headland at its western end, which terminates in the famous Needles rocks, forms a marked contrast to the softer sediments to the north and to the south. In northern France the processes of coastal erosion and weathering have created a dramatic coastal environment of textbook landforms including sea caves, stacks and arches along the chalk cliff frontage of the Côte d'Albâtre. Elsewhere sediment transport has resulted in the accretion of huge sand dunes such as those near Arcachon along the Aquitaine coast of south-west France.

In southern England the dramatic rise in sea levels between 10-6,000 BP, by as much as 100 metres, resulted in aggressive coastal erosion leaving many parts of the coastline in a vulnerable, over-steepened state. The effect of the erosion process has been to de-stabilise some coastal frontages resulting in a legacy of landsliding and instability problems. The largest urban landslide complex in north-western Europe is the Isle of Wight Undercliff which extends for 12 kilometres along the south coast of the Isle of Wight. A combination of coastal erosion and the effects of high ground water levels have promoted a series of landslide events within the complex which continue to this day.

In England and Wales the Department for Environment, Food and Rural Affairs (Defra), has provided funding for the development of coastal defence (shoreline management) plans (Defra, 2006[6]) in order to contribute to wise coastal risk management. Following the completion of the first round of these plans for the whole of the coastline of England and Wales by the Millennium a review highlighted the importance of undertaking further research to re-emphasise the need for attention to be paid to the understanding of coastal evolution and natural processes to support decision-making. The result was a further major study (Futurecoast, 2002[3]) which provided a wealth of supporting information in order to ensure that decisions, which may have an impact on the coast for a hundred or more years to come, are based upon the fullest possible knowledge of how the coastline may change. The LIFE 'Response' project aims to assist that process by illustrating the preparation of a sequence of maps which demonstrate a process of assessing the physical environment, coastal processes and the susceptibility of different coastal frontages to change, thereby allowing the development of hazard and risk maps which highlight those locations where particular problems are likely to be encountered in the future.

*Plate 1.2: The more resistant chalk outcrop forms the Needles headland at the western end of the Isle of Wight, UK, whilst the softer sands and clays to the north, at Alum Bay, have eroded more rapidly.*

For nearly 200 years geoscientists have provided evidence of coastal change. These include the records of lost villages, coastal structures such as forts, lighthouses and churches (McInnes, 2004[4]) as well as important archaeological sites which may have been constructed thousands of years before. Some important or historic assets have been lost through coastal erosion whilst elsewhere sea ports have been stranded from the coast following the accretion of extensive mudflats and saltmarshes. A major tool to aid this process has been the use of radio-carbon dating by archaeologists (McInnes et al, 2000[1]) which has helped provide a chronology of coastal settlements and in turn coastal change over the last 4,000 years.

With over 70 million people living within the coastal zones of the European Union, representing approximately 16% of the EU population, wise decision-making is vital. Along 20,000 kilometres of the European Union's coastline (about 20%) serious impacts arise from coastal erosion (EUrosion, 2003[5]); 15,000 kilometres are actively retreating and nearly 5,000 kilometres are artificially protected. Coastal resilience is the inherent ability of the coast to accommodate changes induced by sea level rise, climate change, extreme events and occasionally human impacts, whilst maintaining the functions fulfilled by the coastal system in the longer term; this must be a key objective. The concept of resilience is particularly important in the light of the latest IPCC predictions of global climate change (EUrosion, 2003[5]).

The impacts of climate change do, therefore, demand a more strategic and pro-active approach to coastal risk management in order to restore the sediment balance, allocate space necessary to accommodate natural erosion and coastal sediment processes and achieve a better understanding of coastal evolution. In most countries coastal erosion risks are not sufficiently assessed, so it is hoped that the information provided from the LIFE 'Response' project will provide common methodologies for coastal hazard and risk mapping. This objective formed a key recommendation from the European Commission's EUrosion project (2003)[5]. By incorporating coastal erosion hazards and risk mapping into long term plans, local and regional authorities can effectively divert new development from areas at risk and seek to modify or reduce risks in areas of existing development.

*Plate 1.3: The dramatic coastal sand dune system on the Aquitaine coast of France near Arcachon.*

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*Plate 1.4: Dense development of the coastal zone at Biarritz, south-west coast of France.*

## *Chapter Two*
# What are the nature and scale of coastal risks?

Natural hazards have significant impacts on coastal zones throughout Europe. The costs of emergency action, remediation and prevention can often represent a significant burden to the communities affected, often local or regional authorities with limited resources as well as for national governments. It is now accepted that the impacts of climate change are real and sea level rise, in particular, poses serious risks to coastal communities. In order to identify risks to assets in coastal zones it is necessary to establish first the current level of risks and then to seek to identify the increasing level of risk resulting from climate change in order to implement sustainable policies to reduce or manage those risks.

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 are a common feature of coastlines in the EU and have the potential to pose significant threats to the communities found within coastal zones. Operating on different timescales they present a varying degree of risk; coastal erosion being a relatively gradual process whilst flooding and landsliding are more spontaneous, episodic events that may be relatively more difficult to predict and are potentially more costly as a result (European Environmental Agency, 2004[1]).

In 2005, Europe suffered 648 natural catastrophe loss events (a loss event being an earthquake, tsunami, volcanic eruption, windstorm, flood, temperature extreme or mass movement). These resulted in 336 fatalities, and overall losses of US$ 16,002 million of which US$ 4,875 million represented insured losses. There are clear signs that there has been an increase in the number of westerly weather conditions and a significant rise in flood catastrophes such as those on the Elbe and the Danube (2002), and in the northern Alps in 1999 and 2005 as well as on the coast. In 2005 there were three instances of serious flood conditions within the space of just six weeks, a clear sign that climate change is already happening in central Europe. Evidence suggests that changing weather patterns will result in more frequent and more severe events and, as a result, more losses and damage, to which the insurance industry and society as a whole must devise an effective response.

Catastrophes will continue to affect Europe's coastal zones and hinterland. The reasons for this include population growth, an increasing concentration of people and assets 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[2]). The future of some coastal areas is particularly uncertain as 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.

Coastal risks arise when the hazards associated with the physical environment such as flooding and erosion or instability interact with society. Risk-based decision-making is seen to provide the means of addressing the challenges put forward by climate change and sea level rise. This is because it is based on a view of the world that recognises uncertainty rather than presenting an over-confident 'this will happen' view of what is known (ie. the so-called 'deterministic' perspective). The approach provides a framework for combining possible hazard events and their consequences along with a way of considering uncertain events and outcomes. It recognises that although current understanding may be limited, decisions still have to be made. It also supports the notion that management measures may reduce risks but they generally cannot eliminate them. Risk-based approaches allow an appreciation of the degree of risk reduction and the residual risk that must be borne by society or individuals after mitigation measures have been implemented (Lee et al, 2004[3]).

Risk evaluation is a judgmental process designed to determine just how significant the estimated risks are and to establish the best course of future action, including the nature of risk management required. Risk management strategies generally accept that there must be a degree of acceptable risk. Above a certain threshold the risks might be considered intolerable or unacceptable. It is widely accepted that between these two conditions the level of risk should be reduced to a level which is 'as low as reasonably practicable', the so-called ALARP principle (Lee, 2004[3]).

*Plate 2.1: Storm surges create huge waves which break against the seawalls of St Malo on France's Brittany coast.*

## Coastal erosion risk

Coastal erosion is a natural and/or human-induced process which is responsible for shaping the great variety of landforms we see around the coastline and can be defined 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. Its importance to the coastal environment lies in the fact that it provides a major source of sediment to depositional features such as beaches, saltmarshes and sand dunes, which not only form natural defences but which often form ideal habitats for a diverse flora and fauna as well as being important recreational amenities. However, the hazard of coastal erosion may result in a range of impacts or risks including:

- loss of life, property, infrastructure and land.
- destruction of natural or man-made defences, which in turn may result in flooding of the hinterland.

Coastal protection requires the allocation of increasing public expenditure 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. 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[4]). Whilst the development issue can and must be addressed through planning policy awareness-raising, the response to climate change is more difficult to plan for. There are three main cost categories for local authorities that involve the greatest expense; these are monitoring, coast protection works, and research.

In 2001 public expenditure dedicated to coast defence in Europe reached an estimated €3,200 million (compared to £2,500 million in 1986). This comprised new investments made (53%), costs for maintaining existing protection schemes and monitoring the coastline (38%) and provision for purchasing coastal land at risk (9%). Between 1999-2002 300 properties had to be abandoned as a result of imminent coastal erosion risk and another 3,000 houses saw their market value decrease by at least 10% (EUrosion, 2004[4]). 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 coast had increased to an estimated €500-1,000 billion in 2000. Whilst it is unlikely that all of these assets would be at risk, the costs of shoreline management strategies clearly represent a tiny fraction of the damages that would be incurred should the coastline be left unprotected; shoreline management, therefore, becomes even more justifiable.

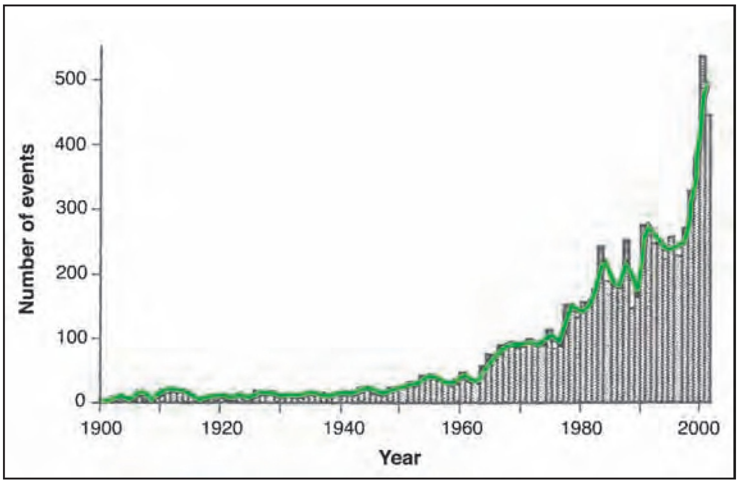



*Figure 2.1: Global natural disasters 1900-2000. (Source EM-DAY (OFDA/CRED database)).*

Coastal risk management involves mitigating and monitoring these risks. In England the main thrust of government coastal defence policy is to reduce risks through the provision of technically sound, economically justifiable and environmentally sustainable coastal defence schemes comprising flood prevention and coastal protection measures. Over the last 100 years some 865 kilometres of coast protection works have been constructed in England to prevent losses; this figure includes protection of low-lying areas prone to erosion. Implicit in all decisions to invest in risk reduction measures is the notion of 'acceptable' risk. The level of acceptable risk is, in part, controlled by legal responsibilities but it also varies with the perception of the individuals concerned and the resources available to manage the problem. Risk assessments address a number of key questions:

- What could happen - and on what timescale?
- Why might such events happen?
- What is the chance of it happening?
- What losses or damage could be caused?
- How can the problems be managed or reduced?

A risk-based framework focuses on the consequences of hazards and the implications of the management responses. For example, it should address not only the likelihood of a damaging event but also the chance of failure of the management measures, for example a coastal defence failure or a breakdown of an early warning system, and the resultant losses (eg. loss of life, injury, economic and environmental losses). The approach also supports the notion that management measures may reduce risks but generally they cannot eliminate them altogether.

On the coast the nature and extent of erosion and cliff recession and the existence of hazards can only be understood after investigations which lead to the development of some form of conceptual model for the processes taking place and an understanding of the coastal cliff behaviour. Their behaviour can be defined in terms of two key parameters:

- the retrogressive potential ie. the size, style and range of coastal recession events that may take place.
- the recurrence interval, ie. the timing and sequence of recession events.

Based on these parameters behavioural models can be developed and can provide a sound understanding of coastal processes and historical coastal evolution - often defined as scenarios which predict recession rates. The development of this 'probablistic' framework often involves a study of a number of key areas including:

- historical records
- the nature of recent changes in coastline form (eg. from historical maps, aerial photographs or monitoring)
- geological and geomorphological mapping
- assessing the relationship between climate and coastal change

Where development exists around the coastline most countries worldwide recognise that a balance must be struck between the need for coastal defences and the financial resources available taking account of the many national competing demands. For this reason, the economic effectiveness of management responses along the coastline is a key factor in terms of decision-making. The most usual approach to resolving these problems is through cost benefit analysis. This analysis takes account of environmental factors as well as property values and plays an important role in formulating the preferred policy options around the coast and in gaining funding towards the cost of new coastal defences (Thompson, 1998[5]).

The basic tools available for decision-making and risk management on the coast include:

- acceptance of the risk; eg. by spreading or sharing the costs through insurance or compensation;
- avoiding vulnerable areas, eg. through measures to control new development in areas at risk from coastal erosion, instability and flooding;
- reducing the occurrence of potentially damaging events, eg. through active land management to reduce the magnitude or frequency of erosion, landsliding and flooding;
- protecting against potentially damaging events, eg. powers to prevent coastal flooding and erosion or to stabilise cliffs and slopes or through building improvements.

The cost of reducing coastal erosion risks mainly relies upon national or regional budgets, rarely by the local community and almost never the owners of assets at risk or by the party contributing to the coastal erosion problem. This is emphasised by the fact that coastal erosion risk assessment has not been incorporated in the decision-making processes at the local level in some countries and information to the public on coastal risks remains poor. This highlights the importance of developing 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.

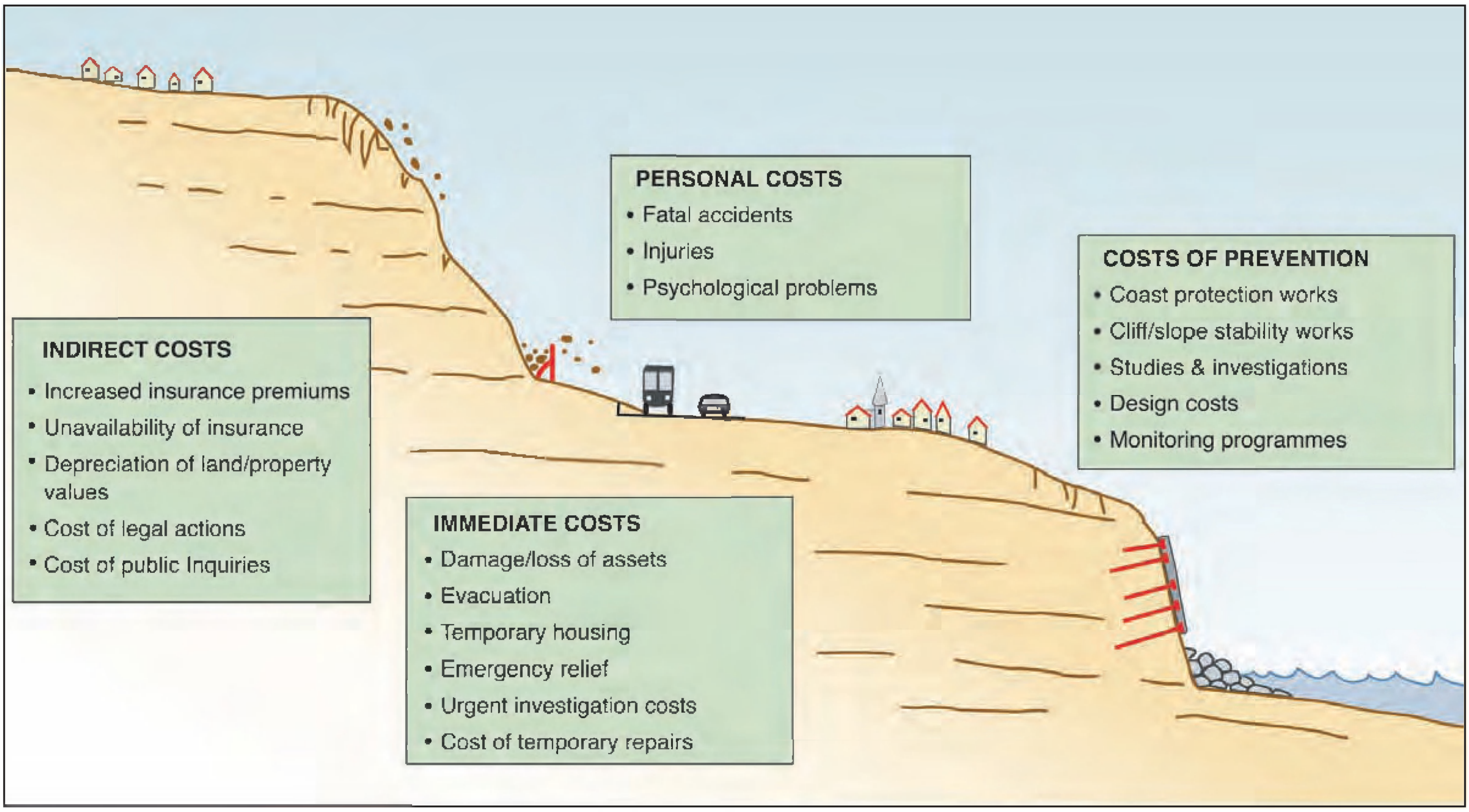



*Figure 2.2: Financial consequences of coastal erosion and landsliding. McInnes 2006 (Adapted from Jones & Lee 1994)*

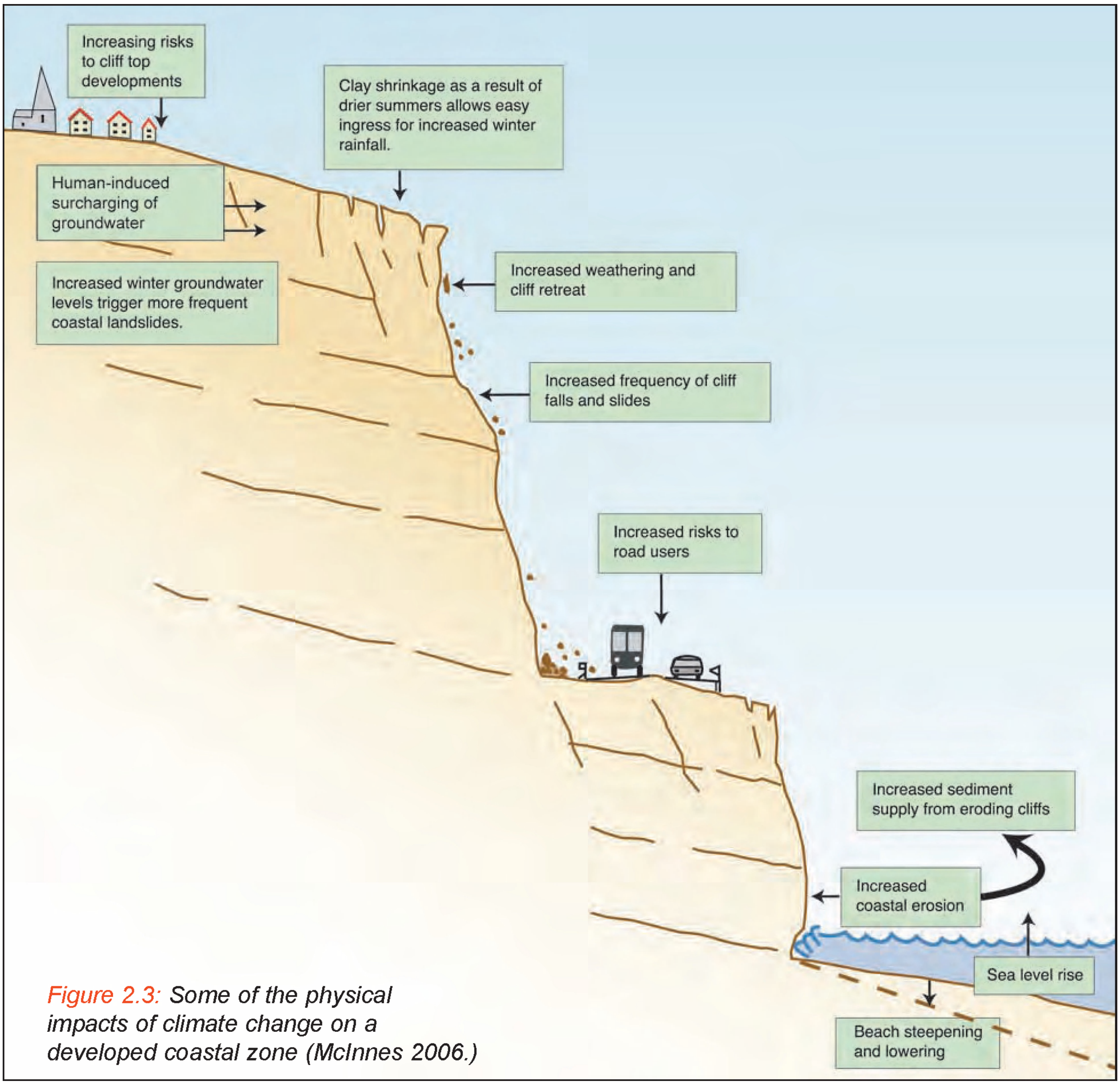
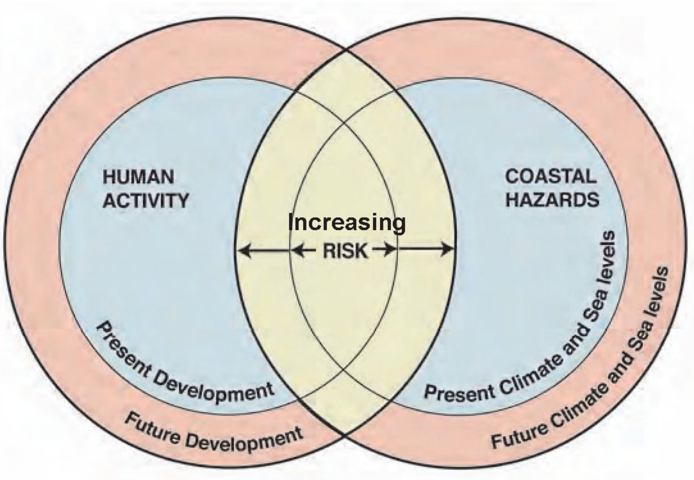



*Figure 2.3: Some of the physical impacts of climate change on a developed coastal zone (McInnes 2006.)*




The concept of risk as the interaction of the human environment with the physical environment is illustrated. 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.

*Figure 2.4: Coastal Hazards, Human activity and Risk. (Adapted from DOE)*

## Landslide risk

Ground instability poses major risks to land use and development in Europe. Examples from Italy, France and Great Britain illustrate its significance. Over the last 40 years major landslide events have caused substantial loss of life and property, particularly in coastal zones, river valleys and mountainous regions. It should be stressed that problems have often arisen because of the lack of co-ordination between land use planning and decisions over coastal defence and other strategies. Many parts of the European Union suffer from an inheritance of unplanned communities and developments built on eroding clifftops and in other unsustainable locations - often, but not always, a result of nineteenth century development, or mass speculative development in the mid-twentieth century.

In Europe many catastrophic landslides are triggered by heavy storms and rainfall, coupled with soil erosion on mountain slopes. Areas with steep slopes, unstable materials and high soil moisture are at risk, and the problems posed by these factors are compounded by human activities such as deforestation and the construction of roads and buildings. Between 1980-2000 there were 535 fatalities as a result of landsliding and hundreds of millions of pounds of damage to property and infrastructure. The risk from landsliding in coastal locations is increasing in the face of climate change, not least because developments, through choice or necessity, are still being situated in vulnerable areas.

The European LIFE Environment study 'Coastal Change, Climate and Instability' (McInnes et al, 2000[7]) noted 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 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 more major ground movement events that occur with little or no warning.

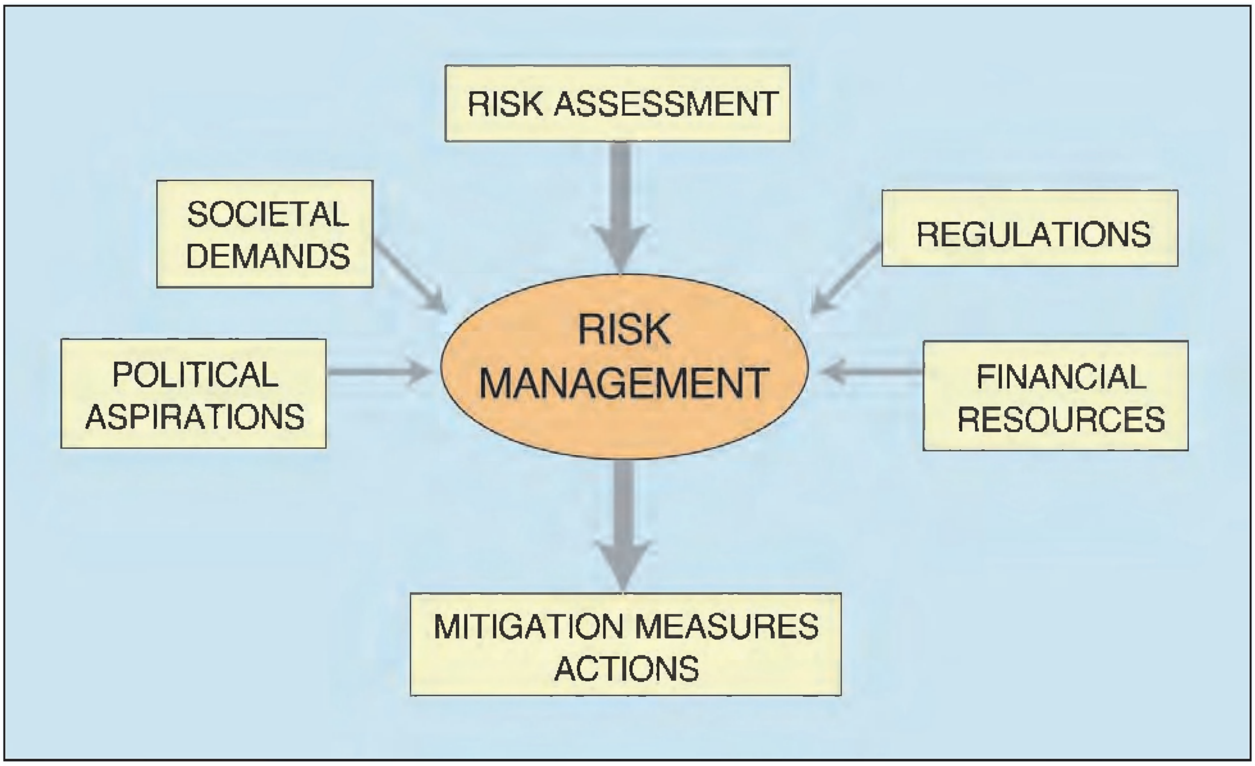



*Figure 2.5: The constraints to be taken into account in Landslide Risk Management. (Adapted from Leroi et al. 2005).*

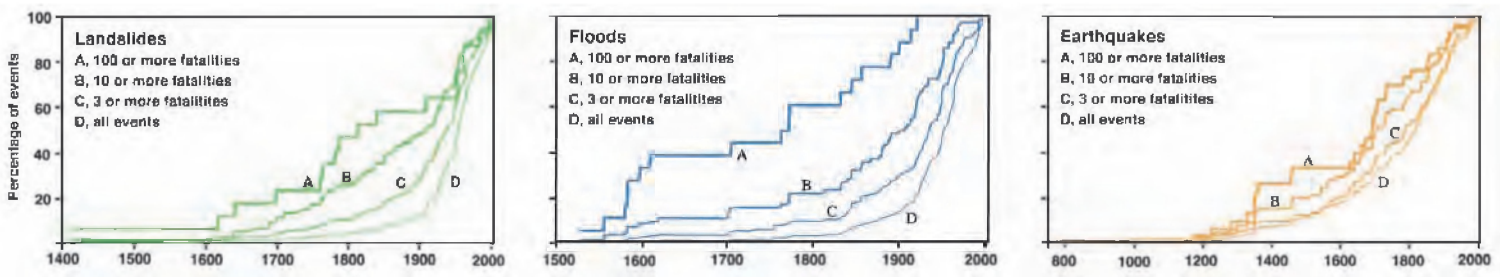



*Figure 2.6: Cumulative distributions of natural events that have resulted in fatalities in Italy (adapted from Guzzetti & Salvati)[25].*

It is widely felt that instability problems are increasing in Europe. The reviews of recent landsliding and climatic changes show that in addition to a trend due to sea level rise there is a variability closely related to short-term climatic rhythms. The effective rainfall levels for southern Britain, for example, also show an increased availability of moisture and, therefore, soil moisture and ground water storage. The landslide record corresponds to this rhythm especially to the sequences of years wetter than the mean. It is, therefore, easy to speculate that the European coastline will become increasingly susceptible to landsliding. Changes in weather patterns will have an impact on inland mountainous areas as well as on the coast and it is believed that the question of instability, be it coastal or inland, remains a major and growing hazard, the implications of which are far from fully appreciated in many EU member states.

It is reasonable to assume that instability will continue to be a significant problem in Europe because, first, economic and technological development has resulted in a massive investment in infrastructure, buildings and industry, combined with increasingly complex patterns of commercial activity, all of which indicate a growing vulnerability to landslide hazard impacts. In addition, development pressures in many parts of the European Union have resulted in the opening up of previously under-developed regions thereby increasingly exposing human activities to natural hazards (Jones, 1999[6]).

Recognition of the more widespread occurrence of slope instability within the European Union leads to the conclusion that the cost of slope failures are likely to escalate as a consequence of both climatic change and development pressures, unless active steps are taken towards mitigation. Much more positive measures of hazard management will be required in the future, increasingly focused on land-use planning based on carefully prepared hazard assessments (Jones, 1992[8]).

In 'A review of landsliding in Great Britain' Jones and Lee (1994[9]) concluded that landslide problems are not 'acts of God', unpredictable, entirely natural events that can at best only be resolved by avoidance or largescale engineering works. The role of human activity in initiating or reactivating many slope problems should not be underestimated. Urbanisation has resulted in the expansion of many towns and cities to such an extent in recent years that the most suitable building land has been fully occupied; so new suburban developments are often being proposed on potentially unstable slopes. Technological developments mean that instability-induced disruption to engineering projects has the potential of being both politically embarrassing and damaging to reputations as well as being extremely costly.

It is also recognised that even minor, inconspicuous and relatively slow-moving failures can have costly repercussions through the disturbance of structures and infrastructure, including the dislocation of underground services. It is equally true that there are numerous examples of instability impacts due, at least in part, to human activity. Leaking water and drainage pipes can contribute to instability as can slope loading through inappropriate construction and indeed slope unloading through excavation. All these factors indicate the value for money that can be derived from the development of a sound approach to the sustainable management of instability problems in urban areas.

*Plate 2.2: The city of Portsmouth, one of Britain's great maritime ports, developed on low-lying land, which is vulnerable to the impacts of climate change and sea level rise.*

Many problems could be reduced if there was a long term programme of active landslide management in place. Local communities need to come to terms with the situation and learn to 'live with landslides'. There is an increasing recognition of the need to minimise the risks and effects of instability on property and infrastructure and the general public. An improved understanding of instability issues, monitoring of instability sites, interpretation of results and the implementation of effective planning measures is also required.

Following the 1990s, United Nations' International Decade for Natural Disaster Reduction (IDNDR), a new challenge has been to communicate the understanding derived from valuable research to policy-makers and to local residents; the subsequent International Strategy for Disaster Reduction (ISDR) supports this task. Landslide risk management cannot be left to government departments and agencies alone. If a strategy is to be successful it must involve all sectors of the community as part of an holistic landslide management strategy.

## Flooding risk

On the coast flood risk is determined by a combination of peak sea levels, wave activity and storm surges. Sea levels are driven by tides, which are controlled by movement of the moon and planets, and surges resulting from air pressure changes and wind speeds on the water surface. Tides, surges and wave action can be significantly modified by the shape and character of the sea bed in coastal locations. The worldwide expansion of the oceans caused by rising global temperatures and the melting of land-based ice will increase sea level.

Coastal flooding can result from a combination of tide and surge levels that exceed the levels of sea walls but is more usually due to wave action in combination with high water levels. Close to the shore the maximum wave height is closely related to the water depth and the amount of wave run-up and overtopping is a function of the nature and configuration of the shoreline. Coastal defence infrastructure including sea walls, tidal barriers and related controls influence pathways and aim to control the impact that water flowing over defences or through breaches can have on the coastal floodplain. Sea walls often operate in combination with beach and foreshore management techniques such as beach recharge, groynes and breakwaters to control wave energy and improve the resilience of the coastal structures and limit wave overtopping.

Flooding can have severe impacts on people in terms of distress, injury or loss of life. Considerable demands are also placed on the emergency and public services during such events, particularly in developed areas (Environment Agency, 2005[10]). Both coastal and inland flooding can cause significant damage to property and developments as well as disrupting businesses and other services.

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[1]). In the United Kingdom 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 (Foresight, 2004)[22]. In the south-east of England alone flood risk areas make up 11% of the total land area posing a risk to 235,000 properties (Environment Agency, 2005[10]). 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. It is estimated that, if flood management policies and expenditure remain unchanged, annual losses in the United Kingdom will increase under every climate change scenario by the 2080s. However, the degree of increase will depend largely upon 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 helping to reduce future costs for coastal communities in terms of economic, social and environmental losses.

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[12]). With the technology available today, the ability to provide early warning has allowed structures such as the Thames Barrier in London 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[13]). In comparison, the initial outlay involved with constructing the barrier and its associated defences reached approximately £535 million (valued at £1,300 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 (at 2001 prices) on walls and embankments (Environment Agency, 2004[13]). The Environment Agency operates many smaller flood barriers across the UK that would also be used in conjunction with emergency response procedures.

*Plate 2.3: Selsey near Chichester, West Sussex, UK. The major flood risks to the area are centred on the caravan sites, the single road link to the north and residential development to the east. The land to the west and to the north is protected by a 4km long narrow shingle ridge whilst to the east over 1,000 residential properties and businesses are protected by a 1.2km groyne-stabilised beach and a concrete seawall built in the 1950s.*

## Quantifying and mitigating risks

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

The economic costs can be 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

Economic costs are the greatest in financial terms and are perhaps the most important from the perspective of local authorities and other organisations responsible for managing coastal defences. There are also other 'indirect costs' such as insurance costs, depreciation of property or land values and legal actions.

The cost of an emergency response may include emergency coast protection works, evacuation, provision of temporary accommodation, mobilisation 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 and preparation of high level plans and strategies to support the formulation of planning policies, the cost of coast protection schemes including design and construction, as well as the cost of coastal monitoring.

The social costs of natural hazards are largely intangible. Fatalities can be measured in real terms whilst 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 may impact upon the individual or society are largely related to inconvenience and are more difficult to measure.

*The village of Sirolo on Italy's Adriatic coast, south of Ancona, is situated at the top of a 125 metre high sea cliff. In parallel with landslide monitoring, extensive engineering works have been undertaken to reduce risks from slope movements.*

*Plate 2.4: Landslide stabilisation measures including ground anchors assist in reducing risks on the seaward slopes below the historic town of Sirolo, Marche Region, Italy.*

Environmental costs are difficult to quantify because natural hazards promote natural coastal change. There are a wealth of ecologically important sites in coastal zones (e.g. SPAs, SACs or RAMSAR sites) and legislation may require the protection of these sites from erosion or flooding in order that they are maintained in a favourable condition. Environmental mitigation and, where possible, enhancement can result in significant additional costs for construction projects.

Costs arising from natural hazards can prove to be a significant burden for local tax payers, particularly in terms of funding the emergency response. Climate change will increase the frequency and intensity of natural hazards, which will further increase the financial burden to be faced by regional and local authorities together with government spending departments. 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:

- forecasting and prediction of impending events;
- processing and dissemination of warnings to political authorities and the population;
- 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.

In most European countries the government bears the brunt of the costs associated with both emergency response and remediation. The emergency services, armed forces, local authority emergency planning departments and national flood warning services could all be mobilised, along with other emergency response teams.

Householders pay a more personal cost as a consequence of a hazardous event; possibly involving fatalities or injury as well as stress. Flooding and landsliding can be traumatic events for those affected, particularly when there is little warning. Rising insurance excesses represent an additional cost to householders and in some locations insurance is no longer available. The economic value of working time can also be calculated; the loss of productive (working) and leisure time is often a very significant factor for householders in a severe natural hazard event (UKCIP, 2004[11]). This may be compounded by the disruption to the transport network and infrastructure that almost always 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[12]), whilst subsidence hazards cost insurers nearly £1 million per day on average (ABI, cited in Crichton, 2003[12]).

One of the most important ways of reducing risk is to continue to develop a "culture of prevention". 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[14]). Whilst this cannot prevent a catastrophe occurring it has the potential to limit significantly the impact on 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. The gauging of floodwaters, particularly during and after heavy rainfall, can allow accurate predictions of how water levels may 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 movements and rates of coastal erosion can allow predictions on future movement in terms of timing and extent. Satellite monitoring of land movements can detect

*Plate 2.5: Fairlight village , East Sussex, UK is located on the top of high, weak sandstone cliffs. Part of the village (at the right hand end of the photograph) benefits from coast protection already and further works are proposed to protect the remainder of the developed frontage.*

*Plate 2.6: Part of the low-lying coastal zone near the town of Sete within the Languedoc-Roussillon Region of France. The barrier beach (lido system) protects assets, and lagoons of environmental importance from coastal erosion. Coastal protection works also reduce risks to the highway from marine erosion.*

minimal changes in the land mass and can help predict the location of possible landsliding events. Monitoring also forms the basis of decisions in relation to coastal protection policy, 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 landsliding or flooding events, and the damage caused by inappropriate and unsustainable defences constructed after poorly informed decision-making.

Research is the third component of effective management of coastal natural hazards. Coastal protection measures have traditionally protected against the current level of risk with some member states making an allowance in their design for sea level rise. However, it has become increasingly apparent that in the light of climate change prediction the level of hazard is likely to vary significantly. It is necessary to define the anticipated level of risk and to plan accordingly. Research into future scenarios and conditions will assist adaptation to those new conditions thus minimising the impacts of hazardous events and the associated costs.

## The insurance industry role

The insurance industry is actively assessing the growing trends and impacts of natural hazards and recognising the effects of climate change. 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. 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 (Munich Re, 2003[15]).

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. 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[15]). 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.

In the immediate aftermath of a natural disaster, one of the most apparent ways 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. It has been estimated that in 2002 there were 459 fatalities in Europe as a result of natural catastrophes, the majority of which were caused by flooding (Munich Re, 2003[15]). Due to the nature of natural catastrophes the number of fatalities experienced in any one year is often unrepresentative of the average losses over a number of years. As a result, a figure for the average losses gives a more accurate picture of the vulnerability. Poorer countries or regions are often more vulnerable as they are less well equipped to protect and prepare themselves. These locations are also more likely to have developments located in areas at risk, leading to greater human costs in the event of a natural catastrophe.

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 by 2020 (EUrosion, 2004[4]). When considering the additional number impacted by landsliding and other hydrogeological problems this figure increases dramatically.

Research carried out following serious flooding in Lewes, Sussex, on the south coast of England 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, sickness and vomiting (Health Protection Agency, 2004[16]). 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 individuals and communities affected by flooding (Health Protection Agency, 2004[16]).

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 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 include reduced losses should a hazardous event occur. However, the implication of this is that people may be unable to live in the areas that they may desire and are victims of forced choice.

## The financial implications of climate change and coastal risks

The effects of predicted changes in climate are causing considerable concern to those responsible for coastal risk management. Without more effective and integrated coastal planning, the consequences for the coastal zone could be severe. Increases in the intensity of precipitation, a rise in sea level and increased storminess will elevate the risk of coastal flooding. 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[17]).

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[18]). 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[17]). Indeed, the EUrosion project (2004[4]) stated 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'.

The potential impacts of a one metre sea level rise in selected European countries suggest that 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 increases in storm intensity or frequency. It is estimated that 9% of all European coastal zones (if defined as a 10 kilometre strip) lie below a 5 metre elevation and are potentially vulnerable to sea level rise, with 85% of the coast of the Netherlands and Belgium under 5 metre elevation, 50% in Germany and Romania, 30% in Poland and 22% under 5 metre elevation in Denmark, where 100% of the population lives within 50 kilometres of the coast. In the United Kingdom 75% of the population live within 50 kilometres of the coast, whereas the average for the EU is one-third of the population (EEA, 2005[19]).

The potential consequences of extreme climate events such as rainfall and storms is also of concern. More intense rainfall has already been recorded, and predictions for the future under the warmer climate scenarios 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. 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.

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 26 December 1999, which killed 87 people and destroyed 5,000 square kilometres of forest. In Western Europe (e.g. UK, France and Germany) windstorms are expected to increase property damage losses by 15% in 2070-2099 (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 (MICE Project, 2005[20]).

Recent research on climate change science is focussing increasingly on rapid climate change. 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 European and regional consequences can provide plausible worst case climate scenarios for impacts studies and adaptation planning.

Ranked by economic losses, Europe suffered the 4th largest natural catastrophe of 2005, the winter storm Erwin/Gudrun, with 18 fatalities, US$ 5,800 million economic losses and US$ 2,500 million insured losses (Munich Re, 2006[15]). In June 2005 Europe also sustained severe damage from climate change, and is warming 40% faster than the world as a whole. Storms in 1999 and floods in 2002 each cost €13 billion, whilst a heat wave in 2003 cost €10 billion. The European Commission has estimated the future cost of potential cumulative global damage, if no effective action is taken, at €74 trillion at present day values.

The IPCC has compiled a selection of national figures to emphasize the scale of the human and ecological assets that could be affected by sea-level rise, which are shown in the following table (IPCC, 2001[17]): Impacts of sea level rise in selected European countries, assuming no adaptation, and with 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 | 2,450 | 3.7 | 560 | 0.8 | 12 | 6 | n.a. | n.a. | n.a. | 20 | 10 |

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 emphasise 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; Ebenhöh 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 Jelgersma, 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 are exposed already to storm surges, and climate change is an important factor to consider for long-term planning and development."

*Figure 2.7: 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, 2001).*

The Netherlands faces 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.

## Insurance as a tool for risk management in the context of climate change

The last few decades have seen increasing concern over the extent and frequency of natural disasters, with great implications for Europe's insurance industry. This is primarily as a result of the continuing steady growth in population and the increasing concentration of people and economic values in urban areas (Berz, 1999[21]). 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 by the year 2050, making some locations uninsurable. The increase is due mainly to 'mounting economic values and insured liabilities in heavily exposed metropolitan areas' (Berz, 1999[21]); losses will bankrupt parts of the industry, which needs government action to halt climate change. Costs to the insurance industry can be minimised by adaptive measures if initiatives are taken soon. The insurance industry itself is expected to take an increasingly active role in controlling its costs (Acacia, 2000[18]).

It is with this understanding that we must address appropriate adaptation strategies, which take into account the continuing existence of risk in the coastal zone. Many of the impacts of sea level rise could be avoided or managed effectively given proactive measures today (Acacia, 2000[18]). However, this requires long term planning strategies to be developed for shoreline management. Indeed, Foresight (2004)[22] 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 economic value of the assets at risk will be carried out; this will be influenced by the level of finance available for protection work. (Klein et al, 1999, cited in IPCC, 2001[17]) argue that successful adaptation requires an integrated approach, including recognising the need for 'adaptation, planning, implementation and evaluation'. The European Environment Agency (2004)[1] believes the need for adaptation to climate change should begin as soon as possible because:

- 'anticipatory and precautionary adaptation is more effective and less costly than forced, last minute, emergency adaptation or retrofitting'; and that
- '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[23]). Active co-operation and sharing of information are required for effective adaptation planning at its highest level. Similarly, synergies are essential in terms of links between regions and local authorities taking note of advice and guidance from central government.

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 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 further deficiency has been the apparent absence of figures for more localised areas, the majority being for the global, European or national costs. In addition, comparisons are difficult to make between member state costs within Europe because there is a lack of a uniform method for data collection. 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.

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 is a major concern. 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 the risk and vulnerability of natural hazards to an acceptable level.

It has been agreed widely that investment must increase to react to the predicted rise in costs associated with climate change within coastal zones. This will still be cost-effective, even if the value of assets at risk does not increase as expected. Hazard mapping is likely to provide the most effective way of providing a basis for managing natural hazards by helping to avoid 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.

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 to assist the formulation of a cost-effective preventative response. The Response Project also provides a range of examples of innovation and best practice to demonstrate how, once identified, these risks can be managed.

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Plate 2.7: At Criel-Sur-Mer on the Channel coast of France rapid erosion of the vertical chalk clifflines has resulted in the loss of residential cliff top properties. For environmental and economic reasons coastal defence was not an option; recently a row of the most vulnerable properties (A) have been demolished under the provisions of the Barnier Law.

## *Chapter Three*
# Legal and Administrative Frameworks for Managing Coastal Risks

The geology and topography of the European Union coastline present an enormous variety of coastal conditions, natural hazards and problems resulting from historical development in unsuitable or marginally stable locations. The interaction between coastal erosion, ground stability and development results in a need for suitable planning and legal frameworks to ensure that appropriate development takes place and for the management of the coastline generally. In some cases coastal erosion and flooding are on-going but elsewhere they are episodic, being activated by climatic events or the effects of weathering or human intervention. Whatever the nature of the problem it is necessary to adopt sound approaches to planning and development of coastal land taking account of the geological and environmental circumstances.

This chapter reviews the legislation, policy and management of natural hazards at the various administrative levels illustrated by a range of examples of approaches from member states. The sustainable development of coastal areas and the management of coastal resources in an integrated manner are two major policy areas. These policies are key concepts when considering the management of natural hazards in coastal zones.

The concept of sustainability was put forward in 1992 at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro. It provided the fundamental principles and the programme of action for achieving sustainable development. At this global conference, Agenda 21 was adopted by more than 178 Governments. Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organisations of the United Nations System, Governments, and Major Groups in every area in which man impacts on the environment. Chapter 17 aims at "the protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources" (UN, 2003[1]).

The objectives of Programme Area A (Chapter 17.5): Integrated management and sustainable development of coastal and marine areas, including exclusive economic zones are as follows: Coastal States commit themselves to integrated management and sustainable development of coastal areas and the marine environment under their national jurisdiction. To this end, it is necessary to:

- provide for an integrated policy and decision-making process, including all involved sectors, to promote compatibility and a balance of uses;
- identify existing and projected uses of coastal areas and their interactions;
- concentrate on well-defined issues concerning coastal management;
- apply preventive and precautionary approaches in project planning and implementation, including prior assessment and systematic observation of the impacts of major projects;
- promote the development and application of methods, such as national resource and environmental accounting, that reflect changes in value resulting from uses of coastal and marine areas, including pollution, marine erosion, loss of resources and habitat destruction;
- provide access, as far as possible, for concerned individuals, groups and organisations to relevant information and opportunities for consultation and participation in planning and decision-making at appropriate levels (UN, 2003[1]).

International Policies on Climate Change have been difficult to achieve as they require global agreement. In 1988 the Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations, bringing together scientists from the world's governments. During the 1980s, discussion about climate change focused on whether the world was warming or cooling and the formation of the IPCC marked an important step towards finding scientific answers.

In 2005 the Kyoto Protocol became a legally binding treaty commiting 55 industrialised nations to making significant cuts in the emission of gases such as carbon dioxide by the year 2012.

The Declaration of the UN International Decade for Natural Disaster Reduction (IDNDR) 1990-1999 helped to raise the profile of discussions surrounding the social and economic causes of disaster risk.

In 1999 the countries participating in the IDNDR's International Programme Forum signed a Declaration of Intent, recognising that the world is increasingly being threatened by large-scale disasters and agreeing to act to guarantee a safer world for future generations. As the successor to IDNDR in 2000, the UN International Strategy for Disaster Reduction (ISDR) was initiated to foster this agenda by focussing on the processes involved in the awareness, assessment and management of disaster risks.

## European level

European legislation and policy provides a strategic framework for all aspects of land use and development within the European Union, including natural hazards. The European Spatial Development Perspective (ESDP), placed increased emphasis on the need for sustainability and environmental protection. As a direct consequence of this, detailed consideration should be given to geological factors in relation to economic development and regeneration. Land use planning and management decisions within the European Union are usually made at local or regional level. However, the Commission has a role to play in ensuring member states take environmental concerns into account when preparing their land use development plans.

Geological factors relate directly to many development issues and, therefore, need to be taken fully into account in land use planning. European legislation covering Ground Water Protection (80/68/EC), Waste Disposal (75/442, as amended) and Health and Safety (89/391, 89/654 and 92/57) all have impacts on development and planning issues in relation to ground instability (Thompson, 1998[2]). To improve the information flow between policy-makers and citizens about land use issues more generally, two Commission initiatives - INSPIRE (Infrastructure for Spatial Information in Europe) and GMES (Global Monitoring for Environment and Security) - aim to help to make information on the environment more accessible to citizens.

Over 80% of the European Union's 377 million citizens live in cities and towns with a significant proportion living in coastal zones. The challenge for policy-makers is to develop a sustainable and integrated approach to urban development and management that works in harmony with natural systems rather than against them. To assist in meeting this challenge the Community's Sixth Environmental Action Programme called on the Commission to develop a new 'Thematic Strategy on the Urban Environment' to help promote a more integrated approach and support action at local level. In January 2004, the Commission adopted Communication COM(2004)60 "Towards a Thematic Strategy on the Urban Environment" which set out the Commission's ideas for the 'Thematic Strategy on the Urban Environment'. The Communication highlighted the problems and challenges facing Europe's urban areas, focusing on urban environmental management, urban transport, sustainable construction and urban design.

Finally the Commission sought to improve the planning, management and use of Europe's coastal zones through Integrated Coastal Zone Management. Many of Europe's coastal zones face problems of deterioration of their environmental, socio-economic and cultural resources. Since 1993, the Commission has been working to identify and promote measures to remedy this deterioration and to improve the overall situation in our coastal zones. The Fifth Community Programme of 'Policy and Action in Relation to the Environment and Sustainable Development' was developed in response to the Council's request for an overall Community strategy on Integrated Coastal Zone Management (ICZM).

From 1996 to 1999, the Commission implemented a 'Demonstration Programme for ICZM' designed around 35 demonstration projects and 6 thematic studies. In 1999 the Commission summarised the findings from these important studies in their documents 'Better management of coastal resources' and 'Lessons learnt from the EU demonstration programme' (European Commission, 1999a[3]; 1999b[4]).

The Demonstration Projects identified particularly the need for participatory planning in achieving ICZM and a range of conflicts between stakeholders in the coastal zone arising from competing interests, differing cultures and traditions, inaccurate, disputed or withheld data, ignorance or unconcern for other’s needs, and clashes of interest on specific issues or procedures.

Based on the experiences and outputs of the Demonstration Programme, the Commission adopted two documents: A Communication from the Commission to the Council and the European Parliament on "Integrated Coastal Zone Management: A Strategy for Europe" (COM/00/547 of 17 Sept. 2002[5]); and a proposal for a European Parliament and Council Recommendation Concerning the Implementation of Integrated Coastal Zone Management in Europe (COM/00/545 of 8 Sept. 2002[6]). This Recommendation was adopted by Council and Parliament on 30 May 2002. The Communication explained how the Commission will be working to promote ICZM through the use of Community instruments and programmes. The Recommendation outlined steps which the Member States should take to develop national strategies for ICZM. The national strategies are due in 2006 and these will be reviewed by the Commission in order to decide whether any new legislation is required.

The Water Framework Directive 2000/60/EC (WFD), which came into force in 2000, established a new, integrated approach to the protection, improvement and sustainable use of Europe's rivers, lakes, estuaries, coastal waters and groundwater. The Directive contributes to the main principles and objectives of the ESDP. The Directive introduced a 'river basin management' planning system that will be the key mechanism for ensuring the integrated management of: groundwaters and coastal waters. River Basin Districts (RBD's) will be established, characterised by ecology, geology, hydromorphology, demography and land use. Coastal waters will be assigned to the nearest and most appropriate RBD; the administrative division of a RBD can also be divided into sub-basins.

In January 2006 the European Commission proposed a Directive to help member states prevent and limit flooding and the damaging effects of these events on life, health, property, infrastructure and the environment. This initiative was in response to recent disasters in Europe but also because the coming decades are almost inevitably going to see greater flood risks and greater economic damage. This proposal will create an EU framework for flood risk management that builds on and is closely co-ordinated with the Water Framework Directive. A three-step process is proposed. First, member states will undertake a Preliminary Flood Risk Assessment of their river basins and coastal zones. Where real risks of flood damage exist member states shall then develop Flood Risk Maps. Finally, Flood Risk Management Plans must be drawn up for these zones (European Commission, 2006[7]).

In order to ensure links between relevant scientific disciplines such as geology and natural hazards the Commission has established several Working Groups which will focus on weather forecasting, risk mapping and land use planning. As stipulated in the European Union's Sixth Environment Action Programme a 'Thematic Strategy on Soil Protection' is being adopted which will lead to a Community Soil Protection Policy and a legislative proposal for a Soil Framework Directive (European Commission, 2006[8]). These measures will take note of previous studies of erosion risks and include issues relating to soil loss through landslides, weathering and erosion.

## Coastal Erosion, Flooding and Instability - Policy Principles

Guidelines for sustainable shoreline management recognise that natural processes should only be disrupted by coastal defence works when life or important assets are at risk. A risk assessment of developed coastal areas should be carried out to determine the impacts of coastal change, sea level rise and coastal retreat so that planning strategies and development zones can be determined. Defence measures should be part of a strategic plan for the relevant coastal area in which all defence works are based on a scientific understanding of natural coastal processes. Wherever possible coastal defence measures should be nationally or regionally incorporated into ICZM plans which:

- are based on detailed knowledge of the coastal geomorphology and ecological processes;
- consider the relationships between physical, ecological and economic parameters;
- integrate these parameters into specific coastal development strategies;
- are founded on suitable administrative and legal structures.

In the past, individuals or private businesses have avoided high risk areas, accepted the losses as the price to pay for living and working in such areas, or have sought to 'improve' the conditions through civil engineering works. Maintenance, repair and clean up often form the central element of most strategies for

*Plate 3.1: The historic coastal town of Lyme Regis in Dorset, UK was developed on a landslide complex. Following detailed studies and ground investigations a major programme of coast protection works and slope drainage has been implemented to reduce erosion and landslide risk. Further works are under consideration for the frontage to the east.*

*Plate 3.2: West Bay, Dorset, UK. Upgrading of coastal defences at West Bay has reduced risks to properties as well as providing amenity benefits.*

dealing with natural hazards (Lee et al, 2000[9]). Insurance has become available for mitigating the losses associated with some natural hazards but excludes losses caused by marine erosion; occasionally compensation has been sought through litigation. Over the last few centuries, in a number of member states the government has gradually acquired a key role in addressing a number of specific problems associated with coastal matters; these include:

- controlling development in areas at risk and minimising the impact of new development on risks experienced elsewhere, through the land-use planning system;
- the provision of publicly funded coastal defence works to prevent erosion or flooding;
- funding and co-ordinating the response to major events.

Generally the cost and complexity of coastal defence or landslide remediation works are beyond most property owners with the exception of some major companies or major landowners. Indeed, it is often neither feasible nor desirable to attempt to protect a single property. To do so would inevitably lead to a patchwork of defence structures of different conditions, standards and performance. State involvement also has a social welfare element. For example, reduced losses as a result of erosion, flooding and instability should help promote greater prosperity by ensuring the security of property, a healthy workforce and efficient business. There is also a need to balance the pressures for reducing the risks faced by communities and obligations to take into account the interests of other groups such as conservation bodies and fisheries interests.

Policies concerning coastal defence, instability and land-use planning developed at a national level are principally implemented at the level of regional or local government or by non-governmental organisations such as the Environment Agency in England. Planning systems are designed to regulate the development and the use of land in the public interest. Such legislation usually aims to provide:

- guidance, which will assist in planning the use of land in a sensible way and enable planning authorities to interpret the public interest wisely and consistently;
- an incentive, with local authorities stimulating development by the allocation of land in statutory plans;
- development control to ensure that development does not take place against the public interest and to allow people affected by development to have their views considered.

Planning systems also have a vital role to play in promoting the principles of sustainable development. The legislation which forms the basis of the planning system is often supported by central government statutory regulations or by non-statutory circulars, planning policy statements and advice issued in various forms by central government. The guidance and advice is aimed primarily at local authorities to assist with the implementation of the legislation through the preparation of development plans and for the determination of planning applications (Thompson, 1998[2]).

Prior to the mid-1980s, local planning authorities frequently viewed natural hazards such as coastal erosion as technical problems that the landowner and developer needed to overcome, or the responsibility of coast protection authorities; they were not seen to be a land-use planning issue (Lee et al, 2000[9]). Since the mid-1980s, however, there has been a notable change in perception about the way in which these problems are managed. These changes reflect a growing appreciation that the past approach was not in the public interest, namely that:

- development in vulnerable areas can lead to demands for expensive publicly funded defence works;
- there are possible adverse effects of development on the level of erosion or flood risk elsewhere;
- defence works can have a significant adverse effect on the interests of other users in the coastal zone;
- defence works can encourage further development in vulnerable areas, increasing the potential for greater losses when extreme events occur.

When considering applications for new coastal development or changes of use, local planning authorities must have regard to their development plans and to any other material considerations including those which relate to the nature and condition of the ground. If the development is in an area at risk of flooding the local planning authority should consult the relevant advisory agency or experts; in England, for example, the Environment Agency, about the risk and take into account their advice. In this respect the local authority will need to consider the physical capability and suitability of individual sites for development and the possible adverse effects of ground conditions and natural processes upon development, including the need for mitigation or precautionary measures to deal with such effects as well as the potential effects of development upon ground conditions, natural processes, physical resources or conservation features both within the site itself and on adjacent land (Thompson, 1998[2]).

In many countries there are no general statutory powers to protect the coast against erosion and instability. However, often regional or local authorities, or major landowners provide defences under general local authority powers or Acts. It is recognised that complete protection is rarely possible; a balance has to be struck between the costs and benefits for the nation as a whole. For example, to attempt to protect every part of the coastline from change would not only be uneconomic but would work against the dynamic processes which determine the coastline and could have adverse effects on defences elsewhere and on the natural environment.

In addition to coastal erosion large parts of the European Union are vulnerable to the effects of coastal flooding. Flood defence policies usually aim to reduce the risk of flooding to people and the developed and natural environments by encouraging the provision of technically, environmentally and economically sound and sustainable measures (MAFF, 1993[10]). This objective can be achieved by:

- encouraging the provision of an adequate and cost effective flood warning service;
- encouraging the provision of adequate flood and coastal defence measures, which are economically, technically and environmentally sound and sustainable;
- discouraging inappropriate development in areas at risk from flooding.

In most countries coastal protection and flood defence policies are implemented by the government working in partnership with regional or local authorities who aim to achieve sustainable shoreline management through:

- the preparation of shoreline management (coastal defence) plans;
- more detailed strategic coastal defence studies, particularly relating to sediment transport, along the open coast, linked to estuarine studies, which identify the most appropriate coastal defence policy option for each frontage taking account of all factors;
- the undertaking of more specific local studies relating to the construction of a particular coastal defence scheme.

In England, more specifically to address flood prevention problems, the Environment Agency is preparing a programme of Catchment Flood Management Plans which are intended to provide the framework for managing flood risk based on catchments. To assist implementation of national coastal defence policy and risk reduction the Department for Environment, Food and Rural Affairs (Defra) has published a number of 'High Level Targets' (Defra, 2005[11]) to measure the level of success by coastal 'operating authorities' in fulfilling their coastal defence objectives. In 2005 Defra published its response to a major consultation programme on its forward-looking strategy for flood and coastal erosion risk management in England entitled 'Making space for water' (Defra, 2005[12]). The intention of the strategy is to seek improved coastal risk management looking ahead for the next 20 years.

Flooding should be a material consideration in the planning process. Local authorities' policies in relation to flooding should be set out in their relevant development plans taking full account of predicted impacts of climate change. Planning authorities should adopt a 'precautionary principle' to the issue of flood risk taking full account of best available information; and they need to undertake strategic flood risk assessments in support of their development plan policies; developers should produce a 'Flood Risk Assessment' for any development at risk.

The assessment and management of risks within an estuary should normally be considered as part of the shoreline management planning process for the particular frontage concerned. However, for a major estuary it may be appropriate to prepare an 'estuary management plan' (EMP) in its own right. Whichever approach is adopted the fundamental requirements will include an understanding of the sediment transport processes, an appreciation of how the estuary has evolved and how it may be changing, and predictions of its long term evolution taking account of such factors as sea level rise and the fluvial input. In addition there may be impacts within the estuary on the open coast and vice versa and, therefore, an holistic approach should be taken when considering the coastal frontage.

## Implementing coastal risk management

The development of sustainable policies for risk reduction in coastal areas necessitates a strategic approach. A Shoreline Management Plan (SMP) (Defra, 2006[13]) or Coastal Sediment Management Plan (CSMP - Eurosion, 2004[14]) will provide a large-scale assessment of the risks associated with coastal processes and allows the development of a policy framework to reduce these risks to people and the developed, historic and natural environments in a sustainable manner. In doing so, these 'high level' documents form an important contribution to the national strategy for flood and coastal erosion risk management. SMPs do of course integrate with other types of coastal plans including Estuary Management Plans and the over-arching Coastal Zone Management Plans.

Coastal engineers recognise that the shoreline cannot be entirely free of risk. Because of the varied nature of the geology, coastal landforms and topography, coastal processes obviously give rise to natural hazards such as flooding, coastal erosion and instability. These hazards can affect people and property in susceptible locations. Coastal defence measures may reduce the resulting risks but cannot eliminate them entirely. In their own right coastal processes and landforms can help minimise the impact of extreme storm events by acting as natural coastal defence solutions.

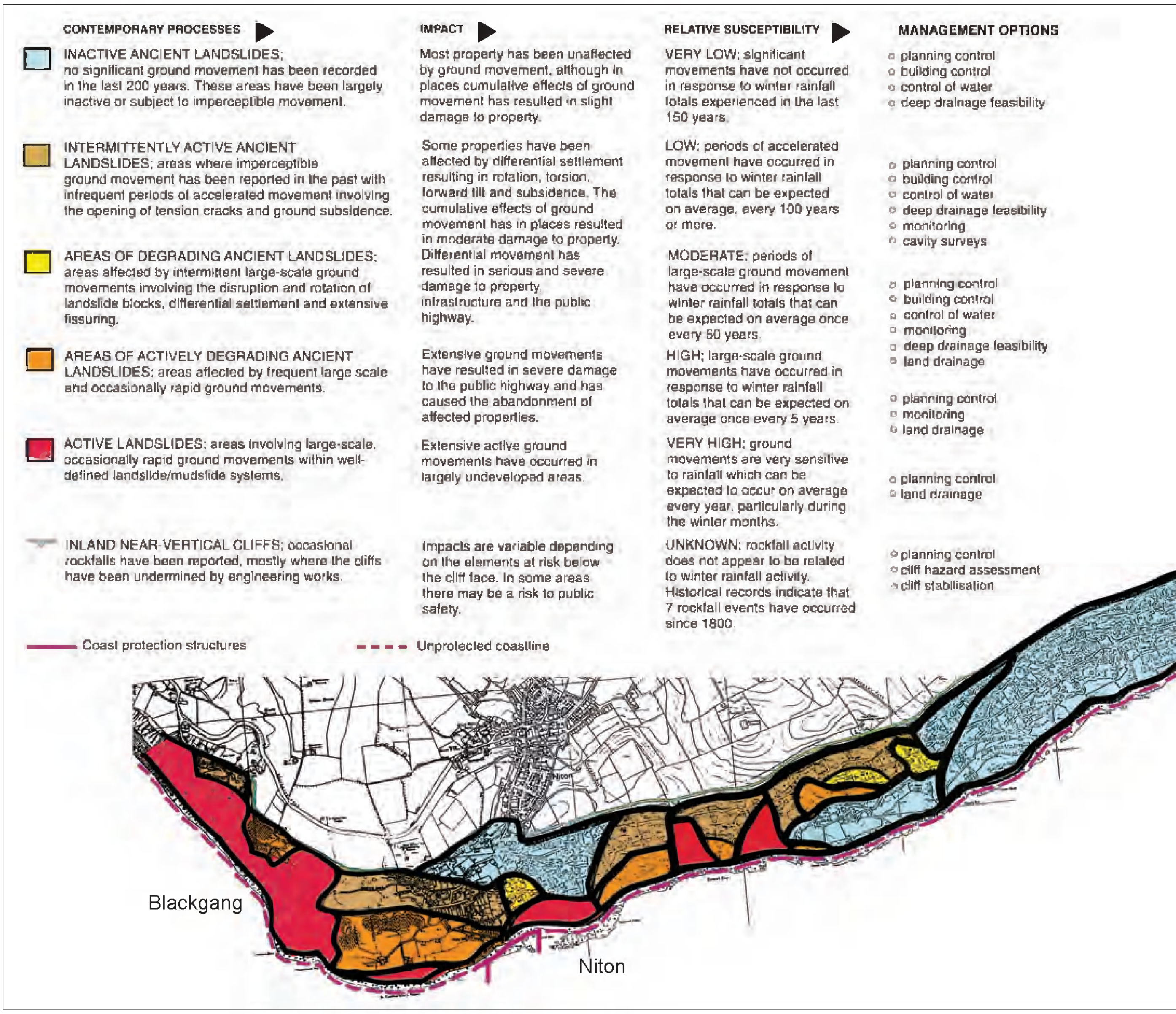
A variety of responses are available to coastal local authorities for managing risks including:

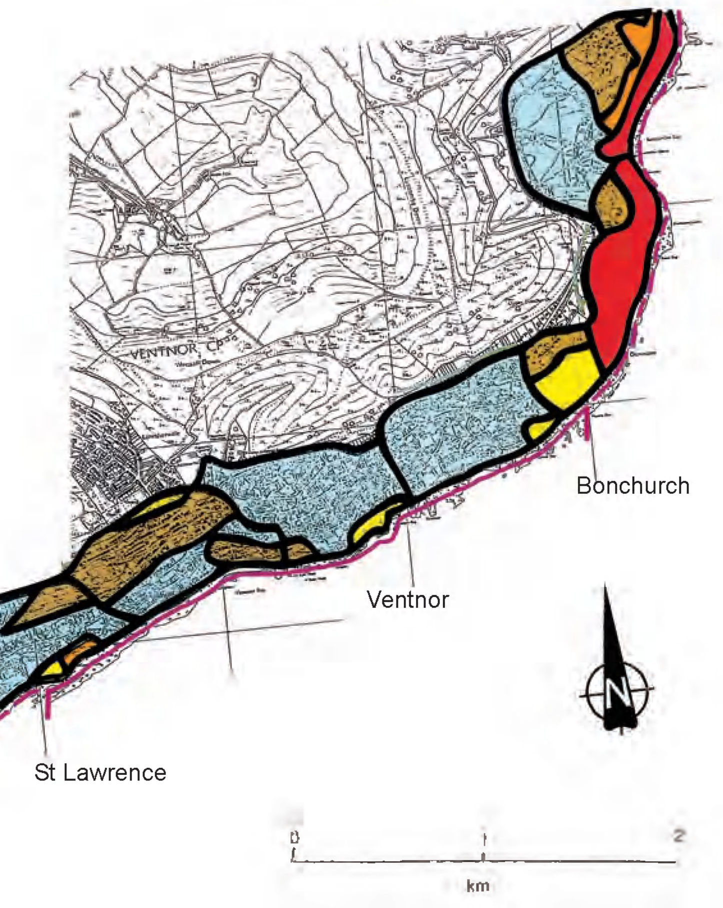
- avoiding inappropriate development in vulnerable areas through land-use planning or realignment of the coastline in a managed way;
- reducing the likelihood of loss of life and property along the coast through effective shoreline management engineering techniques;
- the provision of suitable monitoring and warning systems;
- protection against damaging storm events through flood and coastal defence schemes or building modifications.

It is clear, therefore, that a key benefit of the SMP process is the 'joined-up thinking' which can be achieved through participation, for example, the Regional Coastal Groups which bring together coastal defence engineers from adjacent local authorities. Coastal Groups ideally contain a cross-section of local authority coastal engineers, strategic planners and environmental and other disciplines. The need for close liaison between the coastal defence authorities and the local planning authorities cannot be over-emphasised. Throughout the development of both shoreline management plans and local authority development plans there are strong links and interactions. For example, the development plan can provide information to assist the preparation of the shoreline management plan, and equally the adopted shoreline management plan will provide informal support and contribute to the development plan and its future reviews (Ballinger et al, 2004[15]).

The shoreline management plan will also inform the development control process by providing information on coastal evolution and coastal risks, and the suitability or otherwise for development of land adjacent to particular parts of the coastline. In summary, therefore, shoreline management plans can support the planning system, firstly, at a sub-regional level by identifying those issues that need to be considered over a wider area than that of a single local authority, and, second, by informing the local planning authority of shoreline management issues and identifying areas at risk from flooding and coastal erosion over the next 100 years. This can be supported by the preparation of coastal evolution and risk maps at an appropriate scale as illustrated in Chapter Five.

Where the local planning authority is considering allocating coastal sites for development the SMP will provide information on the risks associated with potential development sites as well as providing information on whether, in principle, any coast defence works may be acceptable. In advance of considering planning applications in defined coastal areas the SMP will facilitate consultation between the relevant local authority engineers and the local planning authority on individual planning applications, especially with regard to planning conditions, planning obligations to mitigate risk or modification to proposed designs (Ballinger et al, 2004[15]).


CONTEMPORARY PROCESSES
IMPACT
RELATIVE SUSCEPTIBILITY
MANAGEMENT OPTIONS
INACTIVE ANCIENT LANDSLIDES; no significant ground movement has been recorded in the last 200 years. These areas have been largely inactive or subject to imperceptible movement.
Most property has been unaffected by ground movement, although in places cumulative effects of ground movement has resulted in slight damage to property.
VERY LOW; significant movements have not occurred in response to winter rainfall totals experienced in the last 150 years.
planning control
building control
control of water
deep drainage feasibility
INTERMITTENTLY ACTIVE ANCIENT LANDSLIDES; areas where imperceptible ground movement has been reported in the past with infrequent periods of accelerated movement involving the opening of tension cracks and ground subsidence.
Some properties have been affected by differential settlement resulting in rotation, torsion, forward tilt and subsidence. The cumulative effects of ground movement has in places resulted in moderate damage to property.
LOW; periods of accelerated movement have occurred in response to winter rainfall totals that can be expected on average, every 100 years or more.
planning control
building control
control of water
deep drainage feasibility
monitoring
cavity surveys
AREAS OF DEGRADING ANCIENT LANDSLIDES; areas affected by intermittent large-scale ground movements involving the disruption and rotation of landslide blocks, differential settlement and extensive fissuring.
Differential movement has resulted in serious and severe damage to property, infrastructure and the public highway.
MODERATE; periods of large-scale ground movement have occurred in response to winter rainfall totals that can be expected on average once every 50 years.
planning control
building control
control of water
monitoring
deep drainage feasibility
land drainage
AREAS OF ACTIVELY DEGRADING ANCIENT LANDSLIDES; areas affected by frequent large scale and occasionally rapid ground movements.
Extensive ground movements have resulted in severe damage to the public highway and has caused the abandonment of affected properties.
HIGH; large-scale ground movements have occurred in response to winter rainfall totals that can be expected on average once every 5 years.
planning control
monitoring
land drainage
ACTIVE LANDSLIDES; areas involving large-scale, occasionally rapid ground movements within well-defined landslide/mudslide systems.
Extensive active ground movements have occurred in largely undeveloped areas.
VERY HIGH; ground movements are very sensitive to rainfall which can be expected to occur on average every year, particularly during the winter months.
planning control
land drainage
INLAND NEAR-VERTICAL CLIFFS; occasional rockfalls have been reported, mostly where the cliffs have been undermined by engineering works.
Impacts are variable depending on the elements at risk below the cliff face. In some areas there may be a risk to public safety.
UNKNOWN; rockfall activity does not appear to be related to winter rainfall activity. Historical records indicate that 7 rockfall events have occurred since 1800.
planning control
cliff hazard assessment
cliff stabilisation
Coast protection structures
Unprotected coastline
Blackgang
Niton




## Legal and administrative frameworks for addressing ground instability in the Isle of Wight Undercliff landslide complex, UK.

The Isle of Wight Council is the Coast Protection Authority for the Isle of Wight as well as being the planning authority and highway authority; the Council is also a major coastal landowner. Research commissioned by the government (1988-91) at Ventnor assisted in the development of national policy guidance for development on unstable land. Coastal and geotechnical studies now inform planning policy guiding development away from areas at risk. This knowledge also assists the Council in managing coastal defences and important coastal highways as well as informing health and safety policies.

**Figure 3.1:** *Summary ground behaviour map of the Isle of Wight Undercliff*

In relation to coastal instability problems there is a continuing need to raise awareness and to identify their extent and significance in the context of development planning. The availability of resources and options for risk management within member states are set by:

- the landslide environment, or the nature of the landslide hazard within an area, ranging from slow ground movements associated with the reactivation of pre-existing landslides to sudden, rapid movement failures such as debris flows;
- the legal and administrative framework; this generally involves mechanisms for the control of new development and the prevention or stabilisation of landslides. Environmental legislation and international commitments have a significant influence on defining what are acceptable options for landslide prevention and stabilisation.

An assessment of risk is a key element when considering development proposals. The framework for risk management can be very complex and is often unique for each member state. However, the basic tools available for risk management are broadly similar:

- acceptance of the risk; eg. by spreading or sharing the cost through insurance, compensation or emergency relief;
- avoiding vulnerable areas eg. through measures to control new development in areas at risk from, for example, coastal instability;
- reducing the occurrence of potentially damaging events eg. through active land management to reduce the magnitude and frequency of landslide events;
- protecting against potentially damaging events, eg. powers to prevent coastal erosion or stabilisation of landslides or building improvements.

In the United Kingdom the Department of the Environment published planning guidance which stressed the need to take instability issues into account at all stages of the planning process (Planning Policy Guidance Note 14 'Development on Unstable Land', 1991[16]). This document states that:

"the stability of the ground, insofar as it affects land use, is a material consideration which should be taken into account when deciding a planning application".

The aim of this advice is not to prevent the development of unstable or potentially unstable land, though in some cases this may be the appropriate response. Rather it is to ensure that development is suitable and that both natural and man-induced physical constraints on land use are considered at all stages of planning. Where development is proposed on unstable or potentially unstable land, the planning authority should ensure that a number of issues are adequately addressed by the development proposal:

- the physical capability of the land to be developed;
- possible adverse effects of instability on the development;
- possible adverse effects on the stability of the adjoining land;
- possible effects on local amenities and conservation interests and the impacts of any remedial or precautionary measures proposed.

The assessment of ground conditions and the preparation of geomorphological, ground behaviour and planning guidance maps will, therefore, assist in the implementation of policies of this kind.

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2. *Thompson A., Hine P.D. Poole J.S. and Greig J.R. 1998. Environmental Geology in Land Use Planning. Report by Symonds Travers Morgan for the Department of the Environment, Transport and the Regions, UK.*
3. *European Commission, 1999a. Lessons from the European Commission's Demonstration Programme on Integrated Coastal Zone Management (ICZM). Luxemburg.*

Plate 3.4: *Barton-on-sea in Hampshire, UK comprises soft clay cliffs which are prone to landsliding particularly when groundwater levels are high. Coastal protection measures, comprising rock armourstone, have reduced the risk to clifftop residential properties from coastal erosion.*

Plate 3.5: *Isle of Portland and Chesil Beach. - The dramatic shingle ridge links the Isle of Portland to the adjacent mainland coast. South-westerly storm waves generated in the Atlantic Ocean attack Chesil Beach posing risks to assets in the low-lying areas.*

**4.** *European Commission, 1999b. Towards a European Integrated Coastal Zone Management (ICZM) Strategy. General Principles and Policy Options. Luxemburg.*

**5.** *European Commission, 2002a Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe. Official journal of the European Community. No.L 148, 06/06/2002 P. 0024 - 0027.*

**6.** *European Commission, 2002b Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme. Official journal of the European Community No. L 242/I.*

**7.** *European Commission, 2006. 'Proposal for a Directive on the assessment and management of floods. Brussels.*

**8.** *European Commission, 2005. 'Consultation on the Soil Thematic Strategy'. Brussels.*

**9.** *Lee, E. M., Jones, D. K. C., and Brunsden, D., 2000. 'The landslide environment in Great Britain'. In 'Landslides - Theory, research and practice'. Thomas Telford, London.*

**10.** *MAFF, 1993. 'Strategy for flood and coastal defence in England and Wales'. HMSO, London.*

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**12.** *Defra, 2005. 'Making space for water - First government response to the autumn 2004 consultation'. Crown copyright. London.*

**13.** *Defra, 2006. 'Shoreline management plans guidance'. Crown copyright. London.*

**14.** *European Commission, 2004. 'EUrosion - Living with coastal erosion in Europe'. Luxembourg.*

**15.** *Ballinger, R., Potts, J., Taussik, J., McInnes, R. G. and Fairbank, H., 2004. 'Local authority coastal risk management pack'. LGA, London.*

**16.** *Department of the Environment, 1991. 'PPG14 - Development on unstable land'. London, HMSO.*

*Plate 3.6: East Head near Chichester, West Sussex, UK. The risk to East Head is from marine erosion of the dune system near a junction between the spit and the hard defences on the open coast. If a tidal breach occurs this could seriously affect the inner harbour and navigation channels.*

## *Chapter Four*
# Assessing and monitoring coastal and climate change

Coastal risk management requires high quality information to support effective decision-making; it relies upon an understanding of coastal processes at work and the effects that these processes have on shoreline evolution. Monitoring provides an invaluable data source for coastal scientists and engineers alike. It also provides a basis for the design and development of coastal defence and landslide remediation works as well as encouraging greater confidence in efficient design of civil engineering works. Future requirements for remediation works can be predicted using monitoring data which may change the risk management philosophy from a reactive to a more pro-active one.

There are a wide range of techniques available to monitor the coastline, while others have wider applications across a number of fields. Monitoring techniques can be airborne or space-borne as well as ship-borne or ground-based. The categories of information needed to assess coastal change include data on waves, wind, tides, currents, topography, geology, geomorphology, hydrogeology, ecology, bathymetry and land use.

Airborne and space-borne techniques are used widely to capture data and to provide coverage of features of interest where these techniques are either more practical or efficient than land-based methods. These techniques are often referred to as 'remote sensing' as they gather data from a distance beyond the immediate vicinity of the sensor device. The main airborne techniques used for remote sensing of the coastal environment include Interferometric Synthetic Aperture Radar (IfSAR or InSAR), Light Detection And Ranging (LiDAR), Airborne Multispectral (MS) camera systems, Airborne thermal Infra-red Radiometers (TIR), and Hyperspectral sensors, analogue and digital photographs (Channel Coast Observatory Website, 2005[1]).

Space-borne techniques refer to sensors that are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth. The main form of space-borne remote sensing is from satellite imagery, of which there are two main types, Moderate Resolution Satellite and High Resolution Satellite. Ship-borne techniques, for example bathymetric surveys, side-scan sonar and grab sampling are limited to the marine environment and collect data on the changes and rates of change of dynamic sediments below Low Water, changes and rates of erosion of fixed bedrock below Low Water, the identification of small-submerged features, which may affect sediment transport processes, changes within offshore sediment sinks, and habitat mapping, to name just a few. Ground-based techniques take the form of topographic surveys, via levelling, a total station theodolite or global positioning system (GPS), although the method used may vary from site to site.

Once the raw data has been collected, numerous models are available to further analyse and predict shoreline change. Modelling techniques can either be in the form of a conceptual mathematical or numerical model which can be used, for example, to predict the volume of sediment transported alongshore as a function of the wave height, period and obliquity; or a computational model. Computational models can be used to analyse and predict sediment transport whilst other packages are available to model coastal change and erosion. Computational hydrodynamic models are site specific and range from lower resolution regional models to high-resolution local models. A hydrodynamic model could be run during extreme events to try to predict how sediments might move within a given area.

## Monitoring methods

Although a variety of monitoring and modelling techniques are used throughout the world, a study undertaken in 2004 found that monitoring techniques are still not widely applied in Europe and not the general rule. There is a significant gap between northern and southern Europe in the systematic use of coastline monitoring techniques as part of shoreline management policies (EUrosion, 2004[3]). The United Kingdom, the Netherlands and Germany have established relatively advanced coastal monitoring programmes using mainly LiDAR, ship-borne techniques or locally applied video systems as a means of shoreline monitoring. However, countries such as Portugal, Greece and France rarely implement coastal monitoring techniques or tend to use such methods for experimental research projects only.

Long-term wave monitoring around the English coast is currently being undertaken by Defra (Department for Environment, Food and Rural Affairs) in conjunction with the Environment Agency and the UK Meteorological Office. This provides a national wave monitoring network using a single source of real time wave data from a network of wave buoys located in areas at risk from flooding. Data from this network improves the management of flood and coastal erosion risk. Local initiatives to monitor the inshore wave regime continue to be implemented and maintained along with regional programmes monitoring nearshore wave conditions such as that of the Strategic Regional Coastal Monitoring Programme for south-East England.

A desktop sediment transport study for the central south coast of England between Lyme Regis in Dorset and Shoreham-By-Sea in West Sussex was first prepared in 1991 for SCOPAC (Standing Conference on Problems Associated with the Coastline). This group of local authorities and other bodies with responsibilities for coastal protection, sea defences and other aspects of coastal management commissioned an updated web-enabled version of the study recently (SCOPAC, 2006[3]). The study provides information on sediment inputs (marine; fluvial; cliff/coastal slope/platform erosion; beach nourishment); littoral drift; sediment outputs (including offshore transport, estuarine outputs); beach morphodynamics; and sediment stores, for the transport compartments (cells and/or sub-cells) along the south coast. Figure 4.1 (below) illustrates the type of interactive maps available for all sites within the region detailing sediment sources, transport pathways and sinks. The accuracy of such information is being continuously refined through a regional strategic monitoring programme (described below).

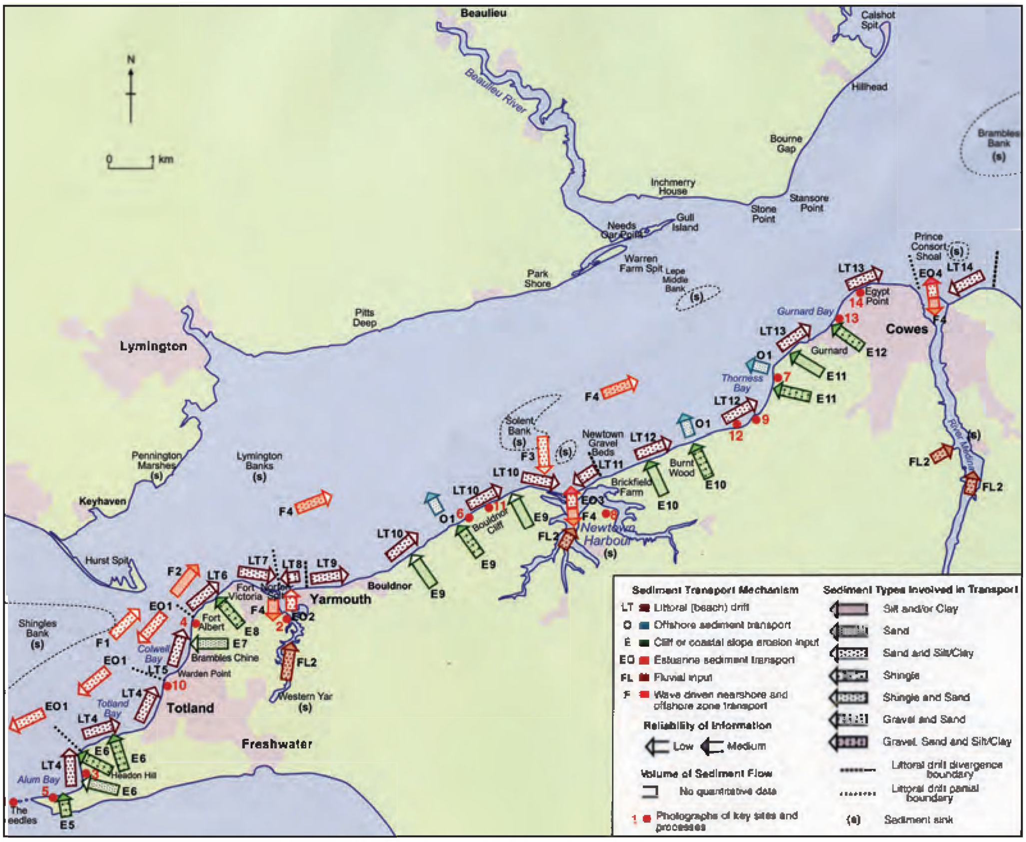



*Figure 4.1: Sediment Transport Map: this map illustrates the sediment transport pathways showing how waves, tides and currents carry silt, sand and shingle around the coastline of the Western Solent. A new web-enabled map has been prepared by the University of Portsmouth for the Standing Conference on Problems Associated with the Coastline (SCOPAC) and covers the whole coastline of central southern England from Lyme Bay in the west to Shoreham-by-Sea in the east, including the waters around the Isle of Wight.*

## Airborne/space-borne techniques

Airborne and space-borne remote sensing techniques have been used to capture data and to provide coverage of features of interest, where these techniques are either more practical or efficient than land-based methods. Such techniques are referred to as remote sensing as they involve the gathering of information at a distance via aerial photography, satellite imagery, acoustic data, and radar imagery.

Remotely sensed data from satellites represents an important source of alternative data to those derived from in-situ measurements (Doody et al, 1998[4]). Satellite data is similar to the data available from aircraft, however as satellites are in constant orbit, data is updated without the need to commission a custom survey (Millard et al, 2000[5]). Satellites provide a means for looking at a very large area within a very short time period. Satellite sensors create pictures of the Earth from space using electromagnetic radiation covering a range of frequencies, from radio waves to gamma rays (The National Oceanic and Atmospheric Administration Coastal Services Centre, 2006[6]).

Satellites can also record accurate sea surface temperatures, which can be used for studying climate change. Radar systems fitted to satellites can observe the sea state recording surface waves, fronts, currents and wind. Long-term data derived from satellites can be used to produce predictive models. Scientists can determine features such as the type of vegetation on the seafloor based on the signature pattern of the reflected signal.

Satellite imaging is desirable because it can cover relatively large areas (spanning several kilometres) at a more modest cost. Remote sensing techniques are usually the most cost-effective means of getting information for areas that are inaccessible or are too large to effectively manage or assess with traditional surveying methods. Whereas surveying a large area with traditional methods can take weeks or even years to complete, remotely sensed data allows for an image to be collected at a specific moment in time. This ensures that no changes have taken place whilst the data was collected and means that the image can also be used in the future for comparisons of the same area over time (the National Oceanic and Atmospheric Administration Coastal Services Centre, 2006[6]).

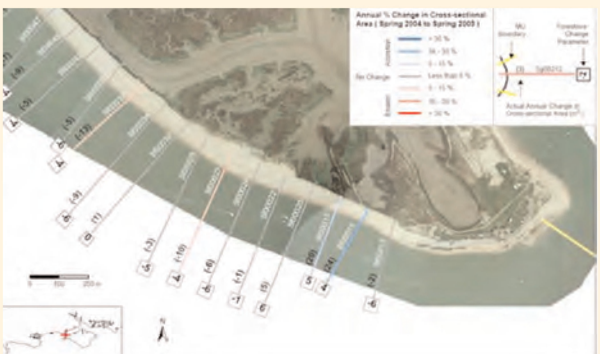
Interferometric Synthetic Aperture Radar is an aircraft-mounted sensor designed to measure surface elevation, used to produce topographic imagery. Radar pulses are aimed at targets on the Earth, and the return ground signals are received by two antennas that record elevations at specific ground coordinates. The ground coordinates are determined by Global Positioning System (GPS) and inertial measurement unit (IMU) technology. Post-processing of these data produces topographic information in the form of orthorectified radar imagery (ORRI).

## GIS and Coastal Monitoring

GIS (Geographical Information Systems) can be utilised in many ways to aid coastal monitoring. Not only can they be used as visualisation tools to present information to the end user, but also as powerful analysis tools. Here are two examples:

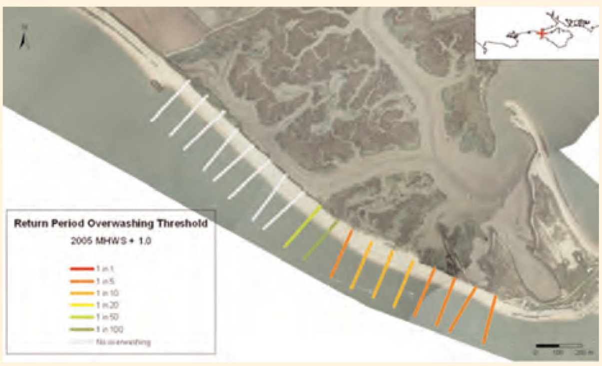
### Beach Change Analysis

The results of the beach change analysis, undertaken as part of the annual coastal monitoring programme, can be summarised for each profile line by assigning 2 key values to it: the Foreshore Change Parameter (an indicator for beach evolution trends) and the change in cross-sectional area can both be shown as text labels for each profile. In order to provide information ‘at a glance’, each profile is colour coded to show erosion and accretion. All the profile information is stored in a spreadsheet which is linked to the mapping. This is a real advantage as it enables non-GIS users to update information easily.



### Overwashing Threshold of Barrier Beaches

GIS can also be used to depict thresholds of overwashing. In the following diagram, the profile lines are colour coded according to the nearshore wave return period that will cause overwashing for a water level of MHWS +1.0m. This provides a useful visual tool for coastal managers.




GIS is increasingly being used in coastal management as a tool for storing, interrogating, analysing and presenting multiple datasets, and the examples presented here are only two of many opportunities to take advantage of the analytical and display capabilities of GIS.

*Plate 4.1: GIS and Coastal Monitoring*

*Plate 4.2: Taking inclinometer readings in the Ventnor Undercliff, Isle of Wight; a datalogger (inset) gathers ground movement data which can be downloaded to assist landslide risk management.*

One of the main advantages of using radar imaging systems is their ability to monitor ground displacements in real-time or near real-time. This allows for images to be used in the future for comparisons of the same area over time, making it ideal for monitoring shoreline changes. Other benefits of radar imaging include remote observation, day and night operability, and maximum flexibility in terms of viewing capacity and frequency of observation. IfSAR/InSAR can be an especially useful tool as it is not dependent on the weather and is less expensive than the LiDAR system.

LiDAR (Light Detection And Ranging) is an airborne remote sensing technique that gathers millions of geo-referenced points on a single survey enabling flood risk mapping, beach monitoring and cliff monitoring to be carried out. An active sensor, similar to radar, transmits laser pulses to a target and records the time it takes for the pulse to return to the sensor receiver, thus determining elevation. Surveys, typically flown at an elevation of 1000m, produce a swathe of data with a width of about 700m. This coverage is perfect for analysis of the coastal zone. A vertical precision of +/-0.15m has been widely quoted; this relates to uncertainties in the attitude of the aircraft, but also relies upon a suitable projection and datum transformation to the local system (Bradbury, 2004[9]).

The LiDAR system is perfect for applications that seek to provide an overview, where the absolute vertical accuracy is less significant. Applications at a strategic planning level, for instance, allow assessment of relative water level changes over large areas and identify detailed relief of cliffs or saltmarsh systems. LiDAR has the potential to supersede conventional photogrammetric methods at some stage in the future, but does not appear appropriate at this stage (Bradbury, 2004[9]).

Aerial photography is used widely in coastal monitoring programmes for interpretation of geomorphological changes and assessment of coastal erosion and accretion. Typical applications include beach profiling and topographic mapping. Good quality aerial photographs are best taken at low water on spring tides at a scale of about 1:10,000; photographs taken at a larger scale may not show enough detail to be useful. Digital aerial photography consists of two types of imagery, georectified and orthorectified photographs. In both cases high-resolution scans of aerial photographs are produced. Georectified digital images are produced from scanned images that are transformed to the local co-ordinate system, by warping the digital images to fit either a map base or an air triangulation model (developed using ground control). Data can be viewed or plotted from within a GIS, at scales of better than 1:500 (from 1:5000 photography), without a significant loss of image quality (Channel Coast Observatory website, 2006[1]).

Digital cameras can capture geo-referenced data in real-time which provides high resolution (5cm ground spacing) and accurate data which negates the need for scanning and rectification of photograph prints (Moore et al. 2003[6]; Moore et al. 2003[7])

The main advantages of using digital aerial photography include the wide area of data coverage, readily obtainable photographs that provide sufficient resolution for detecting subtle submerged features and resolving features smaller than one metre, and results that are easily integrated into the coastal management process. In addition to this, images are available instantly and there is a quick turnaround from acquisition, through processing to distribution to end-users. Imagery is transferable over the internet and there is no need for expensive digitising.

Digital raster aerial photographs offer tremendous advantages, when compared with ordinary contact prints, and with conventional large scale OS maps. When correctly geo-referenced, the data sets can be used within GIS in combination with vector map data for many shoreline management applications.

## Ship-borne techniques

Ship-borne techniques, for example bathymetric surveys, hydrographic surveys, side-scan sonar, and grab sampling are limited to the marine environment and collect data on the changes and rates of change of dynamic sediments below low water, changes and rates of erosion of fixed bedrock below low water, the identification of small-submerged features that may affect sediment transport processes, changes within offshore sediment sinks and habitat mapping. Bathymetry is the underwater equivalent of topography. A bathymetric map gives the depth contours of the soil, rock or sand forming the sea bed. In addition to this a bathymetric chart provides navigational information. Hydrographic measurements on the other hand include the tidal, current, and wave information of physical oceanography.

Analysis of existing beach data in many regions fails to provide a mass balance of erosion and accretion. In order to understand sediment circulation and sediment transport within the system, there is a need to identify and monitor potential sediment sinks. Such monitoring will help to provide an understanding of sediment circulation and may also provide possible opportunities for sources of beach recharge materials, which may be recycled to the coast, on a sustainable basis. Bathymetric surveys are particularly valuable in these areas; this particular aspect of bathymetric monitoring has been neglected completely in most areas until now (Channel Coastal Observatory Website, 2006[1]).

Side-scan sonar is a specialised sonar (SOund NAvigation and Ranging) system for searching and detecting objects on the seafloor. Side-scan sonar differentiates between types of surface sediments and identifies the direction of sediment movement. Multibeam sonar systems provide fanshaped coverage of the seafloor similar to sidescan sonars, but the output data is in the form of depths rather than images.

Sub-bottom profiling systems identify and measure various sediment layers that exist below the sediment/water interface. These acoustic systems use a technique that is similar to simple echosounders. A sound source emits a signal vertically downwards into the water and a receiver monitors the return signal that has been reflected off the seafloor. Some of the acoustic signal will penetrate the seabed and be reflected when it encounters a boundary between two layers that have different acoustical properties. The system uses this reflected energy to provide information on sediment layers beneath the sediment-water interface (The National Oceanic and Atmospheric Administration Coastal Services Centre, 2006[8]).

Information on tidal currents, levels and wave patterns is essential for use in coastal defence studies and for the validation of numerical wave models. Historical wave data can provide information for use in climate change studies and near real-time wave data can be used for coastal flood forecasting and warnings. Wave measurements are often made through a network of nearshore wave recorders and the deployment of wave buoys, typically in a minimum water depth of 10-12 metres. Data is then telemetered by radio link to a nearshore base station. Waverider Buoys can be categorised into two types, directional and non-directional. Directional buoys send wave height and direction data in bursts to an onshore receiver whereas non-directional buoys send only wave height data. As a buoy is raised by each passing wave, its vertical acceleration is measured and processed. In addition to this, most buoys will also measure sea temperature whilst also providing accurate positional information via an internal GPS system.

Tidal data is needed to provide estimates of extreme water level conditions; this aids the determination of standards of service of flood defences. Lengthy and reliable data sets are needed for provision of reliable forecasting of extreme water levels and determination of mean sea-level changes. Data is also needed to provide validation and development of storm surge warning models (Channel Coastal Observatory Website, 2006[1]). A permanent tide gauge network was set up in the United Kingdom in 1953 following violent storms in the North Sea. The UK Tide Gauge Network records tidal elevations at forty four locations around the country whilst programmes, such as The South-East of England Strategic Regional Coastal Monitoring Programme, allow real-time tidal data to be downloaded from the project website.

## Ground-based techniques

The most well developed long-term historical programmes within many regions all include land-based topographic surveying, in one form or another. Survey techniques can include the use of kinematic GPS, total station theodolites and levels. A common approach to monitoring surface movements is the use of ground surveys by triangulation and trilateration. Fixed survey markers are established and the horizontal and vertical co-ordinates of each are calculated through successive surveys.

Levelling of profiles, with an automatic level, provides the basis for development of most of the existing long-term beach survey programmes. Profiles can be measured by recording elevations relative to a fixed reference datum. Differences of elevation are recorded by measuring vertical distances directly on a graduated staff with the use of a levelling instrument such as a level, transit or theodolite. Levelling has the advantage that it can be conducted with cheap and simple equipment; it is generally reliable and properly maintained equipment rarely fails to perform (Channel Coastal Observatory, 2004[10]).

The Global Positioning System (GPS) system is a worldwide radio-navigation system comprising a network of twenty-four satellites orbiting at 20,000 kilometres above the Earth's surface. Ground-based GPS receivers analyse the phase/timing difference of radio signals transmitted from these satellites in order to determine the distance of the satellite from the base. By comparing how late the satellite's pulses appear compared to the receiver's code it is possible to determine how long it took to reach earth, therefore enabling the distance to be calculated.

## Monitoring ground instability

**Dataloggers** are often used to record and periodically transfer ground movement monitoring data to an operator. They can also be used to provide an early warning system if linked to telephone alarms when recorded ground movements exceed pre-set limits. They are ideal for use in coastal areas prone to landslides, where constant monitoring is required.

**Total pressure cells** measure the combined pressure of effective stress and pore-water pressure. In general pressure cells are used to verify design assumptions and to warn of soil pressures in excess of those a structure is designed to withstand. Typical applications include:

- monitoring total pressure exerted on a structure to verify design assumptions.
- determining the magnitude, distribution, and orientation of stresses (Durham Geo website, 2006[11]).

**Settlement cells** are used to record ground settlement in soils at specific points. The system consists of a pressure transducer, liquid filled tubing and a reservoir. The reservoir is fixed to a point outside of the area of settlement and acts as a reference point against which the pressure transducer, buried within the soil in fill or a borehole, is compared. The liquid filled tubing connects the transducer to the reservoir, and the transducer measures the pressure created by the column of liquid in the tubing. This pressure reading is converted to millimetres or inches of liquid head to give a measurement of ground settlement.

As the transducer settles along with the ground in which it is buried, the pressure increases and more settlement is recorded. It is important to correct for atmospheric pressure, which can have a very significant effect on the readings, and for this purpose settlement cells usually include an integrated barometer. Settlement cells are commonly attached to dataloggers to record continuous readings. Settlement cell systems require careful installation to minimise above-ground runs of cable and to minimise deviations in the upward slope of the tubing from cell to reservoir (Durham Geo Website, 2006[9]).

**Tiltmeters** are electrical devices used to monitor changes in inclination to a very high resolution. They are essentially precision bubble-levels forming a resistance bridge, with the bridge circuit outputting a voltage proportional to the tilt of the sensor. The sensor may be attached to any structure, but in the case of monitoring ground movement it is normally attached to a stake driven into the ground and housed within a protective cover. Changes in inclination are determined by comparing the initial current reading to all subsequent readings, and this comparison can yield continuous ground movement data when the unit is attached to a datalogger.

## Hydrological studies

An investigation of hydrological conditions usually comprises an analysis of rainfall input to the slope, evaporation, infiltration and surface run-off. A study of these inputs, transfers and outputs helps to identify thresholds and the possible timing of slope failure in relation to climatic conditions. Rainfall can be monitored most effectively using a weather station linked to a datalogger. Weather stations monitoring rainfall and evapotranspiration rates are used to determine the volume of water entering the ground, which can be a very significant factor in promoting ground instability, and will be increasingly significant due to climate change. Continuous data obtained in this way allows rainfall intensity and storm duration and antecedant conditions to be determined, enabling analyses of the development of slope failure over time.

**Piezometers** are devices used to measure ground water pressures. They may be installed within boreholesor directly into the ground. They are located at specific depths to measure water levels and artesian pressures. A standpipe tube with a porous piezometer tip connected at its lower end is installed in a borehole, and bentonite and grout are then used to seal the borehole above the tip. This allows groundwater to enter the tube only via the tip. The water pressure is then read by using a dipmeter (a tape measure with a water sensing element on the end that emits a sound when it contacts water) and corresponds to the height of the water surface in the standpipe above the piezometer tip. This can be automated by installing a vibrating wire pressure transducer piezometer tip within the borehole, connected to a datalogger at the surface.

There are different types of piezometers. The standpipe piezometer, which is installed in a borehole, consists of a filter tip joined to a riser pipe. Readings are obtained with a water level indicator. The

Contined on page 56

## South-East of England Strategic Regional Coastal Monitoring Programme

The Strategic Regional Coastal Monitoring Programme for south-east England began in August 2002; it includes thirty one Local Authority and Environment Agency partners and provides a co-ordinated approach to coastal monitoring. The Programme is grant aided by the Department for Environment, Food and Rural Affairs and its priority aim is to provide a standard, repeatable and cost effective method of monitoring the coastal environment between Portland in Dorset and the Thames Estuary.

Historically, coastal monitoring and data management has been carried out on an 'ad hoc' basis throughout the region. This has been both financially inefficient and technically inadequate. The new regional initiative provides a co-ordinated and consistent region-wide approach to data collection that provides economies of scale, a good technical solution and a sound management framework.

### Programme management

Survey work, data analysis and project management is co-ordinated by a specialist team established specifically for the programme. The Channel Coastal Observatory is hosted by New Forest District Council and based at Southampton Oceanography Centre. Recent months have seen new collaborative undertakings such as sharing staff resources; this has enabled improvement of skills and exchange of expertise between local authorities. A number of authorities are now actively involved with data collection and analysis.

### Strategic monitoring programme content

The Programme includes:

- topographic beach surveys
- hydrographic nearshore bed surveys
- aerial photography
- LiDAR
- Hydrodynamic data (waves and tides)

*Aerial survey - Ringstead Bay, Dorset, Uk*

Topographic survey programmes are carried out by Local Authority in-house survey teams using state-of-the-art Real Time Kinematic GPS. Bathymetric surveys are conducted by a combination of Local Authorities and commercial survey firms.

### Training

Regular training events are arranged on data management and surveying techniques by the Channel Coast Observatory; these have been well attended by Local Authority and Environment Agency staff.

*GPS Survey training*

### Data management

All data are managed and archived at the Channel Coastal Observatory in Southampton. Expertise is made available to all authorities for data interpretation. Data is provided to each authority in a format fine-tuned to each authority's individual needs.

### Technical benefits

The project plan presents a long-term vision to provide essential information for improved decision-making within shoreline management. Issues such as climate change and provision of coastal defences, that are sustainable in the long-term, are particularly reliant on good quality data. Long-term data sets (several decades) are needed to deliver these benefits. There are many short-term gains already arising from the programme; these include provision of high quality data for coastal defence scheme design and efficiency savings arising from collaborative working.

Many coastal defence schemes within the region now involve dynamic management solutions such as beach recharge and beach recycling; whilst these techniques are sustainable they require considerable management effort, including monitoring, to ensure that they function efficiently. Good examples of well established schemes that have benefited from long term monitoring can be seen within Poole and Christchurch Bays and at Hayling Island on the Dorset and Hampshire coastlines. Long-term monitoring programmes at these sites have helped to provide cost-effective management solutions by reducing engineering costs whilst maintaining safety. The monitoring programme will continue to provide data for these schemes as well as for new sites.

*Long-term monitoring at Bournemouth has helped to optimise design of beach management schemes*

## Assessing storm damage

Most of our sea defences are designed to withstand major storm events. Understanding the performance of these systems is essential for effective planning of maintenance and long-term management. Storm damage is often assessed visually but high quality post-storm beach surveys together with wave data and predictive models enable risks of breaching to be quantified.

*Wave data and beach profiles are used to predict the risk of breaching at Hurst Spit, Hampshire*

## Improved coastal defence design

Supply of materials for beach recycling is often a problem. Long term monitoring data has helped to identify suitable sources of cheap and suitable material. It is anticipated that new recycling sites will be sourced with the aid of the new monitoring programme. Such data will help to reduce costs of beach management schemes.

*Hydrographic surveys of the nearshore zone off Hayling Island, Hampshire, have identified a cheap source of beach recharge material*

Wave recorders have been deployed along this study area coastline at Boscombe, Milford, Sandown Bay, Hayling Island, Rustington and Lymington. The Programme will use the data to improve modelling methods, fine-tune scheme designs and for analysis of storms.

*Deployment of new wave buoy*

## Long-term cost savings

Many of the benefits of the programme will not be realised for 10-15 years, but it is anticipated that the benefits of the programme will exceed 6 times the cost within 10 years.

## Data dissemination

All the local authority and government agency partners are kept up-to-date with progress reports, formal meetings every 6 months and by the monthly e-newsletter, the Channel Coast News.

## Website

Real-time wave and tidal data, along with a host of other information including aerial photographs, are displayed on the project website

www.channelcoast.org

pneumatic piezometer consists of a pneumatic pressure transducer and pneumatic tubing. It can be installed in a borehole, embedded in fill, or suspended in a standpipe. Readings are obtained with a pneumatic indicator. The vibrating wire piezometer consists of a vibrating wire pressure transducer and signal cable. Readings are obtained with a portable readout or a data logger.

**Inclinometers** are used to measure ground deformation via deflection away from true vertical of specialised casing installed within a borehole. The system consists of the casing inserted and grouted into a borehole, and an inclinometer probe and logger. The casing is designed to move sympathetically with the ground, and to allow passage of the probe to measure this movement. The probe does this by employing two force-balanced servo-accelerometers that measure tilt. One accelerometer measures tilt in the plane of the inclinometer alignment, the other measures tilt in a plane perpendicular to the first. The probe is typically drawn up from the bottom of the borehole, stopping at half-meter intervals to measure tilt, which is recorded cumulatively along the length of the borehole. When the casing is first installed, an initial survey records the casing profile as a reference against which all subsequent readings are compared. Any deviation from this initial profile represents ground movement (after taking into account the measurement resolution of the probe).

**Borehole extensometers** are used to monitor settlement, heave, convergence and lateral deformation in soil and rock. Typical applications include monitoring settlement or heave in excavations, foundations and embankments, monitoring settlement or heave above tunnels and other underground openings, monitoring convergence in tunnel walls and monitoring lateral displacement in slopes.

**Crackmeters** are used to measure movement across joints such as tension cracks in soils and joints in rock, as well as the construction joints in buildings, bridges, pipelines, dams, etc. The instrument typically consists of a vibrating wire-sensing element connected to a spring, which is in turn connected to a connecting rod at its other end. When permanently placed across a dilating joint, the connecting rod is pulled out from the instrument body, and the spring stretches and causes an increase in tension, which is sensed by the vibrating wire element. The tension in the wire is directly proportional to the extension, which allows the amount of extension to be recorded very accurately.

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## *Chapter Five*
# Coastal Risks - Informing Planning Policy

An assessment of risk is a key factor when considering development proposals. The framework for risk management can be very complex and is often unique for each member state. However, the basic tools available for risk management are broadly similar:

- acceptance of the risk; eg. by spreading or sharing the cost through insurance, compensation or emergency relief;
- avoiding vulnerable areas, eg. through measures to control new development in areas at risk from, for example, coastal flooding, erosion or landsliding;
- reducing the occurrence of potentially damaging events, eg. through active land management to reduce the magnitude and frequency of events;
- protecting against potentially damaging events, eg. powers to prevent coastal erosion, stabilisation of landslides or building improvements.

Planning systems are designed to regulate the development and use of land in the public interest. Most planning systems are intended to:

- provide guidance which will assist in planning the use of land in a sensible way and enabling planning authorities to interpret the public interest wisely and consistently;
- provide an incentive for local government to stimulate development by the allocation of land in statutory plans;
- development control regulations in some member states help to ensure that development does not take place against the public interest and allows people affected by development to have their views considered.

It is only comparatively recently that planning authorities in some countries have considered coastal erosion, flooding and instability issues within the planning framework. More recently there has been an increasing change in perception about the way in which risks and planning are being addressed. These changes reflect a growing appreciation that the past approach was not always in the public interest. The assessment of physical conditions and the preparation of geomorphological, coastal evolution, ground behaviour, coastal risk and planning guidance maps will, therefore, assist in the implementation of policies of this kind.

A sequence of maps to inform planning of coastal risks in the context of climate change has been developed as part of the EU LIFE Environment 'Response' project (McInnes et al, 2006[2]). The Response project partners have based their research on detailed investigations within five European coastal regions which are representative of conditions fronting the European seas:

1. Central south coast of England (Channel/La Manche coastline)
2. North Yorkshire coast of England (North Sea frontage)
3. Aquitaine coast of France (Atlantic Ocean frontage)
4. Languedoc-Roussillon Region, France (Mediterranean Sea frontage)
5. Regione Marche, central eastern coast of Italy (Adriatic Sea frontage)

A careful assessment has confirmed that these varied and extensive coastal frontages represent the wide range of geomorphological features and coastal landforms to be found around the European coastline. The purpose of this assessment was to develop and test an effective, transferable methodology for coastal evolution studies and risk mapping that could be applied across the European Union.

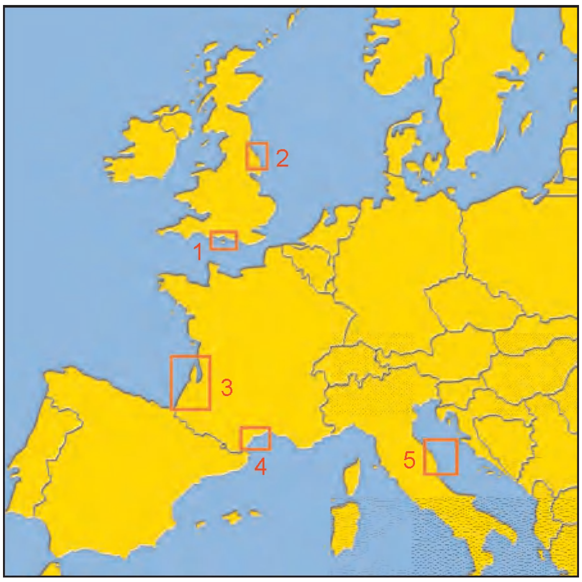


*Figure 5.1: Location of the five RESPONSE project study areas.* 

The first objective of the Response project was to assess the current impacts of forcing factors along these coastal frontages and then to establish the sensitivity to change of the coastal landforms when climate change scenarios are applied. This task helped to define risk where development and socio-economic factors interact with the physical landscape and this process has contributed to a wider risk management framework.

In the five European study areas a uniform approach to the mapping work was followed which comprised, first, the completion of a desk study review involving collation of factual information on coastal processes, coastal landforms and historical climatic data. Following completion of the desk review, an historical events database was established which brought together information on the frequency and size of natural events, including the extent of coastal erosion and sea flooding, records of historical landslides, ground movement and cliff failure.

This was followed by a geomorphological appraisal to develop a coastal risk assessment. The first stage was to refine and make use of an updated coastal landform classification based upon work previously commissioned by the Standing Conference on Problems Associated with the Coastline (Hosking et al, 2001[3]) for a 400 kilometre length of the central southern coast of England. This approach classified the coastal landforms into three zones:

- the shoreface - which controls wave energy, sediment transport and deposition;
- the shoreline - which controls erosion and inundation of the backshore;
- the backshore - which controls sediment availability (eg. supply from cliffs and sediment storage within estuaries).

'Coastal behaviour systems' are defined according to the following key features:-

- interlinked landforms that control the system response to forcing events;
- the connectivity of landforms cross-shore and longshore;
- changes in one landform can trigger adjustments to the others.

In summary, therefore, the process of developing coastal behaviour systems comprised an examination of, first, the landform elements and the process response mechanisms and, second, historical behaviour. This has allowed consideration of the sensitivity of the coastal behaviour system to climate and the 'change potential' of that particular coastal behaviour system and knowledge transfer to similar landforms if carefully applied. Once sensitivity and behaviour have been established a consideration of coastal hazards and risks taking account of the predicted impacts of climate change, based upon European regional climate models, can be applied. The study aims to inform decision-makers of the impacts of future pressures on coastal zones which will include:

- overtopping of coastal defences due to sea level rise
- loss of fronting inter-tidal deposits
- increased wave forces
- change in longshore drift patterns
- increased cliff groundwater levels and reduced toe support for coastal landslide systems
- tidal/fluvial flooding interaction
- potential for flash flooding

Plate 5.1: *Eroding soft clay and sandstone cliffs at Chale, Isle of Wight, UK*

| Coastal Behaviour Systems | | | | | | |
|---|---|---|---|---|---|---|
| **Landform Element** | **Hard Cliff** | **Soft Cliff** | **Lowlands, Barrier Beaches and Dunes** | **Spits, Inlets and Tidal Deltas** | **Estuaries and Tidal Rivers** | **Rising Coastal Land** |
| **Shoreface** | Steep | Gentle | Gentle | Gentle | Gentle | Gentle |
| **Shoreline** | Fringing boulder beach and/or shore platform | Fringing sand, shingle or mixed beach | Fringing sand, shingle or mixed beach; Free standing shingle barrier; Fronting sand or shingle beaches | Inlets; Tidal Deltas; Free standing shingle beach. | Tidal flat; Saltmarsh; Tidal River. | Fringing sand, shingle or mixed beach. |
| **Backshore** | Hard Cliff | Soft Cliff | Lowland | Lowland | Lowland | Gently Rising |
| **Management Techniques** | None | Control structures; Static holding structures; Full cliff stabilisation; Cliff remedial (reduction of retreat); Abandoned defences | Sediment management; Control structures; Static holding structures; Abandoned defences; | Sediment management; Control structures; Static holding structures; | Static holding structures; Abandoned/ Dilapidated defences (continuing to affect processes) | Static holding structures or sediment management and/or control structures. |

*Figure 5.2: Classification of Coastal Behaviour Systems applied to the Response project study areas.*

*Plate 5.2: Hard cliffs, e.g. Collioure, Pyrénnées orientales, France*

*Plate 5.3: Soft cliff, e.g. Chale, Isle of Wight, UK*

*Plate 5.4: Lowlands and barrier beach, e.g Lancing, West Sussex, UK*

*Plate 5.5: Spits, inlets and tidal deltas, e.g. Pagham Harbour, West Sussex, UK*

*Plate 5.6: Aquitaine dunes, France*

*Plate 5.7: Estuaries and tidal rivers, e.g. Western Yar river, Isle of Wight, UK*

Information gathered from the European case study areas have been illustrated through a logical sequence of regional-scale coastal maps which can be carried out as a paper-based excercise, or using a GIS, depending on the availability of resources.

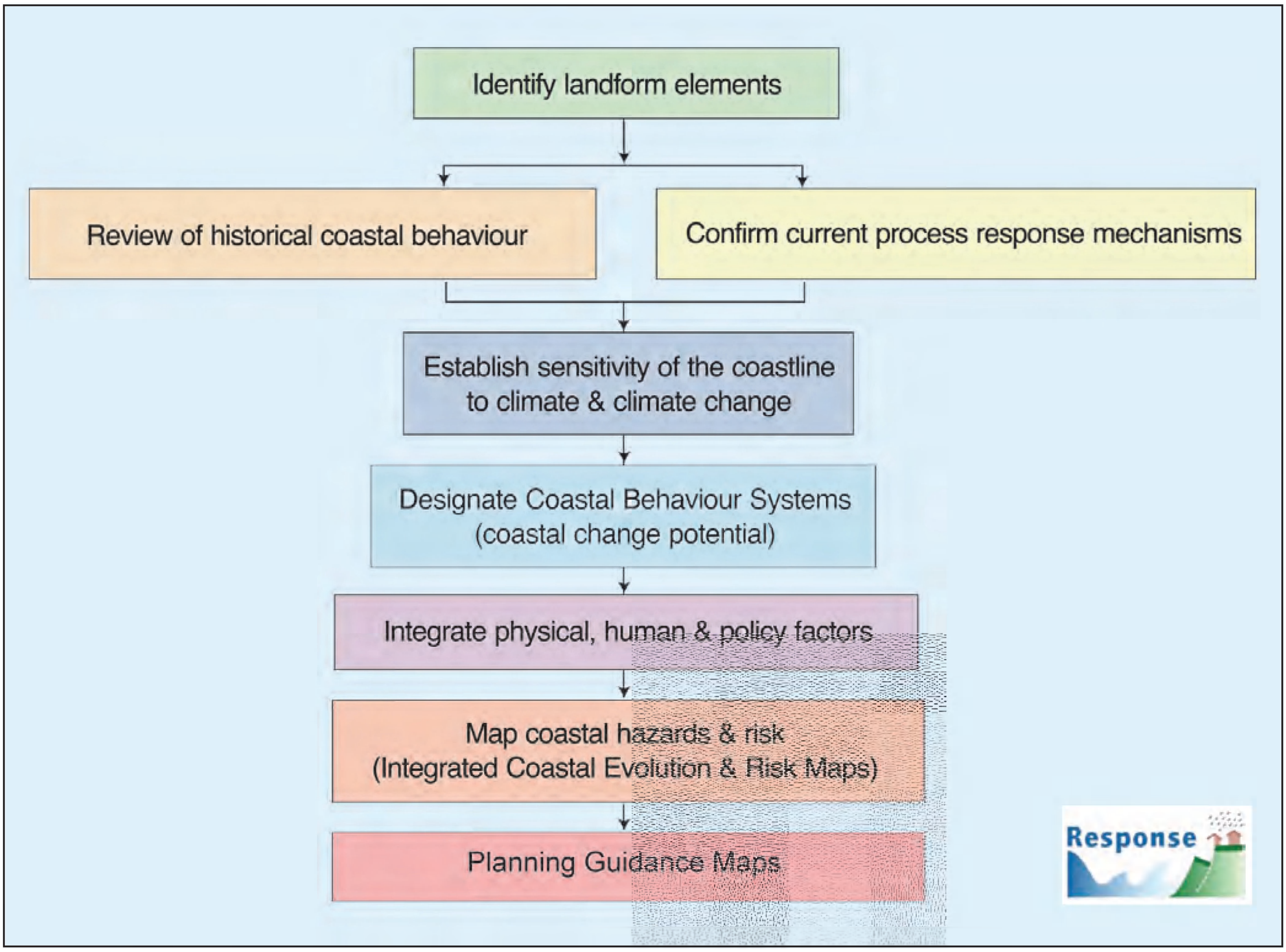


*Figure 5.3: - 'Response' Project methodology for development of 'integrated coastal evolution and risk maps. (adapted from Hosking and Moore, 2001)*

## Map 1. Coastal landforms and geomorphology

Phase 1 of the mapping (Maps 1 to 4) provide a representation of factual data, identifying the physical setting and key management issues for a stretch of coastline. Map 1 illustrates coastal landforms and coastal processes and provides important background information about the coastline.

Coastal landforms are classified according to the form and behaviour of the shoreface, shoreline and backshore. The map therefore represents features such as dunes, cliff types, beaches and estuaries. It should be noted that significant variability of form and behaviour is evident within most of the generic landform types. If required, further sub-divisions may be developed as necessary.

Map 1 also includes a representation of coastal processes. The map should include a representation of sediment cell and sub-cell boundaries, sediment transport, net drift direction, coastal erosion inputs, sediment sinks and stores, as well as information on coastal wave energy, coastal erosion and active slope processes. An understanding of coastal processes such as the movement of sediment around the coast and trends of erosion and deposition are important when assessing the future impacts of climate change.

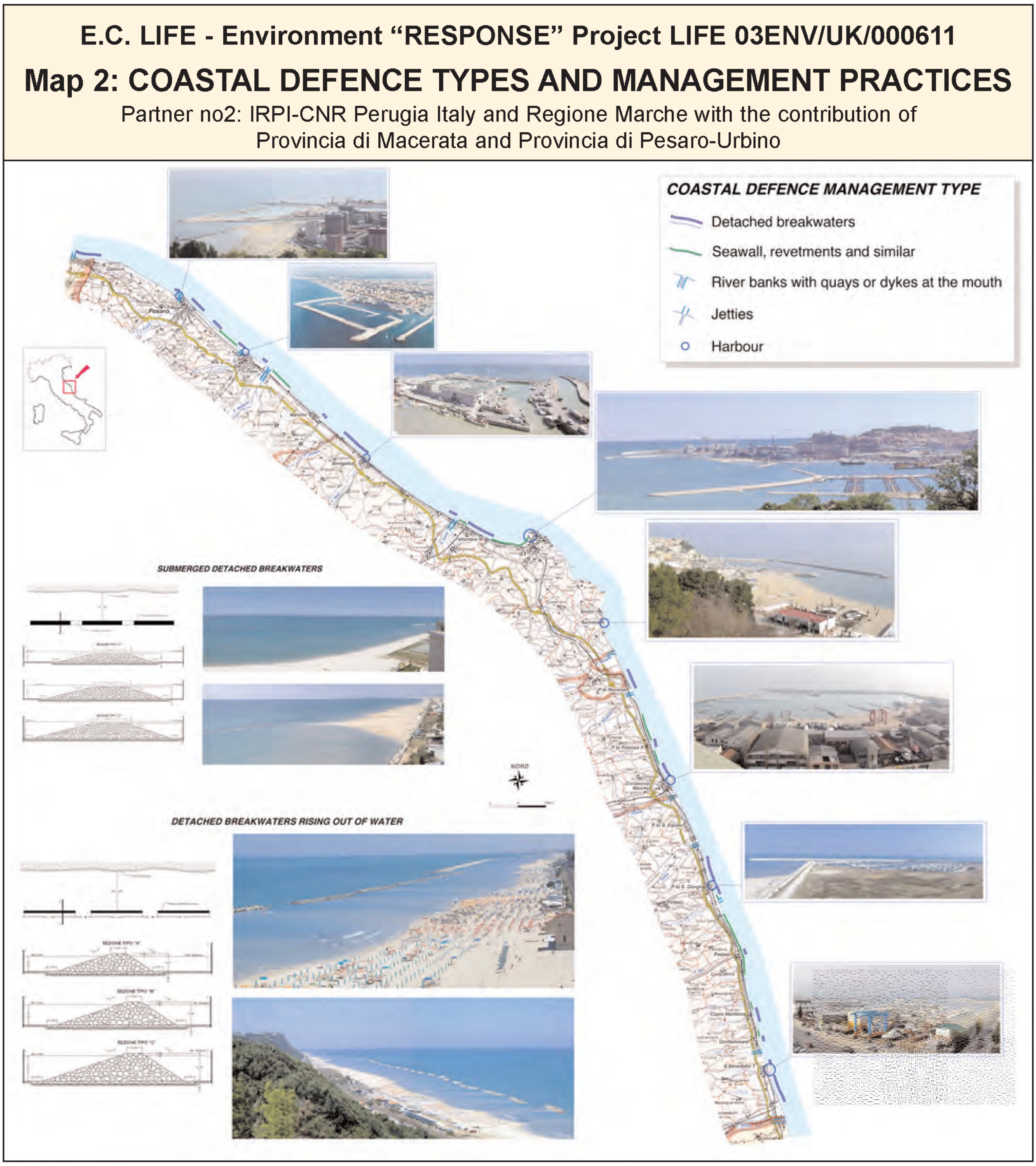


*Figure 5.4: Example of Map 2 ‘Coastal defence types and management practices from the Regione Marche study area, Italy.*

## Map 2. Coastal defence management types and practices

This example of Map 2 is drawn from the Regione Marche study area on the central east coast of Italy. Much of the coastline of Europe is not able to operate 'naturally' because of the impact of coastal defence structures. The distribution and nature of coastal defences need to be understood as they have an effect on the coastal morphology and change the impact of forcing factors. Defences have value in terms of the protection afforded to assets such as towns or agricultural land, and also in terms of the economic cost of their construction and maintenance. This is important when assessing the potential coastal risks if the defences fail. Coastal defences may degrade in the future leading to an increase in the probability of failure through time and an associated increase in the risk to the assets protected. Management policies may change in the future, with the potential for defences to be removed or realigned to allow coastlines to begin to operate naturally.

## Map 3. Historical coastal hazards

Records of past and present coastal hazards highlight hotspots of activity and are a good indicator of potential hazards. Historical records provide a useful source of information on the location and nature of past and present hazards. The maps from the study areas provide three types of data, including flood envelopes showing current areas of land affected by tidal and fluvial flooding; information on the approximate locations of past coastal erosion or past landslide events from historical records; and information on the approximate current areas of active landsliding.

For the central south coast of England, for example, flood plains are indicated by shaded polygons derived from accurate, ground-truthed outputs of numerical modelled datasets. The location of current and historical events are indicated by points on the map, which can be cross-referenced to a database which provides further information. Information stored in the database includes details such as the date, size, related costs and location of the event.

## Map 4. Coastal assets and population

Figure 5.5 (below) shows part of the southern Aquitaine frontage on the south-west coast of France. As discussed above, risk is often defined as the result of combining hazards with their consequences, which may include loss of life, property or habitat. These features are presented on Map 4, which illustrates the human assets and population, and environmental assets.

Map 4 provides a representation of factual data. Human assets including main population centres are displayed in terms of population density, and important industry together with environmental (natural) assets such as nationally designated areas and European sites.

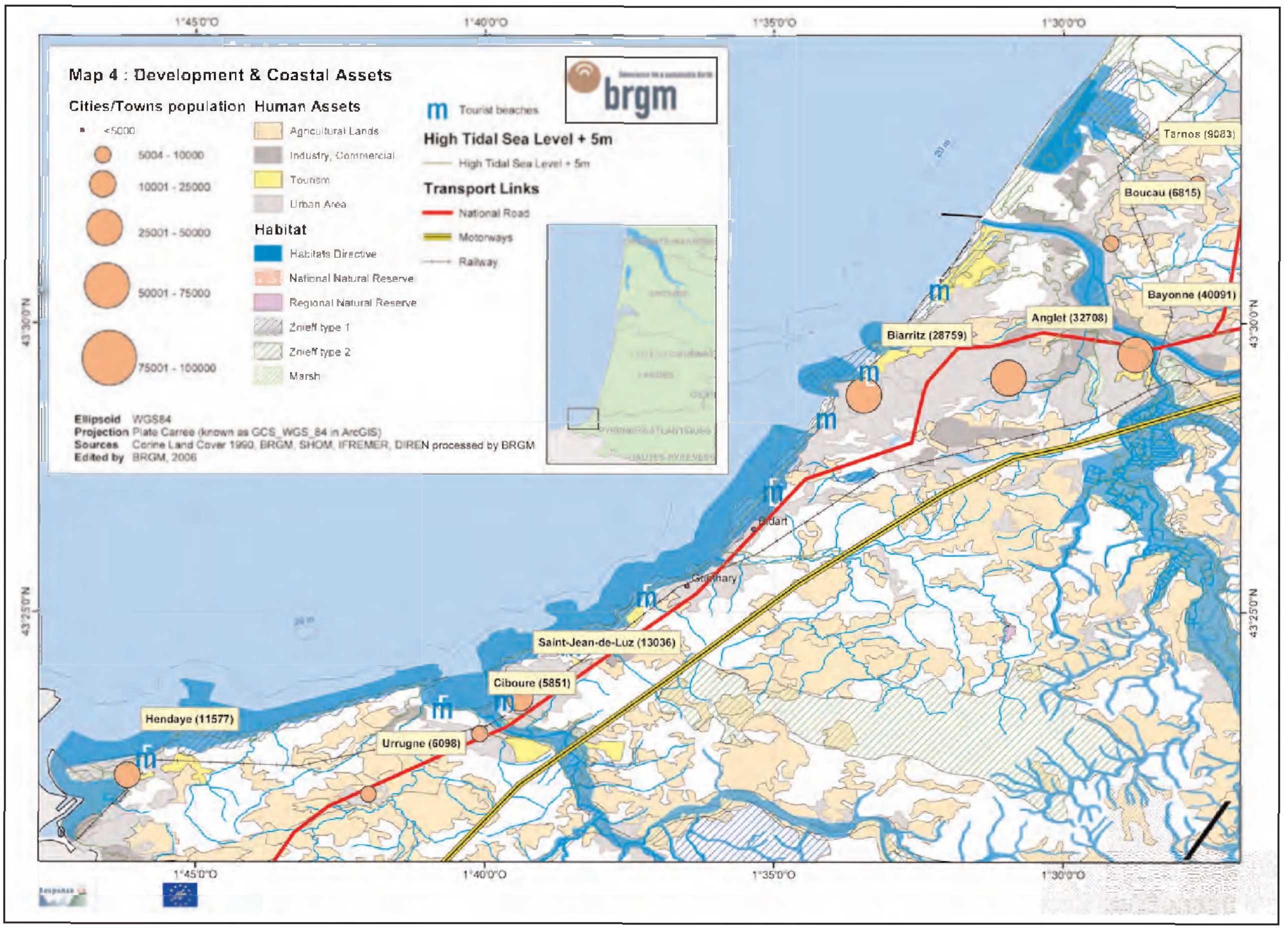


*Figure 5.5: Map 4 - 'Development and coastal assets'; part of the Atlantic coastline of south-west France. (Prepared by BRGM, France)*

**E.C. LIFE - Environment "RESPONSE" Project LIFE 03ENV/UK/000611**

## Map 5: COASTAL BEHAVIOUR SYSTEMS

Partner no2: IRPI-CNR Perugia Italy and Regione Marche with the contribution of
Provincia di Macerata and Provincia di Pesaro-Urbino

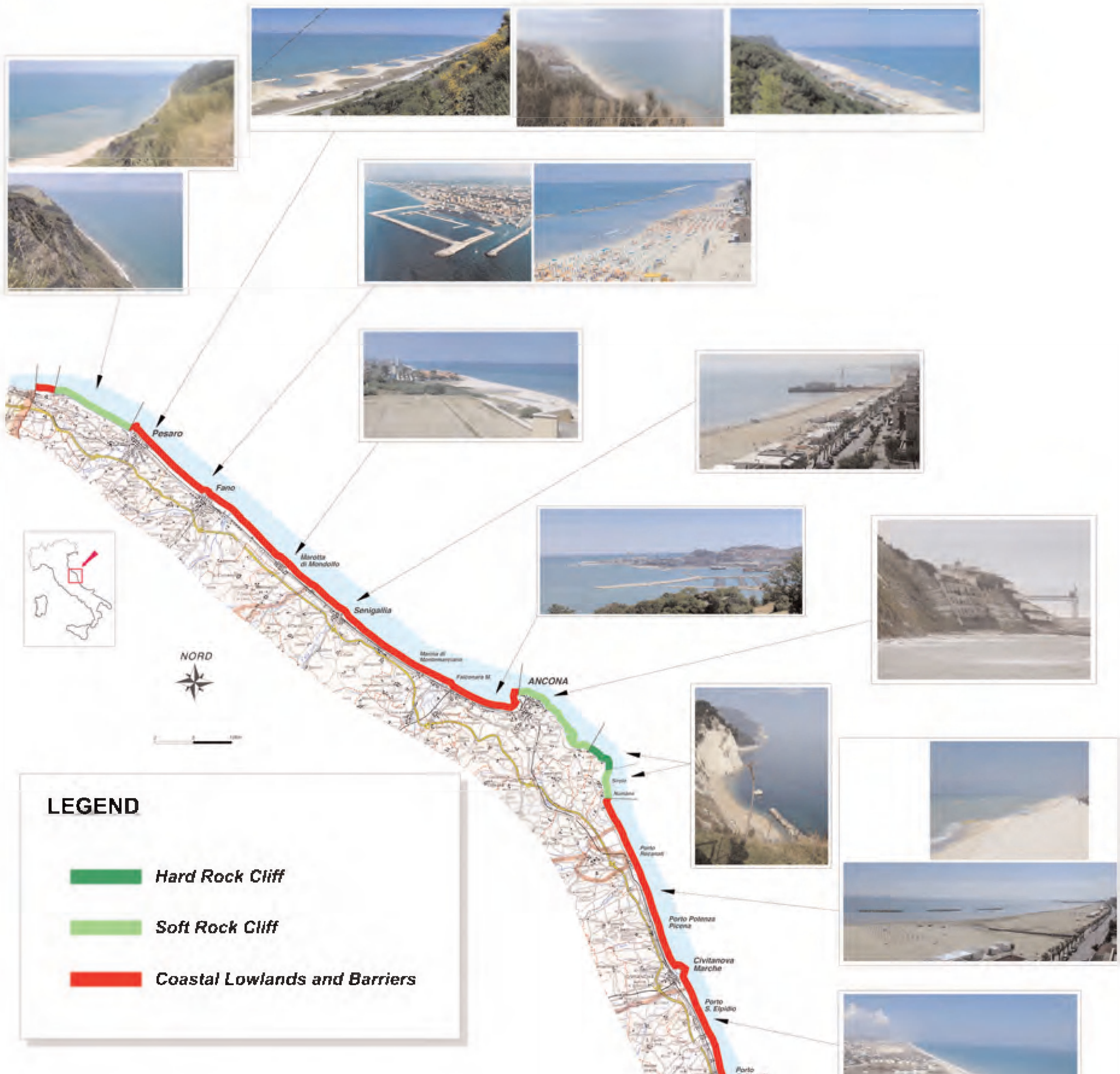


*Figure 5.6: Coastal behaviour systems*

## Map 5. Coastal Behaviour Systems

Based upon the landforms present and their interactions, it is possible to define appropriate Coastal Behaviour Systems (CBS) for each study area coastline. The landforms present along each coastline have been reviewed and placed within one of the six Coastal Behaviour System (CBS) categories (eg. Hard cliffs, Soft cliffs, Barrier beaches, etc.). Should additional CBS's be required they should be determined by the coastal forms present and their generic sensitivity to climate change factors. Possible refinements include differentiation of coastal lowlands from barriers, and separate treatment of spits, inlets and tidal lagoons.

## Map 6. Potential coastal hazards (year 2100)

Global climate change projections for the next 100 years have been published by the Intergovernmental Panel for Climate Change (IPCC, 2001).

In some parts of Europe sea level may rise by up to 80 cm by the 2080s (UKCIP, 2005) and, under the medium high scenario, mean annual temperatures may rise by 4ºc and winter rainfall may increase by as much as 30% above today's levels. These changes in climate have a direct impact on the rates and nature of coastal processes, leading to changes in the nature of future coastal hazard.

Map 6 (see opposite page) identifies three types of hazard, namely: flooding, coastal erosion and reactivation of coastal landslide complexes. In each case, the hazard is identified as being 'current' where no defences are present or 'potential' where the hazard is conditional on defence failure.

Future hazard classifications are determined by overlaying maps of coastal behaviour systems, coastal defences and past and present hazard events. Coastal erosion hazard is classified according to the expected average recession rate over the next 100 years from either progressive or episodic failure. The coastal erosion hazard classes are classified as low, medium or high, and reflect the possible areas of coastal hinterland that could be lost over the next 100 years.

*Plate 5.8: Landslide damage to A3055 coast road, Niton, Isle of Wight, UK, Spring 2001.*

*Plate 5.9: Increasing risks of flooding on the coast will result from sea level rising and less predictable weather patterns.*

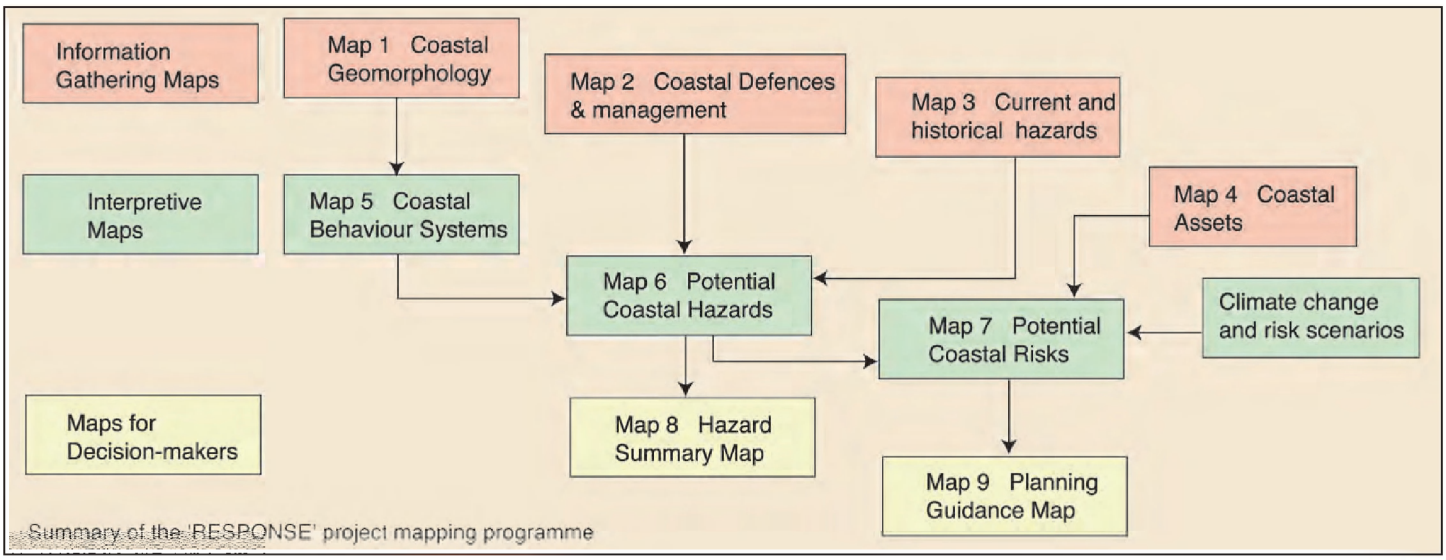


*Figure 5.7: Response maps and their associations.*

**E.C. LIFE - Environment "RESPONSE" Project LIFE 03ENV/UK/000611**

## Map 6: POTENTIAL COASTAL HAZARDS

Partner no2: IRPI-CNR Perugia Italy and Regione Marche with the contribution of Provincia di Macerata and Provincia di Pesaro-Urbino

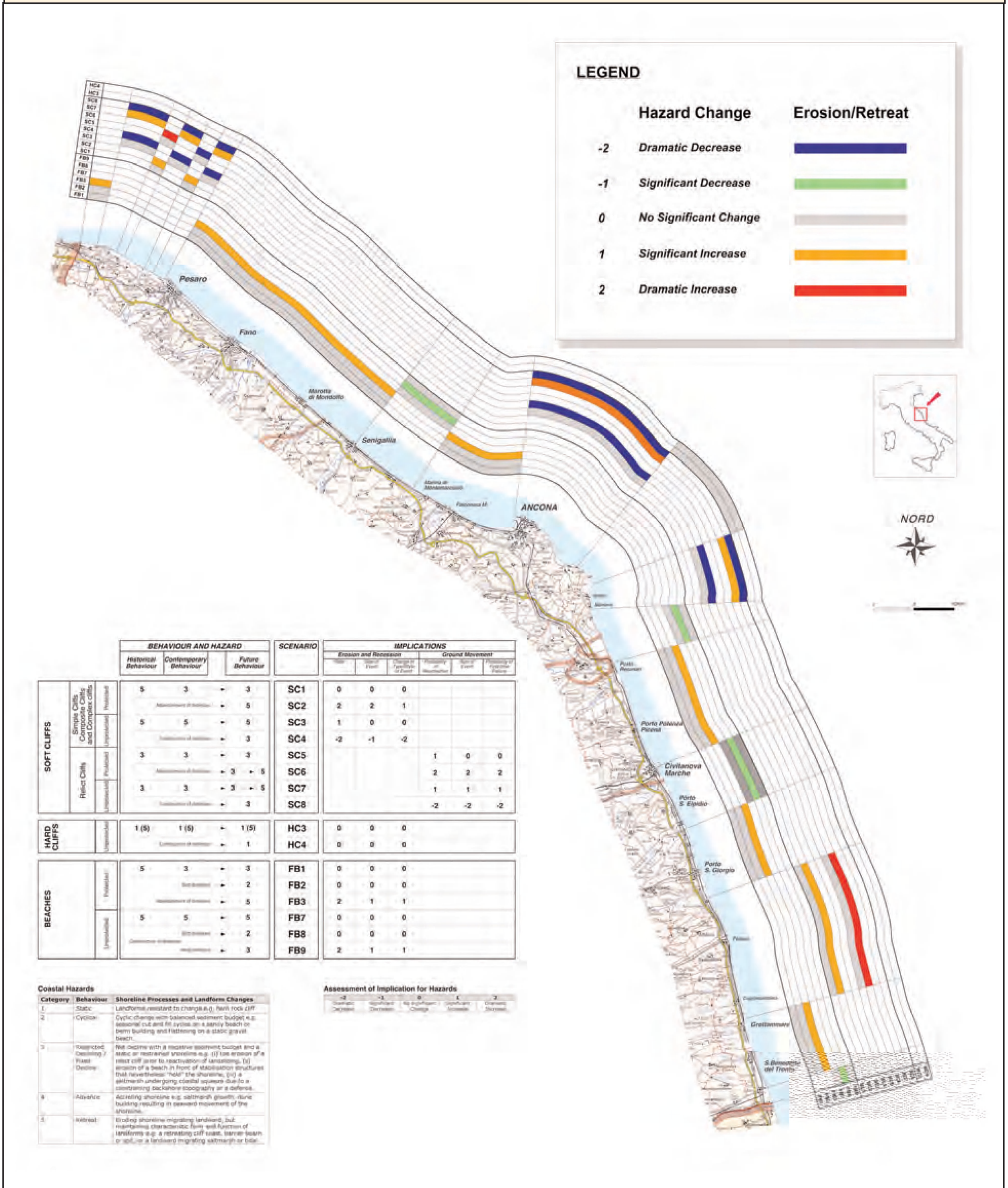


*Figure 5.8: Map 6 - Potential coastal hazards.*

## Map 7. Potential coastal risk (year 2100)

There is no baseline quantitative measure of risk against which changes can be compared (such as present value of properties), therefore a descriptive approach using a matrix of relative risk ratings is used. This approach assessed risk by comparing the economic consequences of flooding, coastal erosion or reactivation of coastal landslides with the likelihood of different magnitude events.

Likelihoods of hazard events are measured differently, according to the hazard type, as follows:

- Coastal erosion may be quantified by expected average recession rate over the next 100 years. Classes are >1m/yr; 0.5 to 1m/yr; <0.5m/yr and no erosion (due to coastal defences);
- Flood risk may be quantified by the expected return interval of flood events. Unprotected floodplains are expected to flood every 10 yrs; areas defended against flooding are expected to be protected against the 1:100 year event; and other areas adjacent to floodplains between 5 and 10m OD are expected to be flooded every 1000 yrs;
- Coastal instability risk may be measured by the return interval of ground movement events, as follows: 1:10; 1:100; 1:500 and 1:1000 year events.

Using these three criteria in a matrix it is possible to assign each 'coastal cell' a relative risk rating. This study uses a four-point classification from 1 (Low Risk) to 4 (Very High Risk), but additional classes can be added if required. It must be stressed that potential levels of risk from different hazards (coastal erosion, flooding and coastal instability) are subjective and cannot be directly compared. This is because quantitative data on hazard and consequence are unknown. The methodology allows for any number of scenarios to be tested, but in the current methodology, the impact on the coastline of two scenarios is assessed:

- 'business as usual', with limited coastal response to climate change and no change in coastal management practices over the next 100 years;
- 'worst case', with climate change having a direct and negative impact on coastal processes and dramatic changes in coastal management practices, with all defences being lost over the next 100 years.

### (a) 'Business as usual' scenario

In the 'business as usual' scenario, the population density and degree of hazard for each segment of the coastline (i.e. the current and future hazards shown on Map 6) is visually assessed and a risk score is allocated to each Coastal Behaviour System.

For erosion risk, the degree of erosion hazard is derived from Map 6, with all potentially eroding coasts, which are currently protected by defences, being classed as 'no erosion'. The highest risk score can only be achieved at locations of greatest population density and greatest erosion hazard, and conversely, the lowest risk scores are achieved where erosion is very slow or non-existent in locations of medium to very low population density.

Flood risk is determined by the presence or absence of flood defences and the population density of floodplain areas. The highest risk score is applied to urban areas situated on undefended floodplains. Lower risk scores are applied if defences are present, and if population density is lower. Coastal instability risk is assessed in a similar way, using the likelihood of significant ground movement as the measure of hazard. High risk scores are, therefore, applied to locations where population density is highest and significant ground movement is expected.

The risk of the different hazards cannot be directly compared because risks are assessed relatively. Therefore the mapping for the Southern England study area shows the relative risk scores for erosion, flooding and coastal instability separately identified with the prefix E, F or C. This means that very high risks of flooding (F4) and erosion (E4) are not the same and cannot be considered to be comparable.

### (b) Worst case scenario

To assess the impact on coastal risk of the worst case climate change scenario, the same series of relative risk matrices can be used. To take account of the impact of climate change at each coastal segment the degree of hazard (i.e. average erosion rate, likelihood of flooding or likelihood of significant ground movement) is increased. Using a matrix (see accompanying 'Response' Training Pack), this is achieved by moving one cell towards the right along the same Consequence (land use class) row. Depending on the structure of the matrix, this may lead to an increase in risk.

The impact of removal of coastal defences on erosion rate and coastal instability is assessed by choosing a likely recession rate/reactivation return period for the unprotected cliffs/landslides, and then moving one cell to the right to account for the impact of climate change. The impact of defence removal on flood risk is achieved by assuming all floodplain areas will be inundated on a 1:10 year basis.

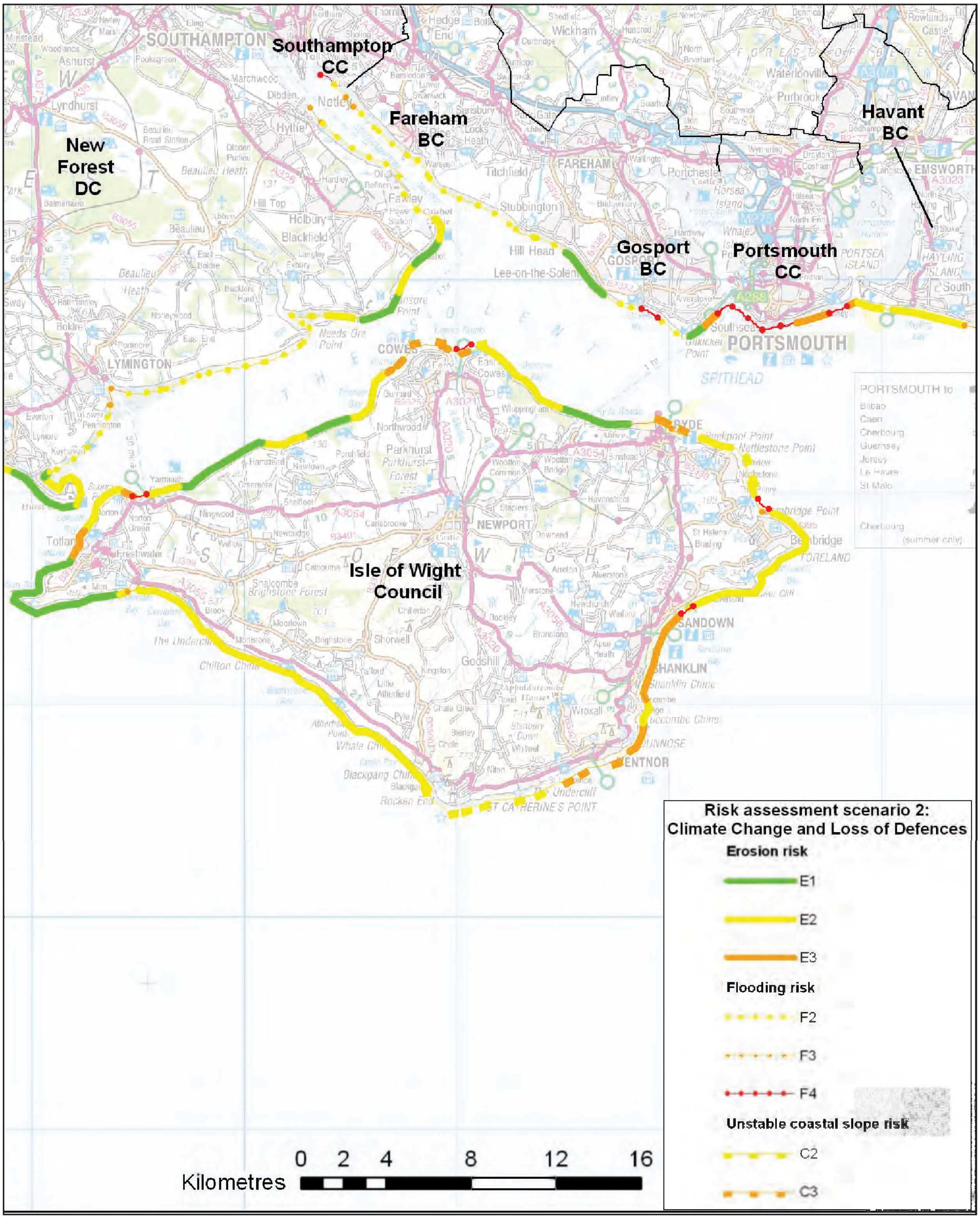


*Figure 5.9:* *Map 7b, potential current and future coastal risk: climate change and loss of defence.*

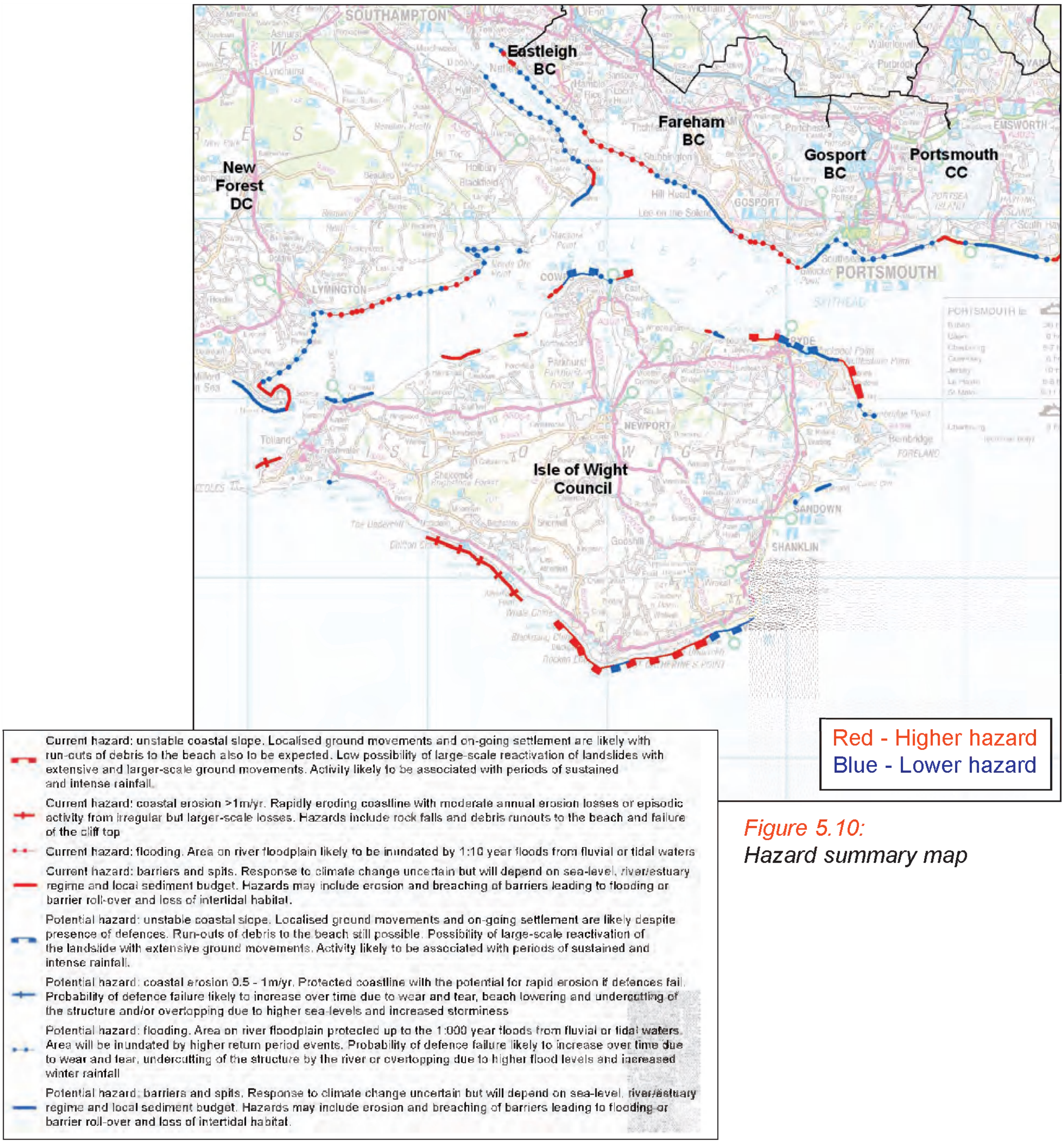


*Figure 5.10:*
*Hazard summary map*

## Map 8. Hazard summary map

To demonstrate potential additional applications of the RESPONSE datasets, two non-technical summary maps have been produced which included additional information and guidance. It should be noted that maps 8 and 9 are appropriate for use only in the UK, where planning regulations place the onus of responsibility on the developer, meaning that Local Authorities only need general guidance. Planning regulations may be different in other EU member states and, therefore, the nature of any additional non-technical maps should be revised as necessary.

Map 8 is a summary coastal hazard map and is intended to highlight 'hotspots' along the South Central England coastline for use by non-experts. The information can be used to give an overview of the processes operating in the study area and can be used to focus further study along certain stretches of the coast. The map is a development of the potential hazards map, but only the most significant hazards are displayed. Therefore, areas of moderate or low rates of erosion are not displayed, to give prominence to more rapidly eroding stretches of coast, unstable coastal slopes and floodplains.

Red - Higher constraint
Blue - Lower constraint

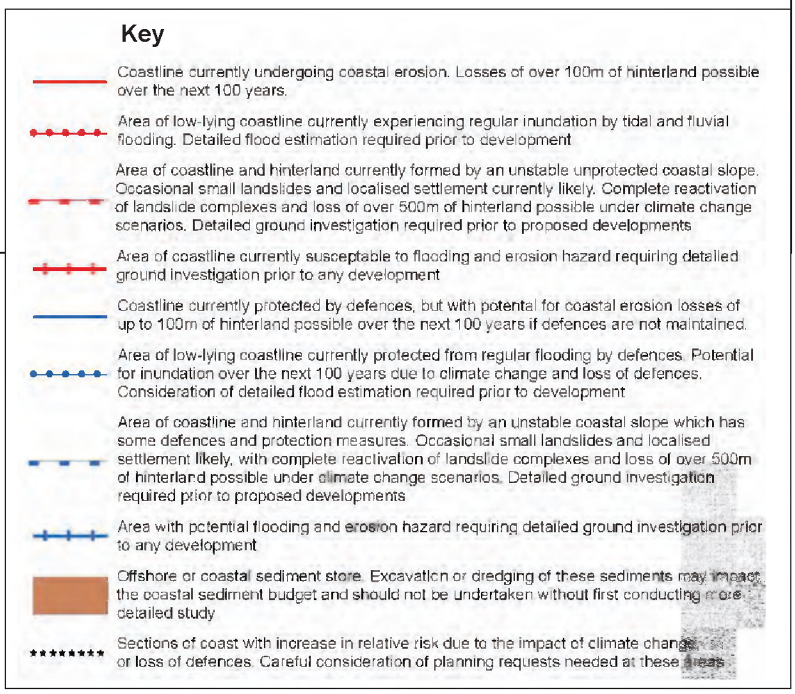


*Figure 5.11: PLanning guidance map*

## Map 9. Planning guidance for the central south coastline of England

The information on Map 9 is derived from the risk mapping and provides guidance on constraints to development at 'hot spots' along the coastline. The map also highlights those stretches of coastline where levels of relative risk have risen due to the impact of climate change and/or progressive loss of defences ie. the level of risk has changed when comparing the 'business as usual' and 'worst case' scenarios (Maps 7). Risk could also increase if the consequence of the hazard increases, which would be caused by the population density increasing.

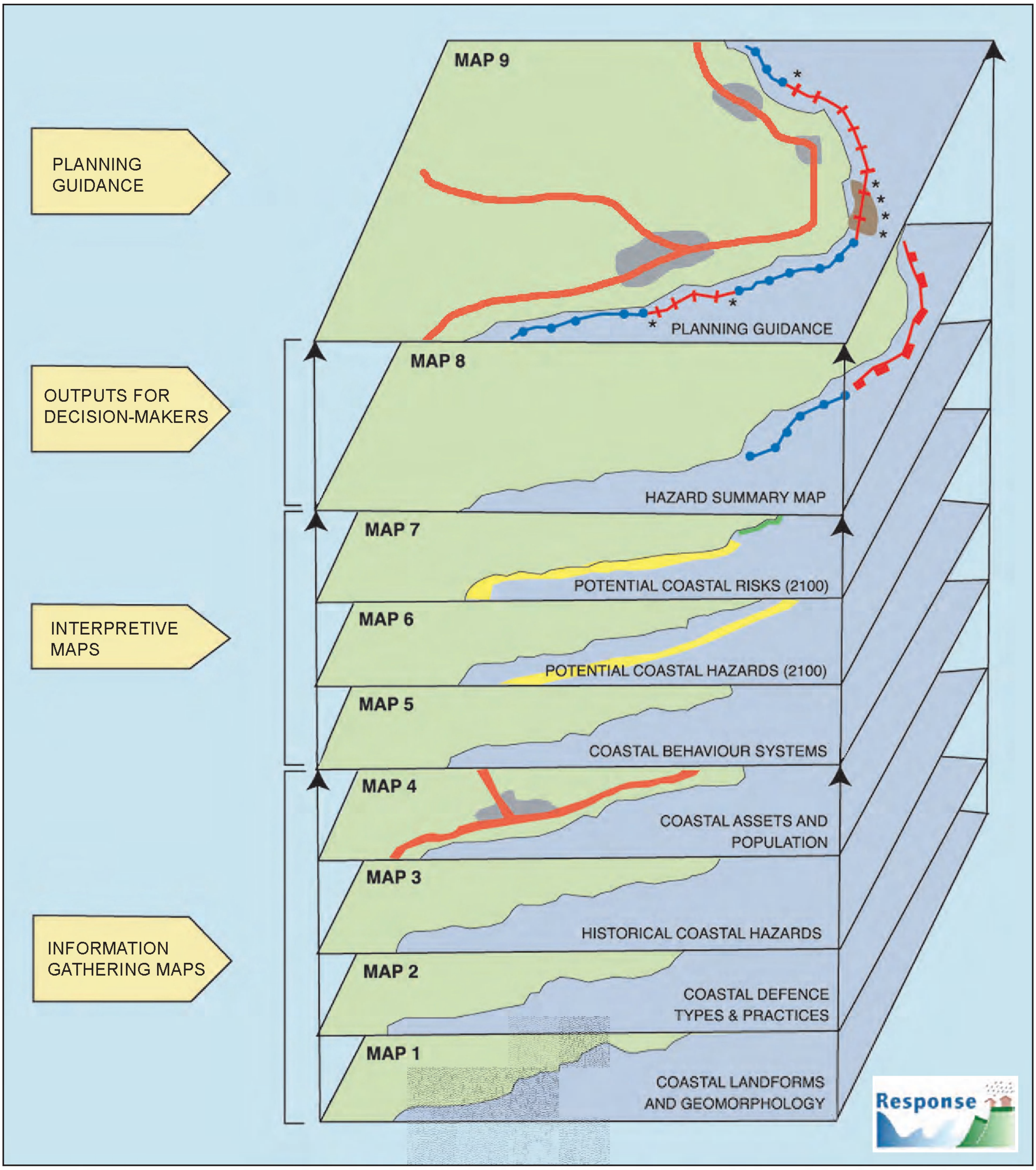


*Figure 5.12: 'Response' project methodology for developing integrated coastal evolution and risk maps.*

## References


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2. *McInnes, R. G., Jakeways, J. and Fairbank, H., 2006. 'Response - Responding to the risks from climate change'. Final report of the European Commission LIFE project. Ventnor, Isle of Wight.*
3. *Hosking, A. and Moore, R., 2001. 'Preparing for the impacts of climate change'. Report for SCOPAC. Swindon.*

## *Chapter Six*
# Coastal risk management in practice

Sustainable development of coastal zones relies upon effective management of risk both now and in the context of increasing impacts of climate change. Fundamental to this is the need to improve our understanding of hazard and risk by providing the tools to better inform planning policy and thereby improve risk management.

In previous chapters many examples of approaches to risk management have been highlighted. The recommendations from the EUrosion project (European Commission, 2004[1]), and the guidance and good practice recommended by the Department for Environment, Food and Rural Affairs (Halcrow, 2002[2], Defra 2005[3] and 2006[4]) relating to their coastal evolution research, operation of shoreline management plans and coastal defence strategy studies are tried and tested examples of a co-ordinated approach being adopted by central government in England providing a lead for local government within a clearly defined risk management framework. Regional or sub-regional groups of local authorities working together with other key players in coastal zones provide a means of implementing sustainable coastal management policies. In some cases (SCOPAC, 2005[5]) research has been commissioned allowing more detailed studies to be undertaken on topics such as sediment transport that can better inform the range of organisations involved in coastal risk management by providing the detailed level of information required for more complex coastal frontages.

The shoreline management plan process, which has been implemented successfully for the whole of England and Wales, and which is shortly to be followed up with a second national programme, provides an excellent example of how coastal risks can be managed in a co-ordinated way drawing upon a thorough understanding of coastal evolution and natural processes. This approach was also supported strongly by the European Commission (EUrosion, 2004[1]) which promoted the concept of 'coastal sediment management plans'. Similarly the EUrosion project highlighted the particular value of providing accessible information on a sub-regional basis for coastal stakeholders. The concept of 'local information systems' (Fairbank et al, 2004[6]) was promoted and it is illustrated well by the regional coastal group for central southern England (SCOPAC, 2005[7]) which has established a web-based bibliographic database comprising some 8,000 references to relevant shoreline management publications for a 400 kilometre frontage along the central south coast of England. Resources are made available through contributions from the constituent members of the coastal groups, comprising mainly local authorities and the Environment Agency, thereby ensuring that the database can be updated on an annual basis.

| COASTAL SITUATION | DEVELOPMENT PLAN | DEVELOPMENT CONTROL |
|---|---|---|
| • rapidly eroding cliffs<br>• actively unstable slopes<br>• unprotected low-lying areas<br>• natural coastal defences (e.g sand dunes<br>• very high-high sensitivity coasts | Areas most unsuited to development due to physical conditions. Planned development proposals subject to major constraints. | Should development be considered it will need to be preceded by a detailed investigation, full risk assessment and/or environmental study. Many planning applications in these areas may have to be refused on the basis of potential physical problems. |
| • eroding cliffs<br>• potentially unstable slopes<br>• low lying areas with low standard of coastal<br>• defences<br>• sand dunes<br>• saltmarsh areas<br>• foreshores in important sediment transport zones<br>• high to moderate sensitivity coasts | Areas likely to be subject to significant constraints due to physical conditions. Local Plan development proposals should identify and take account of the nature of potential problems and address the requirements for suitable coastal defences. | A site reconnaissance study will need to be followed by detailed site investigation, including a risk assessment and/or environmental study, prior to lodging a planning application. |
| • areas behind eroding cliffs<br>• problem ground conditions<br>• estuaries<br>• foreshores | Areas which may or may not be suitable for development but investigations and monitoring may be required before any Local Plan proposals are made. | Areas needed to be investigated and monitored to determine risks, sediment budget, or sensitivity. Development should be avoided unless adequate evidence of suitable conditions is provided. |

*Figure 6.1: Generic planning guidance for different coastal types to assist risk management. (after Hosking and Moore, 2001)*

# What are the potential risks within the Cote d' Albâtre coastal zone on the Channel coast of France?

The 130 kilometres of coastline of the Cote d'Albâtre comprises unique chalk cliffs interspersed with valleys similar to the coastline of East Sussex in England. There is a long history of erosion along the coastline of the Seine-Maritime region. The erosion can be spectacular with very large sections of the cliffs collapsing, resulting in damage and loss of infrastructure as well as posing risks to local residents and visitors. Risks from erosion pose a threat to the various activities within the cliff area. Fortunately, no loss of life has been incurred. Ground movements have had a much more serious impact on property and infrastructure. For example at Criel-sur-Mer, residential properties have been seriously affected by the retreating coastline.

Coastal risks are a permanent issue on the local authorities' agendas and a major concern for the local population. However, the major processes at work are not always very well understood. Cliff falls are the result of the natural processes of coastal erosion and weathering. Tensions within joint lines in the cliff increase as marine erosion removes rock material from the base of the cliff. Infiltration of rain water increases the problem by decreasing the homogeneity of the cliff material as well as increasing the ground water level in the chalk; in addition, storms attack the sea cliff; the absence of beach material at the foot of the cliff is also a problem. All these factors contribute to the risk of cliff collapse.

When a part of the cliff collapses it leaves the surrounding areas more subject to erosion and leads to a continuous circle of weakening and failure. The University of Caen Research Laboratory has been able to estimate the rates of cliff retreat. The average rate within the coastal cliffs of the Seine Maritime region is about 20cm per year. However between Veuves-les-Roses and Puys, where the chalk is very weak, the retreat rate is 51cm per year. Between Benouvilles and Veulettes-sur-Mer, where the rock is much harder, the rate is between 14 and 17 cm per year. In Étretat, the cliffs have hardly moved over the last few centuries as the chalk at the foot of the cliff is "du Tilleul", a very hard material.

Urban development along the coastal zone resulted in the construction of coastal defences particularly at the end of the 19th century when a "policy against the sea" was adopted. As a result many substantial defence structures were built, including jetties and sea walls, in order to try and combat coastal erosion. More recently, reinforcement of some of these structures was suggested but was judged inappropriate as the sea always wins.

To respond to coastal erosion, one of the main strategies is now to create retreat zones. The definition of the zones of retreat can be based on population migration within an area.

The creation of retreat zones, even if essential, presents some disadvantages, but the necessity of this policy has been accepted by the public and local government. The issue that remains concerns the safety of visitors who venture close to the cliff edges regardless of the warning signs. All the development along the coast has created an illusion of security in those areas, but coastlines still remain vulnerable to the forces of nature and may therefore, present a number of risks to coastal users.


*Figure 6.2: The eroding cliffs at Crièl-sur-Mer posed a risk to residential properties. Recently, under provisions of the Law Barnier, the properties were demolished as they became unsafe.*

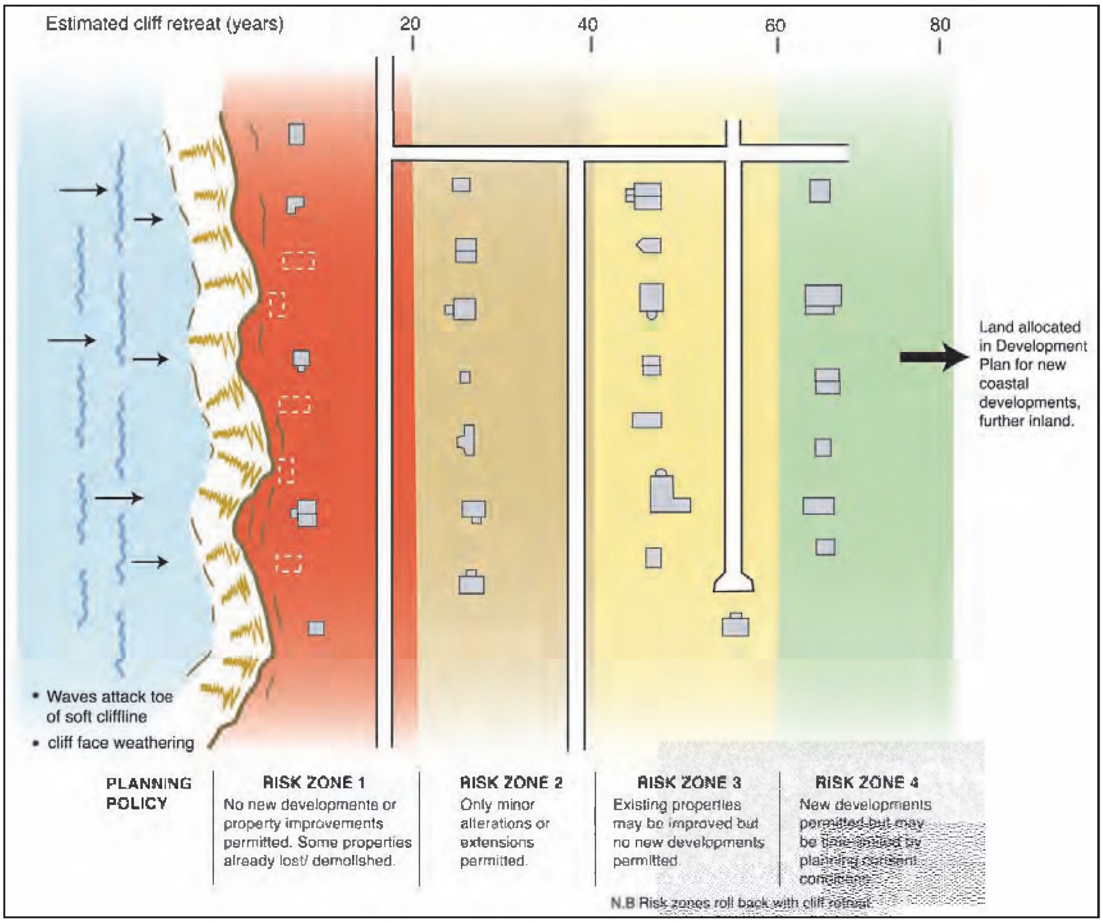



*Figure 6.3: A possible model for planning set back along an eroding coastal frontage- where defence works are unsustainable. (McInnes, 2006)*

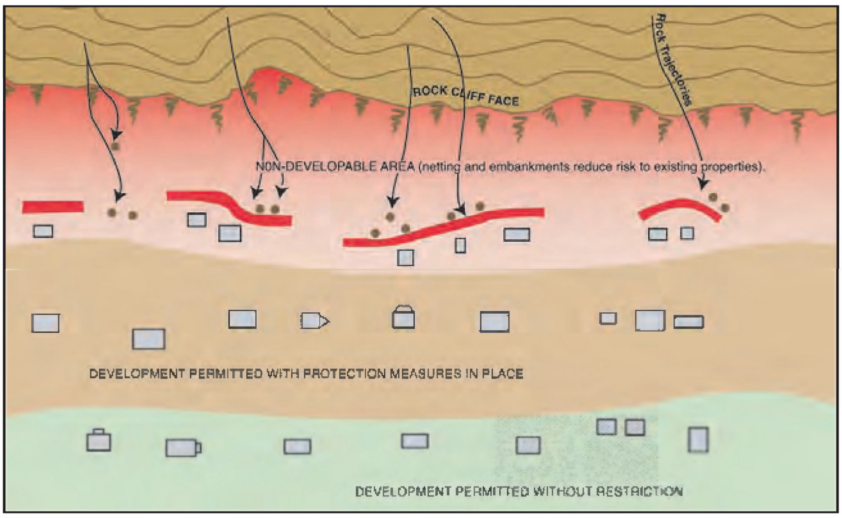



*Figure 6.4: Management of rockfall run-out risk through planning zoning (adapted from Capans 2004).*

The various initiatives described above will fulfil a key objective of providing better information to inform planning policy. It has been highlighted previously that planning plays a key role in terms of coastal risk management. It helps ensure that risk is balanced against other considerations such as economic development, conservation and recreation (Ballinger et al, 2005[8]). A strategic planning system also helps to minimise the risks to life and property by ensuring that only development which will not generate unacceptable risk is permitted. It can take advantage of increasing knowledge and expertise in the fields of coastal risk management relating to coastal erosion, flooding and landslides and thereby better inform decision-making relating to the appropriateness or otherwise of coastal developments, looking ahead for the next 50-100 years. Coastal scientists can, therefore, assist planners by identifying coastal hazards along their frontage and explaining the resulting risks, thereby clearly identifying whether development should be permitted, and, if so, for what time period.

# MENTON: Landuse planning in a region affected by landslides

## An innovative study offering new perspectives on landslide management

Is it possible both to develop in the vicinity of Menton, France, and also to protect it from natural phenomena such as landslides? This was the question to be answered through a study undertaken for the Commune of Menton, in collaboration with the Departmental Direction of Equipment (State service), The Departement of Alpes-Maritimes, and Provence-Alpes-Côte d'Azur Region.

*Plate 6.1*

Fig: 6.5: Landslide risk management in Menton, France

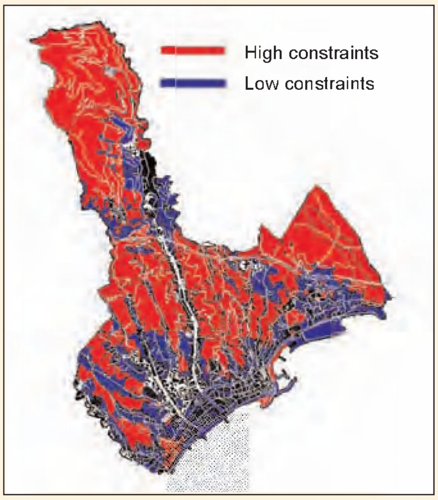
## A TERRAIN AFFECTED BY LANDSLIDES

Due to the heavy rainfall events at the end of November 2000, more than 400 landslides occured over the territory of Menton, located in the French Riviera. Damage to buildings, roads and infrastructure took place. Such phenomena are neither exceptional nor unique in this commune.

In 1952 a landslide caused the death of 11 people; in 1887 a major earthquake led to the collapse of several buildings, and the village of Castillon located 5 km north from Menton was totally destroyed. Though less dramatic, floods regularly cause serious damage within parts of the town.

## CONSTRAINTS ON LAND USE

The Risks Prevention Plan prepared for the commune of Menton by the State resulted in 30% of this territory being designated as unsuitable for development. These constraints on development had to be added to those already induced by other regulations, in particular the ‘Littoral Law’ which safeguards natural areas, and in addition those defined within the Urban Development Plan.




**Land-use Planning (POS)**

## SIGNIFICANT COSTS

Following landsliding 10 million euros was spent on implementing remedial works, so that access to properties could be re-established. Furthermore, general studies on risk assesment and risk mitigation were carried out.

## COST/BENEFIT ANALYSIS

A balance has to be found between land development and protection, natural risks being only one constraint among others.

Solutions were based on:

- understanding of the phenomena
- understanding of the territory using historical data
- establishing an inventory of all the assets and ranking their vulnerability
- the development of tools (eg. GIS) for managing and displaying the data

Solutions had to be understood by all the partners (State, Commune, local residents), and were developed based on a win/win logic.

A KEY PRIORITY: MANAGEMENT AND CONTROL OF SURFACE WATER FLOWS

Menton MA VILLE EST UN JARDIN

Région Provence-Alpes-Côte d'Azur

CONSEIL GENERAL DES ALPES-MARITIMES

**Contacts**: E. Leroi, URBATER, 48, avenue Trespoey, 64000 PAU, FRANCE. Tel +33 (0)559304650 email: e.leroi@wanadoo.fr
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## A framework for managing rockfall risks on La Désirade Island, French West Indies

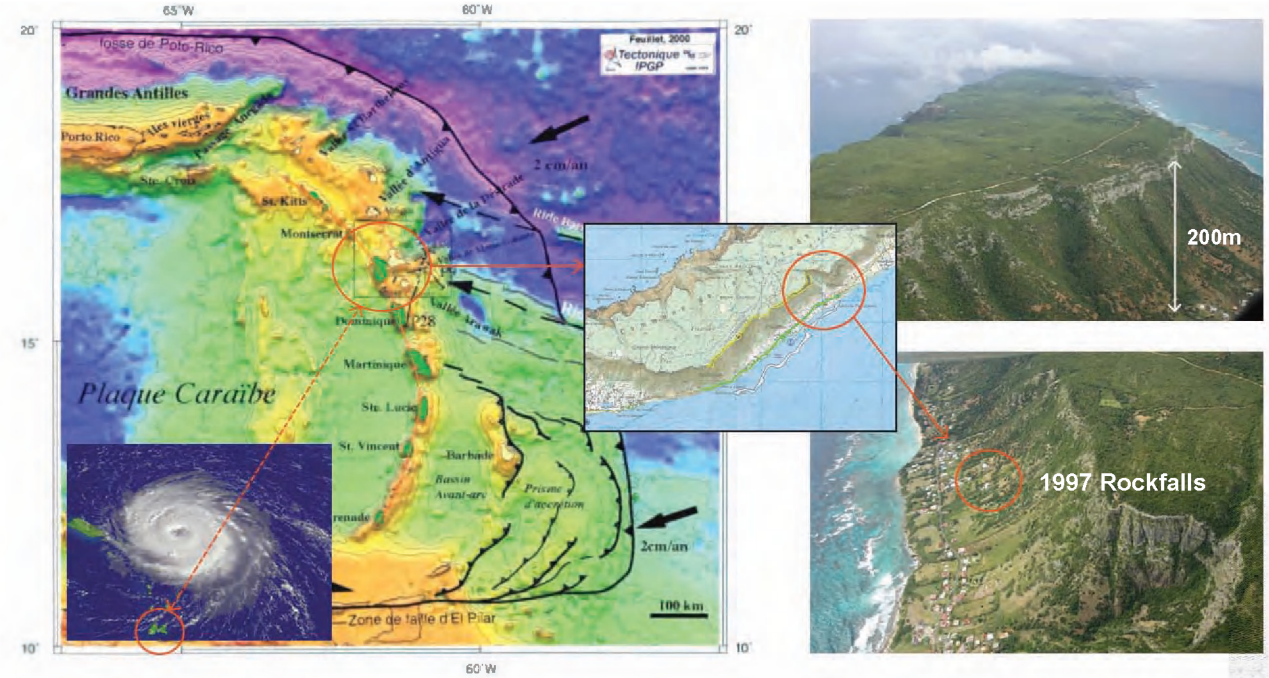



Plate 6.2: *Location of La Désirade and the site of the 1997 rockfalls at Le Souffleur*

### La Désirade: an example of integrated risk management

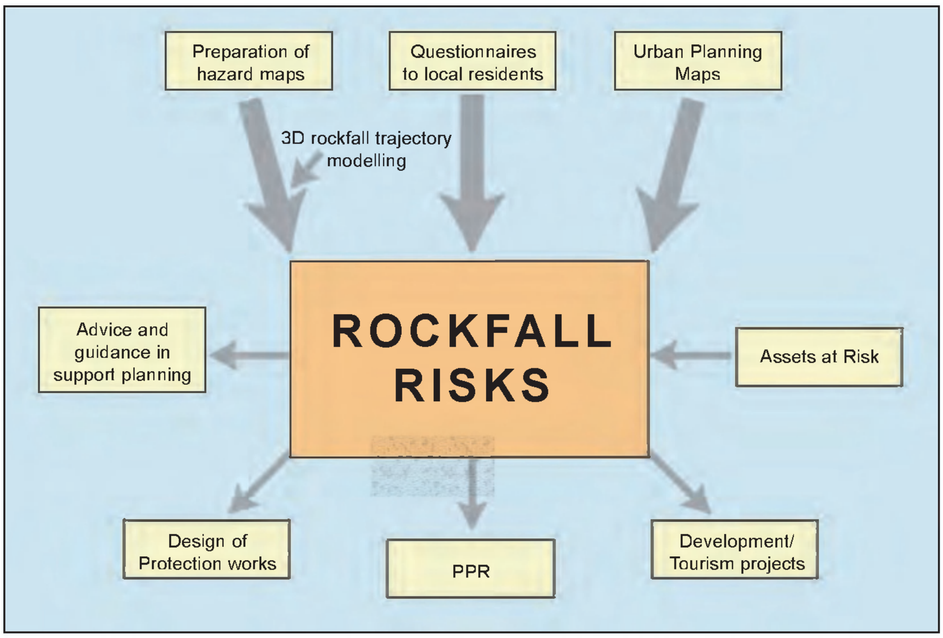
The island of La Désirade in the French West Indies is 11km long and 3km wide. It forms part of the eastern end of the Guadeloupe archipelago. The island is capped by a chalk plateau with a 200m high face towards the coast. La Désirade is located on the path of cyclones and on the zone of interaction between the Caribbean and Atlantic tectonic plates and has, therefore, a high natural risk exposure from landslides, earthquakes and cyclones.

At Le Souffleur a house was badly damaged by a rockfall in 1997 and two people were injured. Temporary protection nets were fitted and the State appointed a consultant to propose sustainable solutions to secure the site. The State also contemplated relocation of some dwellings if the protection solutions were too costly.

Studies showed that protection nets were not economically justifiable compared to the number of properties benefiting and residents were strongly opposed to relocation solutions.

The State then decided to undertake the simultaneous preparation of the Risk Prevention Plan (PPR)* for La Désirade, and a planning and development study of the Le Souffleur area, in order to analyse the land available to accommodate those families exposed to the highest levels of risk. The methodology adopted comprised:

- an exhaustive territorial diagnosis of La Désirade island;
- the proposal for a risk reduction solution and a planning and development project based on an integrated approach to the solutions (protection and environment) together with a multi-scale approach (local analysis and global analysis);
- the ability to listen, communicate and educate (including a survey of the population to understand its perception of the risks and identify its aspirations; public meetings explained the approach and the proposed actions);
- regulatory risk zoning and associated regulations.




Through a combination of physical works, social improvements, planning and risk policies solutions were developed that were both sustainable and acceptable to the local population.

**** The Risk Prevention Plan (PPR)*** *is a major element of natural risk management in France, it combines land occupancy, information for the population and compensation in the event of a disaster.* (Leroi 2005)

Figure 6.6: *General framework for managing rockfall risk on La Désirade Island. (Adapted from Leroi 2005)[9]*

## Flood risk management in the city of Venice, Italy

Over the last few decades, high tides in Venice have increased in terms of their frequency and intensity. This is due to the combined effects of a rise in sea level (eustasy) and a reduction in land level (subsidence). The result is a loss in the height of the land with respect to sea level of about 23 centimetres since the beginning of the twentieth century.

The lowest areas of the city are the most seriously affected. Saint Mark's Square begins to flood with tides just over +60 centimetres, and at +100 centimetres the square is almost entirely submerged; water invades the Square about 250 times a year.

A new programme of flood relief works aim to protect the area from the most frequent floods, to restore the pavement and to improve sub-surface conditions.

*Plate 6.3: A flooding event in St Mark's Square. The square is partially flooded about 250 times each year.*

The project aims to protect Saint Mark's Square from the most frequent high tides and will ensure access across the square at tides of up to +110 centimetres through a combination of measures that address each of three types of flooding. To combat water that overtops the lagoon, the waterfront and the pavement behind it will be raised and re-formed; to combat water that comes up through the drainage systems and from underground filtration the works will restore and then close-off ancient tunnels under the Square and then a new rainwater disposal network will be installed. The collapse of these old tunnels has, in turn, caused damage to the pavement above. They will be restored without modifying the present level of the Square. Additionally, a layer of Bentonite will be laid under the pavement of the Square in order to render it impermeable.

The flood defences for the Square are part of the major programme of measures to protect the city and lagoon from flooding and is integrated with the scheme under construction at the three lagoon inlets to defend the entire lagoon area from all high waters, including extreme events.

*Plate 6.4: Flood prevention works in progress adjacent to St Mark's Square.*

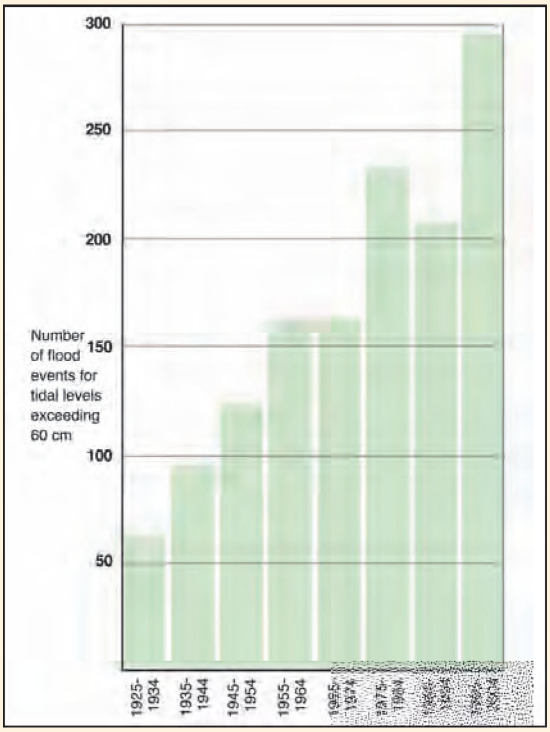



*Figure 6.7: Frequency of flood events by decade in the city of Venice*

## Coastal hazard simulation - planning for future sustainable management

Predicting trends in coastal morphology and subsequently assessing the associated hazard focuses on an understanding of the changes that have taken place in the past. Historically this has been achieved by monitoring and reporting with a variety of datasets such as topographical surveys or aerial photogrammetry. This methodology has advanced recently to produce a quantitative tool for rapid assessment of future coastline evolution using GIS. Taking advantage of historical sets of aerial photographs dating back to the middle of the twentieth century it is possible to obtain an accurate account of coastal change which offers many advantages over more traditional approaches such as the comparison of retreating clifflines obtained from early maps. Increasingly sophisticated methods of data manipulation including Ordnance Survey data sets and satellite data are available to produce a range of models and simulations. Combined with aerial photographs, these techniques provide a powerful tool to assist in dissemination of information on a range of earth science and engineering geological issues.

*Figure 6.8: Simulation of cliff base recession of a fifty year timescale for part of the south-west coast of the Isle of Wight, UK.*

*Plate 6.5: The simulation (Figure 6.8 above) represents a section of the rapidly eroding weak sandstone cliffs on the south-west coast of the Isle of Wight. This photograph of the actual cliffline illustrates the scale of the erosion processes which the Council wishes to quantify in the context of climate change.*

# Risk management in the Marche Region of central eastern Italy

The Marche Region stretches for 172 kilometres 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 leading Regions in Italy for investigating and addressing worsening natural hazards and risks.

The coastline of the Marche Region is both economically and environmentally highly valuable. However, intense urbanisation over the last five decades, the development of residential and tourism infrastructure, industrial and commercial activities have not always taken account of the physical and environmental constraints of the coastal zone. The Marche coast is affected by coastal erosion, river flooding, landsliding and seismic risks. Among these, coastal erosion represents one of the most important factors of concern with regards to the stability of the economy, particularly in relation to the tourism industry.

The Marche Region developed two key planning instruments in 2004:

- to address coastline erosion: a regional law concerning the 'Integrated Management of Coastal Zones'[10], being followed by a specific Plan to address issues relating to coastal erosion and development.
- to address river flooding and landsliding: the 'Plan for Hydrogeological Assets'[11] concerning river flooding and landsliding at a regional scale - including coastal areas. This aims to define hazard and risk conditions, to establish land use rules, to identify priority actions to improve safety and reduce risks generally.

*Plate 6.6: The coastline of the Marche Regione of Italy is heavily developed for tourism. The coastal zone also contains an important north-south railway and motorway links which pass through tunnels within a topography affected by coastal landsliding as well as seismic activity. This photgraph of the important town of Grottamare has been the subject of detailed studies with the aim of informing planning policies and risk reduction generally.*

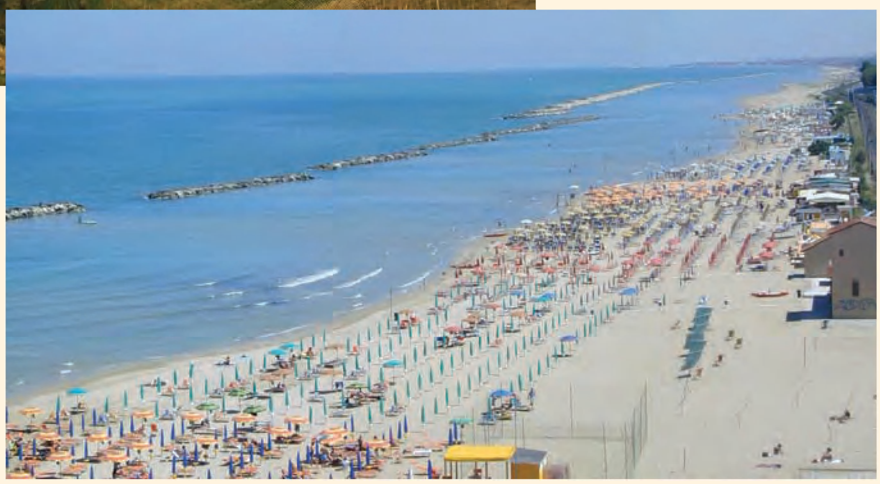


Plate 6.7: Much of the Marche Regione coastal zone is densely developed to support the tourist industry.

In order that regional and local authorities may assess their progress towards implementing coastal risk management the following questions are relevant:-

- do you regard your coastal risk management policy statements in the development plan as comprehensive, partial, limited or non-existent?
- does your development plan consider the limited life of some coastal defences in relation to potential future developments?
- do your forward planning documents reflect a collaborative approach involving coastal engineers, specialists in flooding, erosion risk and landsliding alongside planning staff?

(Ballinger et al, 2005[8]).

It is vital that advice from experts on coastal risks are taken on board by the planning system and by politicians. Increasing risks arising from erosion, landslides and flooding can only be reduced if statements are provided in development plans which are actually adhered to throughout the development control process. If this is not achieved then it may be necessary for additional regulatory measures to be imposed in order to prevent a vast escalation in costs to member states in terms of emergency responses or post-disaster remediation works.

Historically there has been a limited relationship between planning and coastal risks. This has resulted in a legacy of inappropriate siting of developments in coastal areas and an ad-hoc pattern of coastal defence works. A false sense of security has often been provided by extensive and aging defences and many communities are still tempted to place an unjustifiable confidence in the long term reliability of engineering solutions such as seawalls. This occurs despite the threat of climate change and associated rapidly-changing physical conditions along the coastline.

There is widespread recognition now that in some locations past mistakes have been made and it is hoped that the advice and guidance and excellent examples of good practice that have been provided from a range of member states and illustrated in this guide will help improve the process by ensuring that new developments, people and property are not put at unnecessary risk (Ballinger et al, 2005[8]).

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## *Chapter Seven*
# Engaging the community and co-ordinating the response to coastal risks

Coastal zone management requires wise decision-making taking full account of past, present and potential coastal conditions. This can be achieved most effectively by means of a co-ordinated approach to coastal risk management minimising risks to vulnerable coastal communities by identifying and understanding the nature and extent of coastal change and thereby guiding development towards the most suitable locations. Such an approach will help to ensure that existing and future developments are not exposed to unacceptable risks and that development does not increase the risk for the rest of the coastal community. There is no doubt that the implications of climate change and sea level rise present serious challenges to future coastal management. Increasingly, present and future policy decisions need to be placed within a long term framework which provides a 'vision' and a 'direction' for policies to aim towards (Lee, 2000[1]). The development of an understanding of long term coastal evolution also helps to ensure that the identification of areas where management problems are likely to arise in the future can be highlighted. The Response project partners believe that the approach adopted which seeks to map coastal change and highlight areas which deserve special attention from a risk management perspective is an example of good practice.

The relevance of natural and manmade risks to the planning system has already been highlighted and it is now possible to take advantage of new technologies providing excellent opportunities for improved information exchange and dissemination of research both within the scientific community and between scientists and practitioners. This study has also highlighted the need for closer integration between the actions of engineers, planners, politicians and other coastal stakeholders and recognises also that local authorities play a pivotal role by co-ordinating coastal zone management and coastal risk management activities 'on the ground' and that they are best placed to maintain the momentum of both coastal zone management and coastal risk management strategies in partnership with other relevant organisations.

Specialists in the fields of earth sciences, coast protection and coastal flooding will be required in increasing numbers in order to manage the increasing risks associated with climate change over the next decades. Living in an often turbulent and unpredictable coastal environment geoscientists, can contribute to decision-making through a risk management framework designed to examine technical and social issues relating to sustainability. This means, in effect, anticipating human-induced natural risks through widespread consultation and calculations of potential future situations and evaluating the certainties, uncertainties and probabilities of vulnerability and exposure of people to hazard. This advice will help assess and determine all available options to control, mitigate and adapt to risk. In relation to the management of flood risk the creation of flood hazard and risk maps of river basins in coastal areas together with establishment of expert teams at national or river basin level and the raising of awareness and education for the general public are regarded as cornerstones of sustainable flood management which is being driven from a European level by the Framework Directive and proposals for a Flood Directive.

Coastal-related studies, ground investigations and other scientific assessments can raise a range of concerns with different groups and individuals within communities. Therefore, the proper dissemination of information to a community during and following coastal risk studies forms a vital part of a successful communications programme. Homeowners in particular, who may have very little knowledge of the history or extent of coastal erosion, instability or flooding problems in an area may be particularly concerned about the results of surveys; the preparation of non-technical information may help in raising awareness and allaying these fears. There has been increasing recognition, therefore, that maintaining a dialogue with stakeholders from the commencement of such research and investigations is vital if the community is to understand and support the end results.

Previous research (McInnes et al, 2000[2]) has shown that much can be done to reduce the impact of natural hazards through a co-ordinated approach involving all sectors of the community as well as the professionals involved in planning, highways, the service industries, the insurance industry as well as builders, architects and developers. It is very important for such groups to work together with the aim

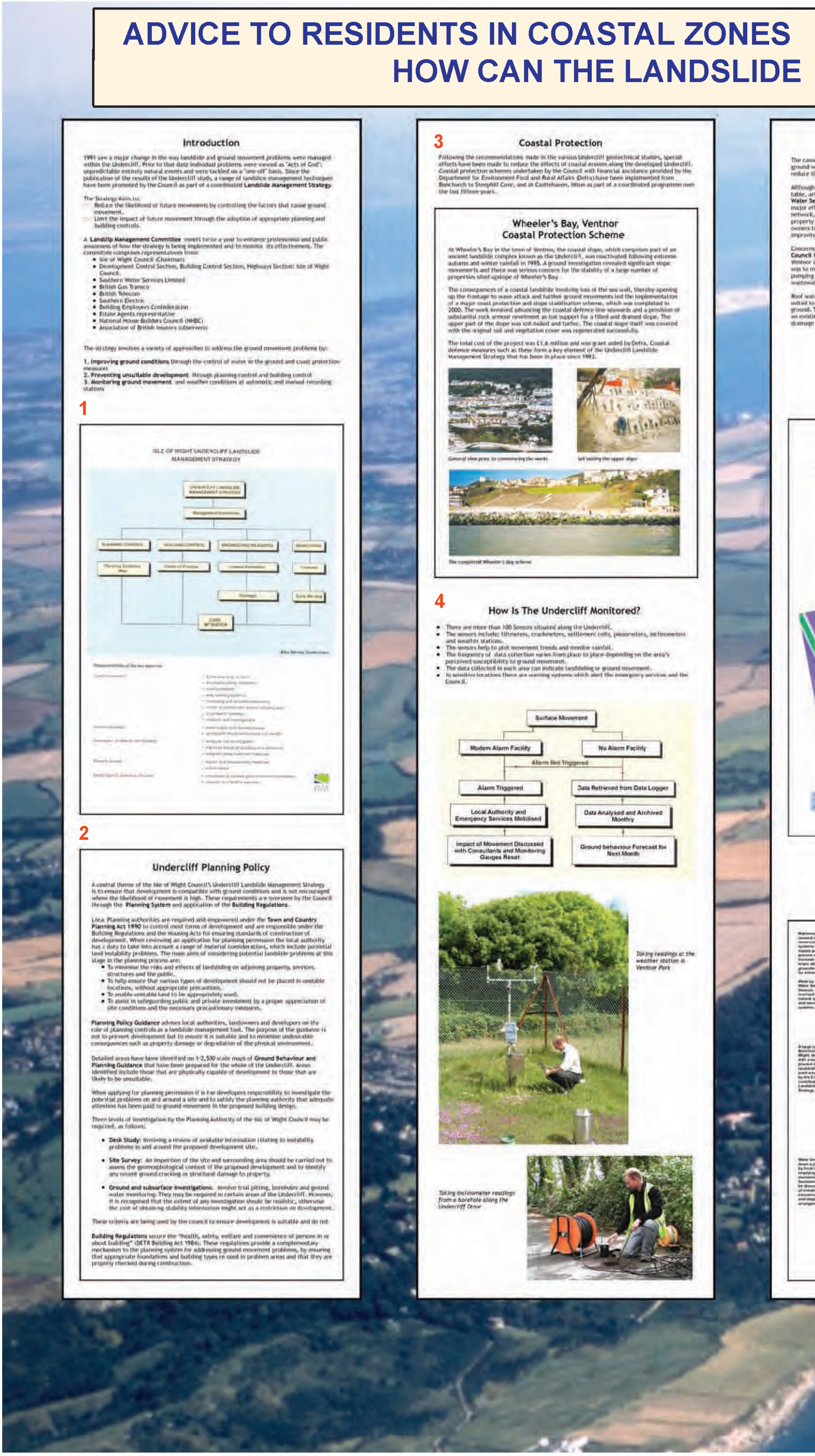


Figure 7.1: In terms of managing coastal risk the local community can play an important role, but this will only be achieved if complex technical issues are explained in a 'non-technical' way. This display panel is one of five designed to explain to coastal residents about landslide risk on the Isle of Wight, UK

The key elements of the advice provided on these display panels are:

1 Current arrangements for managing landslide risk on the Isle of Wight.
2 The role of the Council as planning authority for the Isle of Wight.
3 How coast protection measures can help reduce landslide risk.
4 Landslide monitoring programmes and warning systems.
5 Improving ground stability by drainage including measures to reduce water leakage from drains and supply pipes.
6 What homeowners can do to ensure that management practices on their land are not aggravating ground instability problems.
7 How new technology such as GIS can assist with data management and the provision of public information.
8 The role of the Isle of Wight Coastal Visitors Centre in terms of assisting with public information alongside its educational work.
9 Advice for homeowners and businesses through publications, leaflets and its website.


AFFECTED BY LANDSLIDE AND EROSION RISKS
PROBLEM BE MANAGED?
Improving Ground Conditions
5
What Can YOU Do?
6
8
Controlling water in the ground
Examples of Good Hillside Practice
Examples of Poor Hillside Practice
Advice to Home owners
6
Isle of Wight
Water Metering
Water Wise
Walls and Slopes
Masonry walls composed of reinforced concrete and faced with natural stone represent a considerable financial investment.
Gabion walls can provide an excellent means of support at some locations. They have the ability to accommodate movement without causing structural damage
Managing drainage in the Undercliff
7
9
Response
ISLE of WIGHT COUNCIL
Raising standards, creating opportunities
ISLE OF WIGHT CENTRE FOR THE COASTAL ENVIRONMENT

of ensuring that risk management problems are not aggravated through inappropriate design or as a result of implementation of engineering, building and other projects. An increasingly wide range of tools are available to assist these processes and there is no excuse for poor consultation. New technology, media sources, coastal information centres and local authority officers as well as education programmes all provide means for raising interest and awareness in coastal risk management problems. The almost daily media coverage of climate change also provides a vehicle for raising interest and awareness of its implications, providing an opportunity to set these global issues in a regional or local context.

It is very much hoped that this guide to good practice together with the accompanying Response Training Pack and previous publications including 'Managing ground instability in urban areas' (McInnes, 2000[3]) and 'A non-technical guide to coastal defence' (McInnes, 2004[4]) will raise interest and awareness and provide practical assistance for those endeavouring to reduce risks in coastal zones. It is equally recognised that much of the advice and guidance provided through the LIFE Response project can be applied in other environments such as mountainous regions.

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*Plate 7.1: Coastal and geotechnical specialists researching the Isle of Wight Coast Shoreline Management Plan at the Coastal Visitors Centre, Ventnor. The Centre provides a focus for coastal risk management with resources available for research by visiting scientists, school groups and members of the public.*

## Some views from experts on climate change

**Professor Jacqueline McGlade, Executive Director, European Environment Agency**

*"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."*

**UN Secretary-General Kofi Annan*, Senior UN official Klaus Toepfer, United Nations**

*"Climate change is not a prognosis, it is a reality that is and will increasingly bring human suffering and economic hardship."*

*"There has been a heightened frequency of extreme weather events in recent years. There is growing concern that this trend is likely to continue."*

**The European Commission**

*"The total value of economic assets located within 500 metres of the European coastline, including beaches, agricultural land and industrial facilities, is currently estimated at €500 to 1,000 billion"*

'Flood risk management: Flood prevention, protection and mitigation' Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee of the Regions, Brussels.

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

*"The effects of climate change on human health, ecosystems, 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 if climate change."*

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

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

*"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."*

**Dr. Gerhard Berz, Head of Geo Risks Research Department, Munich**

*"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 envionmental changes generated by human activity is growing."*

Re (2006), Climate change – Modest warming, dramatic effects.

**Association of British Insurers**

*"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)."*

Association of British Insurers (2005), Financial Risks of Climate Change, Summary report, June 2005.

www.coastalwight.gov.uk/response.html